Ministry of Environment, Forest and Climate Change

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ZOOLOGICAL SURVEY OF INDIA 1916

Volume 123

Special Issue II, 2023 on
Animal Taxonomy
Summit 2023

ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Records of the Zoological Survey of India

A Journal of Indian Zoology

www.recordsofzsi.com
Zoological Survey of India

CITATION
Editor-Director, 2023. *Rec. zool. Surv. India*, 123 (Special Issue)2: 01-808. (Published by the Director, Zool. Surv. India, Kolkata).
Published: July, 2023 (Special Issue 2)
ISSN (Online): 2581-8686
ISSN (Print): 0375-1511

PRICE
Published at the Publication Division by the Director, Zoological Survey of India, M-Block, New Alipore, Kolkata – 700053.

Foreword

It is indeed a pleasure for me to bring out the special issue of **the Records of the Zoological Survey of India** (Volume 123, Special Issue), to achieve the purpose of 'Animal Taxonomy Summit 2023', in commemoration with 108th foundation Day of Zoological Survey of India. The Zoological Survey of India (ZSI) was established on 1st July, 1916 with 10 primary objectives and 7 secondary objectives and one of pioneer institutes in India to develop Taxonomy in the country. The institute mainly focus on exploration, survey, inventorying and monitoring of faunal diversity in various states, periodic review of the status of threatened and endemic species, ecosystems and protected areas of India, bio-ecological studies, and training, faunal identification, advisory services for forest department and maintenance and development of National Zoological Collection.

Since the past 267 years, about 1.25 million species are described as a result of taxonomic investigation. But there are still 86% of all plants and animals on terrestrial species and 91% of from Marine species seas have yet to be named, categorized and catalogued in publications. Taking an account based on the average rate of describing new species from past decades, some studies assumed that describing all remaining species on earth could require 13 centuries of work by more than 3,00,000 taxonomists required. Indian subcontinent situated north of the equator with diversified climatic conditions, represents Palearctic and Indo-Malayan Realms, five biomes such as Tropical Humid Forests, Tropical Dry or Deciduous Forests, Warm deserts and semi-deserts, Coniferous forests and Alpine meadow, 10 biogeographic zones viz. Trans-Himalayas, Himalayas, Desert, Semi-arid, Western Ghats, Deccan Peninsula, Gangetic plain, North-east India, Islands, and Coasts with 27 Biogeographic Provinces and Eastern Himalayas, Western Himalayas, Western Ghats, and Andaman and Nicobar Islands Biodiversity hotspots.

This special issue includes 74 articles focusing on the following 3 major themes: Taxonomy, Biodiversity and Conservation and Biogeography. I wholeheartedly appreciate the hard work of the entire ZSI Team, coordinators of different themes, reviewers, officers and staffs of publication division for their dedication and collective team efforts, to bring out the publications on time. I also congratulate to all the authors for their articles, published in this issue.

Jai Hind

Dr. Dhriti Banerjee
Director
1st July 2023
Kolkata

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Garra lungongza, a new species of cyprinid fish (Teleostei: Cyprinidae) from Nagaland, India

Ng. Catherine[1], I. Linthoingambi[2]
[12]Department of Zoology, Dhanamanjuri University, Thangmeiband, Imphal-795001, India.
E-mail: [1]pipingangbam@gmail.com, [2]irengbamlinthoi78@gmail.com

Abstract

Garra lungongza, new species, is described from the Dei-thung Shumang River, Nagaland. It belongs to the member of "smooth snout" group. It differs from its congeners in having the following characteristics: head strongly depressed; snout tip with 23-34 rounded hollow pits; Gular disc elliptical; torus crescentic; labellum covered by lateral distal margin of rostral cap; pre-dorsal scales irregularly arranged with 12-14 scale rows; lateral line with 37+ 2(1)-3(5) scales.

Keywords: Brahmaputra drainage, Tuensang district, Nagaland, new species.

Introduction:

Members of the genus *Garra* Hamilton,1822 are bottom-dwelling rheophilic cyprinids which are distributed in Africa and Southwest, South, Southeast, and East Asia (Zhang and Chen, 2002). The genus is highly diversified, accounting for 261 valid species (Fricke *et al.*, 2023), of which 79 species were distributed in different river basins and regions of South and South East Asia (Nebeshwar and Vishwanath,2017).

Nagaland is drained by three drainage systems: Brahmaputra, Barak, and Chindwin drainages. Ezung *et al.* (2020a) in their checklist recorded 11 *Garra* species from Nagaland viz. *G. annandalei* Hora, 1921, *G. gotyla* (Gray 1832), *G. gravelyi* Annandale 1919, *G. kempi* Hora 1921, *G. lamta* (Hamilton, 1822), *G. lissorhynchus* (McClelland, 1842), *G. mcClellandi* (Jerdon, 1849), *G. naganensis* Hora,1921, *G. nasuta* (McClelland, 1838), *G. notata* (Blyth, 1860), *G. rupecula* (M'Clelland, 1839). Later two species of *Garra* were described from Brahmaputra drainage of the state i.e. *G. chathensis* Ezung *et al.*, 2020b and *G. langlungensis* Ezung *et al.*, 2021. Ezung *et al.* (2022) reported *G. birostris* Nebeshwar &Vishwanath 2013 from Dikhu River Nagaland. Thus, the present account of *Garra* species in Nagaland is 14. The ichthyofaunal diversity of these drainages and their tributaries in Nagaland are yet to be properly explored.

A collection of fishes in the Dei-thung Shumang River near Sangsangyu village, Tuensang district, Nagaland, India, included undescribed species of *Garra* belonging to the proboscis species group, which is described herein as *Garra lungongza* sp. nov.

Material and methods: Specimens were collected using drag nets and assigned with a specific ID. It is stored in 10% formalin for morphological studies. All measurements were made using a digital calliper, point to point on the left side of the specimen closet to 0.1 mm. Meristic counts, scale counts, and measurements follow Nebeshwar and Vishwanath (2013) and Kottelat (2001). Fin rays and the number of scales were counted using a Stereoscopic zoom microscope. Predorsal scales are counted at the immediate regularly arranged scale row alongside the irregularly arranged scales. Head length and other measurements are given in percent standard length. Sub-units of the head are given in percent head length. Terminology for lips and associated structures follows Kottelat (2020). The holotype (ZSI F9798, Calcutta) and the paratypes (DMUMF-CN011-DMUMF-CN015) are deposited in Freshwater Fish Section, Zoological Survey of India, Kolkata and Museum of Fishes, Dhanamanjuri University respectively.

*Author for correspondence

Article Received on: 02.04.2023
Accepted on: 24.04.2023

Results:

***Garra lungongza*, sp. nov.** (Figure 3 and Figure 4)

Holotype: *Garra lungongza*: male: 108.0 mm SL; Dei-thung Shumang River, Sangsangyu village, Tuensang district, Nagaland, India. coll. Idohangbe, 13th April, 2022 (ZSI F9798, Calcutta).

Paratype: 5 specimens; 64.1mm-125.0mm SL, (DMUMF-CN011-DMUMF-CN015); same data as holotype.

Diagnosis: Among the five groups of *Garra* species categorized by Nebeshwar and Vishwanath, 2017, *G. lungongza* sp. nov., belongs to a member of the "smooth snout" group. It differs from its members of smooth snout group in having more lateral line scales 39-40 i.e., 37 + 2(1)-3(5), except *G. chakpiensis* and *G. compressus.* It further differs from *G. chakpiensis* in the absence (vs. presence) of one faint midlateral stripe on the body, anus closer to pelvic fin origin (vs. closer to anal fin origin); and from *G. compressus* in having rounded (vs. pentagonal) gular disc, snout broadly rounded (vs. slightly conical). It is distinguished from *G. abhoyai, G. naganensis, G. nambulica* and *G. rupecula* in absence (vs. presence) of W- shaped band on caudal fin; from *G. annandalei* in having irregular pre dorsal scales (vs. regular); from *G. chaudhurii* and *G. chivaensis* in having scales well-developed (vs. poorly developed) on abdomen; from *G. ukhrulensis* in having fewer scales between lateral line and anal fin origin (3 or 3½ vs. 4½ or 5).

Description: General body shape as in Figure 3. Morphometric data and meristic counts are presented in Table 1 and Table 2 respectively. Body elongated; gently compressed anteriorly, strongly compressed at caudal peduncle region, dorsal profile straight along the length of the body, depressed at supra-occipital, then gently slopes towards snout tip. Ventral profile from snout till pelvic fin origin flat, between pelvic fin origin and anal fin origin slightly rounded, beyond anal fin origin till caudal fin base straight. Body depth at dorsal-fin origin less than head length.

Head short, its length 19.6-20.9% SL; strongly depressed, its depth 10.5-12.8% SL; broadest at pre-opercular region, its width 16.2-17.8% SL. Eye small and dorsolaterally placed, its diameter 14.4-19.6% HL; inter orbital space almost flat and wide i.e., 49.9-50.5% HL. Snout broadly rounded, smooth without transverse lobe, transverse groove, and proboscis. Round hollow pits on snout tip and each lateral surfaces in holotype with 23 and 10, and in paratype with 23-34 i.e., 23 (1), 24(3), 34(1) and 8-12 i.e., 8(1), 9(3), 10(1) respectively. Rostral flaps and rostral lobes are absent. Sublachrymal groove deep continuous with rostral groove.

Barbels two pair: rostral barbel present anterolaterally, lesser or equal to eye diameter, longer than maxillary barbel. Rostral cap well-developed, less fimbriate, completely cover the upper jaw. Gular disc slightly elliptical, wider than its length (62.1-66.5% HL vs 50.0- 52.2% HL), posteriorly positioned. Torus well-developed, crescentic, lateral distal margin reaching at the level of posterior margin of labellum, moderately papillated, not covered by rostral cap, toral groove deep. Labellum with moderate papillation, covered by rostral cap. Pulvinus wider than long (43.6-47.1 vs 34.5-38.2% HL); anterior part thicker than posterior without any papillation. Labrum with minute papillation, posterior part extending beyond level of eye, not reaching level of pectoral fin origin and lower inclination of gill opening.

Dorsal fin with two simple and 7½ branched fin rays; inserted closer to snout tip than caudal fin base (pre-dorsal length 46.8-50.6% SL), distal margin straight. Pectoral fin with one simple and 13 branched fin rays, slightly longer than head length (19.1-23.3% SL vs 19.6-20.9% SL), when adpressed longest fin ray reaching midway between pectoral fin origin and pelvic fin origin, distal margin slightly rounded. Pelvic fin with one simple and 8 branched fin rays, inserted slightly posterior to dorsal fin insertion, when adpressed its length shorter than pelvic fin length (16.5-18.9% SL vs 19.1-23.3% SL) and surpassing anus, distal margin subacuminate. Anal fin with two simple and 5½ branched fin rays, longest fin ray reaching mid-way of caudal peduncle, its margin straight. Caudal fin with 10+9 fin rays, distal margin emarginate, lobe tips slightly pointed. Anus closer to pelvic fin origin than anal fin origin, i.e., Distance between pelvic fin origin to anus 46.4-49.9% pelvic fin origin to anal fin origin.

Lateral line scales complete with 39-40 i.e., 37 + 2(1) - 3(5) scales. Scales in transverse row above lateral line 3½; between lateral line and pelvic fin origin 2; between lateral and anal fin origin 3 (3) or 3½ (3). Circumpeduncular scales 16. Pre-dorsal scales irregularly arranged with 12 (1), 13 (3) or 14 (2) scales. Pre-anal scales 6 (2) or 7 (4). Chest and belly scaled, those on chest smaller than in belly, visible to naked eye. Dorsal fin base scale 5 (5)- 6(1), all connected to its base. Anal fin base scale 4(6), all connected to its base. An axillary scale at the base of pelvic fin reaching its base.

Colour in preservation: Dorsum, head dark brown; ventral surface of head, chest, and abdomen yellowish. A small black spot present at the upper angle of gill opening. Distal rim of dorsal fin with short dark grey bands along the fin rays. First four branched fin rays of anal fin with dark grey bands. Caudal fin with dark grey stripes in the middle, occupying 9th – 14th fin rays and distal rims of lower lobe.

Etymology: The species is named after its local name Lungongza: *Garra lungongza.*

Habitat type: The river is a clear "pool-riffle" type as shown in Figure 2(b). The flow of water fluctuates in speed so that below dammed pools, the speed increases, and decreases. River substrate is composed of gravel, cobbles, boulders, sand, and clay particles. The species in the study are collected from the dammed pool areas. The riverbank is mostly covered by bushes and shrubs and trees.

Distribution: *Garra lungongza* is presently only known from its type locality, Dei-thung Shumang River (26°20'32.1"N 94°53'37.6"E), Sangsangyu village, Tuensang district, Nagaland, India [Figure 1 and 2(b)].

Discussion:

The Labeoninae group of the genus *Garra* is a highly diversified cyprinid with various morphological modifications on the snout region, varying shapes, and distribution patterns of tubercles which aid in species distinction (Nebeshwar and Vishwanath, 2013). Nebeshwar and Vishwanath (2017) categorized this genus into five groups on the basis of snout morphology, viz., a) smooth snout, b) a transverse lobe, c) a proboscis with transverse lobe, d) a pair of rostral flaps with or without a transverse lobe, and e) with a pair of rostral lobes. *G. lungongza* belongs to the member of smooth snout group. Among the eleven *Garra* species with smooth snout group, three are from the Brahmaputra drainage, viz. *G. annandalei*, *G. chaudhurii* (Hora, 1921) and *G. rupecula* (McClelland,1839); one from the Barak-Meghna drainage, viz., *G. naganensis*; and seven from the Chindwin drainage, viz., *G. abhoyai* (Hora, 1921), *G. chakpiensis* (Nebeshwar and Viswanath, 2015), *G. chivaensis* (Moyon and Arunkumar, 2020), *G. compressus* (Kosygin and Vishwanath, 1998), *G. nambulica* (Vishwanath and Joyshree, 2005), *G. ukhrulensis* (Nebeshwar and Viswanath, 2015) and *G. ngatangkha* Arunkumar & Moyon 2019. Menon (1964) grouped the species of these genus with broad W-shaped band on caudal fin in the "*G. lissorhynchus*" complex. Hence, *G. abhoyai, G. dampaensis* (Lalronunga *et al.,* 2013), *G. lissorhynchus*, *G. matensis* (Nebeshwar and Vishwanath, 2017), *G. ngatangkha* Arunkumar and Moyon, 2019, *G. nambulica*, *G. namyaensis* (Shangningam and Vishwanath, 2012), *G. paralissorhynchus* (Vishwanath and Shanta Devi, 2005), *G. rupecula*, *G. tyao* (Arunachalam *et al.,* 2014) belong to this complex. This distinctive character is absent in *Garra lungongza*.

Garra lungongza differs from *G. abhoyai* in having more lateral line scales (37+2-3 vs. 30-33 + 1-3), predorsal scales well-developed (vs. much reduced), present (vs. absent) of scales on chest and abdomen, lesser scale rows between dorsal fin base and lateral line (3½ vs. 4½), and that between lateral line and pelvic fin base (2 vs. 4½); *G. annandalei* in having more lateral line scales (39-40 vs. 34-35), more pre-dorsal scales irregularly arranged (12-13 vs. 9-10 regularly arranged), anus closer to pelvic fin (vs. closer to anal fin), caudal fin emarginate (vs deeply forked); from *G. chakpiensis* in having a deep distinct sublachrymal groove (vs. two shallow grooves), rostral barbel shorter or equal to (vs. shorter) eye diameter, toral groove deep (vs. shallow), lesser branched dorsal fin rays (7½ vs. 8½ or 9½ fin rays) and its distal margin straight (vs. slightly concave), anus closer to pelvic fin origin (vs. closer to anal fin origin); from *G. chaudhurii* in having head broadly rounded (vs. conical), dorsal fin height greater than body depth at its origin (vs. equal to body depth), scales well-developed (vs. poorly developed) on abdomen, more lateral line scales (39-40 vs. 32-33); from *G. chivaensis* in having more lateral line scales (39-40 vs. 34-36), lesser pre dorsal scales (13 vs. 16), well-developed scales on chest and belly present (vs. absent on chest and poorly developed on belly), dorsal fin insertion closer to snout tip (vs. closer to caudal fin base), anus closer to pelvic fin (vs. closer to anal fin), presence (vs. absence) of dark grey stripes on 9th –14th fin rays and distal rims of ventral lobe of caudal fin, short dark grey bands along distal rim of dorsal fin rays present (vs. absent); from *G. compressus* in having snout broadly rounded (vs. slightly conical), gular disc rounded (vs. pentagonal), more pectoral branched fin rays (13 vs. 11), and caudal fin emarginate (vs. deeply forked); from *G. naganensis* in having well-developed scales on chest and belly (vs. greatly reduced), and fewer caudal peduncle scales (16 vs. 19); from *G. nambulica* in having more lateral line (39-40 vs. 34-35), lesser pre dorsal scales (12-14 vs. 19-26), lesser scale rows between dorsal fin base and lateral line (3½ vs. 4), and that between lateral line and pelvic fin base (2 vs. 3); from *G. ngatankha* in having more lateral line scales (39-40 vs. 33-35) and more caudal peduncle scales (16 vs. 14) and from *G. rupecula* in having more lateral line scales (39-40 vs. 35 scales), lesser rows of scales between dorsal and pelvic fins (6½ vs. 9), more pectoral fin rays including simple ray (14 vs. 10), more dorsal branched fin ray including simple rays (9½ vs. 8), more pelvic fin rays including simple rays (7½ vs. 6); from *G. ukhrulensis* in having one sublachrymal groove deep (vs. two shallow), longer gular disc (50.0- 52.2% HL vs. 24-27% HL), toral groove deep (vs. shallow), posterior part of labrum extending beyond vertical to eye (vs. extending vertically to anterior margin of eye), anus closer to pelvic fin origin (vs. closer to anal fin origin), caudal fin emarginate (vs. forked), well-developed scales on chest and belly present (vs. absent), and fewer transverse scale rows above lateral line (3½ vs. 4 or 5), fewer scales between lateral line and anal fin origin (3 or 3½ vs. 4½ or 5).

From the above mentioned drainages and Koladyne drainage, twelve of the *Garra* species have smooth snout but possess either a pair of rostral flaps or rostral lobes. Among the "*G. lissorhynchus*" complex, *Garra lungongza* further differs from *G. lissorhynchus, G. namyaensis, G. matensis* and *G. paralissorhynchus* in absence (vs. presence) of rostral flaps; in having more lateral line scales (39-40 vs. 32-35 vs. 31 vs. 30-31 vs. 30-31). It differs from *G. matensis* in having anus closer to pelvic fin (vs. closer to anal fin); further differs from the former in having lesser scale rows between lateral line and anal fin base (3-3½ vs. 4-4½). In the original description of *G. ngatangkha* Arunkumar & Moyon 2019, in the abstract presence of rostral lobe is mentioned however in description (page 286) and discussion (page 289) it is mentioned rostral lobe absent and compared with *G. namyaensis*. Image is also not clear. However it should be noted here that rostral lobe and rostral fold are two distinct structures (See Nebeshwar and Viswanath 2017). The rostral lobe of *G. namyaensis* mentioned in Arunkumar & Moyon 2019 should be rostral fold. On examination of the specimen deposited in museum the species is found to not have rostral lobe. Also during our study of *Garra* from Manipur, we have noticed rostral lobe only in *G. manipurensis*. It also differs from *G. dampaensis* and *G. tyao* in absence (vs. presence) of rostral lobes; more lateral line scales (39-40 vs. 27-29 vs. 31); more pre dorsal scales (12-14 vs. 10-11 vs. 9-10); anus closer to pelvic fin (vs. closer to anal fin).

Garra lungongza further differs from *G. khawbungi* (Arunachalam *et al.*, 2014) in having Absent (vs. present) of rostral lobe, more lateral line scales (39-40 vs. 36-37), more pre anal scales (6-7 vs. 2-3), more predorsal scales (12-14 vs. 9-10), anus closer to pelvic fin (vs. closer to anal fin); from *G. manipurensis* (Vishwanath and Sarojnalini, 1986) in having more lateral line (39-40 vs. 34), more pre dorsal scales (12-14 vs. 10-11), present (vs. absent) of scales on chest; from *G. mini* (Rahman *et al.,* 2016) in having absence (vs. presence) of transverse groove, absence (vs. presence) of lateral lobe, scales present (vs. absent) on abdomen, more lateral line scales (39-40 vs. 31-33), and absence (vs. presence) of contrasting dark bands from head to caudal fin base. Arunachalam, 2013 described four species from Arunachal Pradesh, among which *G. alticaptus, G. minimus* and *G. nigricauda* are similar to *Garra lungongza* in having smooth snout, but differs in having rostral lobe, however, Nebeshwar and Vishwanath (2017) commented that original descriptions of these species are ambiguous and are closely similar to *G. birostris*, *G. quadratirostris* and *G. kimini*, and *G. arunachalensis* and respectively.

Garra lungongza differs from *G. arupi* (Nebeshwar *et al.,* 2009), *G. kempi* and *G.lamta* in having transverse lobe absent (vs. present). It differs from *G. arupi* and *G.lamta* in more lateral line scales (39-40 vs. 35-36 vs. 30-31); it further differs from the former in having more pre-dorsal scaels (12-14 vs. 11-12), while the latter differs in having absent (vs. present) of a faint spot at caudal fin base and gular disc posteriorly positioned (vs. medially positioned). It further differs from *G. kempi* in having more caudal peduncle scales (16 vs. 12), anus closer to pelvic fin origin (vs. midway between pelvic fin and anal fin origin). It differs from *G. jenkinsonianum* (Hora,1921) in having absent (vs. present) of transverse groove, more lateral line scales (33-34), more predorsal scales (12-14 vs. 10-11), anus closer to pelvic fin (vs. closer to anal fin). It differs from *G. gravelyi, G. langlungensis,* and *G. nasuta* in having absence of proboscis (vs. presence of incipient proboscis), more lateral line scales (39-40 vs. 32-34 vs. 34 vs. 34); from *G. gravelyi* in having well-developed scales on chest (vs. almost naked); from *G. langlungensis* in having gular disc posteriorly positioned (vs. medially positioned), more pre dorsal scales (13 vs. 8-9), more Circumpeduncular scales (16 vs. 13-15), anus closer to pelvic fin origin (vs. closer to anal fin origin). It also differs from *G. birostris, G. chathensis*, and *G. gotyla* in having absence of proboscis (vs. presence of bilobed proboscis in *G. birostris* and *G. chathensis*, and quadrate proboscis with or without a depression appearing to be bilobed in *G. gotyla*), anus closer to pelvic fin origin (vs. anal fin origin), more pre dorsal scales (13 vs. 10-11 vs. 9-10 vs. 10-12), more lateral line scales (39-40 vs. 33-34 vs. 32-33 vs. 33-34), more pre anal scales (6-7 vs. 3-4 vs. 3 vs. 3-4), from *G. mcclellandi* and *G. notata* in having more lateral line scales (39-40 vs. 36 vs. 33-34), lesser scales between dorsal fin origin and pelvic fin origin (6½ vs. 9 vs. 8).

Garra lungongza is similar to *G. magnacavus* Shangningam *et al.*, 2019 and *G. magnidiscus* Tamang, 2013 in morphological appearance. However, it differs from the former in having more rounded hollow pits on snout (23-34 vs 15-19), absence of proboscis (vs. presence of incipient proboscis), absence of transverse groove (vs. presence of thinly demarcated transverse groove), rostral cap less fimbriate (vs. highly fimbriate), labellum well-developed and covered by rostral cap (vs. reduced and not covered), toral groove deep and narrow (vs. deep and wide), pulvinus slightly elliptical (vs. rhomboid), distal margin of dorsal fin straight (vs. concave), pectoral fin reaching midway to pelvic fin (vs. beyond), anus closer to pelvic fin origin (vs. midway between pelvic and anal fin origin), caudal fin emarginate (vs. forked), lesser lateral line scales (39-40 vs 42), predorsal scales irregularly arranged (vs. regularly arranged). It also differs from the latter in having a shallow dorsal furrow extending obliquely from just above rostral barbels to lateral extremities of rostral fold absent (vs. present), posterior margin of labrum not reaching to the level of pectoral fin origin (vs. reaching to or very close to), labellum covered by rostral cap (vs. not covered), anus closer to pelvic fin origin (vs. closer to anal fin origin), more circumpeduncular scales (16 vs. 12-14), scales on chest visible (vs deeply embedded making it invisible to naked eye), caudal fin emarginate (vs. deeply forked), absence of a faint black blotch on caudal fin base (vs. presence).

After a thorough comparison among species closely similar to or members of same group, *G. lungongza* is described as a new species, whose habitat is only known from its type locality Dei-thung Shumang River, Brahmaputra drainage, Nagaland, India.

Comparative materials:

Garra abhoyai - MUMF 6296-6305, 10, 49.3- 54.90 mm SL, Iril R. at Phungdhar, Manipur, 17.i.2003, K. Nebeshwar, M. Shantakumar and I. Linthoingambi

Garra annandalei (Hora) Holotype: ZSI Calcutta, F 6082/2-1; 60.17 mm SL; Kokha nallah, Koshi river, District: Barabakshetra. India. Date of collection: 30.01.1946.

Garra chakpiensis: Holotype. MUMF 4308, 83.0mm SL; India: Manipur: Chandel district: Chakpi River at Tangpol (Chindwin River basin); B. D Sangningam, 30-31, December 2010.

Garra chathensis - ZSI FF 8037, 65.6 mm SL, India, Nagaland, Chathe River, Brahmaputra Basin (25 47'50.1918"N, 93 47'57.4213"E) collected on October, 2016.

Garra chaudhurii - ZSI F 8146-8148, 3 (holotype and 2 paratypes), 49.5-53.0 mm SL; India: West Bengal: Darjeeling district.

Garra compressus - MUMF 2316, holotype, 68.1 mm SL; MUMF 2314-2315, 2, paratypes, 78.6-83.2 mm SL; India: Manipur: Ukhrul district: Wanze stream at Khamson

Garra gotyla - ZSI Calcutta, F 198/2; 121.92 mm SL; (Kumaon Hills survey – May to June 1948). Location: Kosi River (Kosi Village – Almorah). Date of collection: 07.06.1948.

Garra gravelyi - ZSI F 11586/1, 107.5–112.4 mm SL; Myanmar, S. Shan States, Lawksawk Canal at Lwaksawk (Chindwin basin).

Garra jenkinsonianum - ZSI F 5736/1, holotype, 55.5 mm SL; India: West Bengal: Sita Nullah, Paresnath hills. Collectors-Jenkins and Annandalei.

Garra kempi (Hora) Holotype: ZSI Calcutta, F 7716/1; 87.0 mm SL; Location: Siyom River, below Damda, the Abor hills, Arunachal Pradesh, India. Date of collection: 25.07.2000. collector - Dr. S. W. Kemp.

Garra khawbungi - ZSI/SRS F8625, male. 89.84 mm SL, Tuipui River, Khawbung Village - Champhai District, Mizoram, India (N 22 38'14.8" E 94 07' 44.0"), Collectors: M. Arunachalam, M. Raja, C. Vijayakumar and S. Nandagopal. 11 May 2012.

Garra langlungensis - ZSI FF7152, 13.i.2017, 54.9mm SL, India, Nagaland, Langlung River near Zutovi Village, Dimapur District, Brahmaputra Basin; collected by Ezung *et al.*

Garra lissorhynchus (McClelland) Topotype: ZSI Calcutta, FF 8098/1; 73.05 mm SL; (Location: Museum Collection, Assam, India). Collected by: L. Kosygin.

Garra magnacavus - ZSI FF 6010, 68.0 mm SL; India: Arunachal Pradesh: Lower Subansiri District, Ranga River, Brahmaputra River Basin, 27°20' N 93°48' E, 547 m above sea level, Bikramjit Sinha, 16 March 2013.

Garra magnidiscus – ZSI/V/APFS/P-622, 83.8 mm SL; India: Arunachal Pradesh: Upper Siang district: a fast-flowing tributary to Siang River, about 3 km from Bomdo village on main road to Tuting, 28°44.04' N 94°51.97' E, 429 m asl; L. Tamang, 26 Oct 2011.

Garra naganensis (Hora) ZSI Calcutta, F 9970/1; 89.93 mm SL; (Location: Senapathi Stream, Naga Hills, Assam, India). Collected by: L. Kosygin.

Garra nambulica (Viswanath) Paratype: ZSI Calcutta, 4139; 50.41 mm SL; Location: Irengloic (Stream flowing to Nambul River) Shingala Village, Imphal West District, Manipur, India. Date of collection: 03.02.2004.

Garra ngatangkha - 110/NH/MUM: 33.5 mm SL; India, Manipur, Chandel district, Purum Chumbang village, Tumit River, Chindwin basin; Wanglar Alphonsa Moyon & party18 December 2018.

*Garra paralissorhynchus (*Viswanath & Santadevi) Paratype: ZSI Calcutta, 4158; 52.35mm SL; Location: Khuga River, Churachandrapur district, Manipur, India. Date of collection: 25.07.2000.

Garra *tyao* - ZSI/SRS F8626, 1 ex. male. 64.31mm SL, Tyao River, Tyao Village, Champhai District, Mizoram, India (N 23 27' 25.5" E 93 4' 35.6"), Collectors: M. Arunachalam, M. Raja, C. Vijayakumar and S. Nandagopal. 10 May 2012.

Garra ukhrulensis: Holotype. MUMF 4311, 119.0mm SL; India: Manipur: Ukhrul district: Challou River at Khamson (Chindwin River basin); L. Kosygin, 17 march 1998.

Tamenglong district: Iyei River at Noney.

From the published literature for the following species:

For *G. arupi*: Data from Nebeshwar *et al,* 2009: *G. mcclellandi, G. nasuta, G. notata, G. lamta:* Data from Hora 1921; *G. alticaptus, G. minimus* and *G. nigricauda:* Data from Arunachalam, 2013; *G. birostris*: Data from Nebeshwar and Viswanath,2013; *G. chivaensis:* Data from Nebeshwar and Viswanath, 2015; *G. matensis:* Data from Nebeshwar and Viswanath, 2017; *G. mini:* Data from Rahman *et al*., 2013; *G. dampaensis*: Data from Lalronunga *et al.,* 2013. Overall systematic data of the genus Garra: Data from Viswanath, 2021

Table 1: Morphometric data of *Garra lungongza*, Holotype: ZSI F9798 and paratypes (n=5).

Morphometric data	Holotype	Range		Mean	SD
		Min	Max		
Standard length (SL) in mm	**108.0**	**64.06**	**125.0**		
In % SL					
Body depth at dorsal fin origin	15.2	15.2	19.0	17.0	1.9
Head length (HL)	19.6	19.6	20.9	20.4	0.6
Head depth at occiput	10.5	10.5	12.8	11.9	1.1
Body width at anal fin	7.4	7.4	8.6	8.0	0.5
Body width at dorsal fin	12.6	12.6	15.3	13.9	1.2
Caudal peduncle length	16.8	14.5	18.7	16.9	1.8
Caudal peduncle height	11.4	11.4	13.2	12.4	0.8
Dorsal fin base length	13.2	12.8	14.1	13.5	0.6
Dorsal fin height	18.8	17.4	20.7	19.0	1.4
Pectoral fin length	20.8	19.1	23.3	21.1	1.7
Pelvic fin length	18.9	16.5	18.9	18.2	1.1
Anal fin base length	6.5	5.8	7.1	6.5	0.5
Ana fin length	15.7	15.2	18.8	16.8	1.6
Pre dorsal length	46.8	46.8	50.6	48.2	1.7
Pre pectoral length	17.3	17.3	19.7	18.5	1.0
Pre pelvic length	49.2	47.1	51.1	48.9	1.7
Pre anal length	76.9	73.9	77.2	75.5	1.8

Morphometric data	Holotype	Range		Mean	SD
		Min	Max		
Pre anus length	62.6	61.5	64.9	62.7	1.6
Distance between pelvic and anus	12.4	11.5	14.0	12.8	1.1
Distance between pelvic and anal fin	26.6	24.2	28.9	26.6	1.9
Snout length	7.3	6.8	7.3	7.0	0.2
Eye diameter	3.3	3.0	4.1	3.5	0.5
Interorbital width	10.0	10.0	10.7	10.4	0.3
Gular disc width	13.0	13.0	13.8	13.2	0.4
Gular disc length	10.2	10.2	10.8	10.4	0.2
Pulvinus width	9.2	9.1	9.5	9.3	0.2
Pulvinus length	6.9	6.9	7.8	7.3	0.4
Head width at occiput	16.7	16.2	17.8	16.8	0.7
Head depth at nape	7.5	7.5	8.6	8.2	0.5
In % HL					
Snout length	37.5	32.5	37.5	34.2	2.3
Eye diameter	17.0	14.4	19.6	17.1	2.2
Interorbital width	51.1	49.9	52.5	50.9	1.3
Gular disc width	66.5	62.1	66.5	64.8	2.0
Gular disc length	52.2	50.0	52.2	51.2	1.0
Pulvinus width	47.1	43.6	47.1	45.5	1.5
Pulvinus length	35.1	34.5	38.2	35.7	1.7
Head depth at occiput	53.5	53.5	62.8	58.4	4.4
Head width at occiput	85.2	77.4	87.6	82.5	4.8
Head depth at nape	38.5	38.5	42.4	40.1	1.7
In % pelvic fin - anal fin distance					
Pelvic fin origin to anus distance	46.4	46.4	49.9	48.1	1.5

Table 2: Meristic counts of *Garra lungongza,* Holotype: ZSI F9798 and paratypes (n=5). .

Meristic counts	**Holotype**	**Paratype (n=5)**
Lateral line scales	37+3	37+ 2(1)-3(4)
Lateral transverse scale rows	3½/1/2	3½/1/2
Scales between lateral line and anal fin base	3½	3(3)-3½(2)
Pre-anal scales	6	6(1)-7(4)
Predorsal scales	12	13(3)-14(2)
Circumpeduncle scales	16	16
Dorsal fin base scales	5	5(4)-6(1)
Anal fin base scales	4	4
Dorsal fin ray	ii,7½	ii,7½
Pectoral fin ray	i,13	i,13
Pelvic fin ray	i,8	i,8
Anal fin ray	ii,5½	ii,5½
Caudal fin ray	10+9	10+9

Figure legends:

Figure 1: Map of Nagaland; Dei-thung Shumang River, tributary of Dikhu River, Brahmaputra drainage indicated by a black drop-pin in the map.

Map source: https://www.arcgis.com

Figure 2: (a) Habitat (map source: https://www.arcgis.com); (b) Specimen collection site; Dei-thung Shumang River, tributary of Dikhu River, Brahmaputra drainage.

Figure 3: *Garra lungongza*, Holotype: ZSI F9798, Calcutta, SL-108.0mm; India: Nagaland: Tuensang District: Dei-thung Shumang River, tributary of Dikhu River, Brahmaputra drainage: a) dorsal view, b) lateral view, c) ventral view of the body.

Figure 4: *Garra lungongza*, Holotype: ZSI F9798, Calcutta, SL-108.0mm; India: Nagaland: Tuensang District: Dei-thung Shumang River, tributary of Dikhu River, Brahmaputra drainage: d) lateral view of the head, e) smooth snout without transverse lobe and proboscis, f) Gular disc.

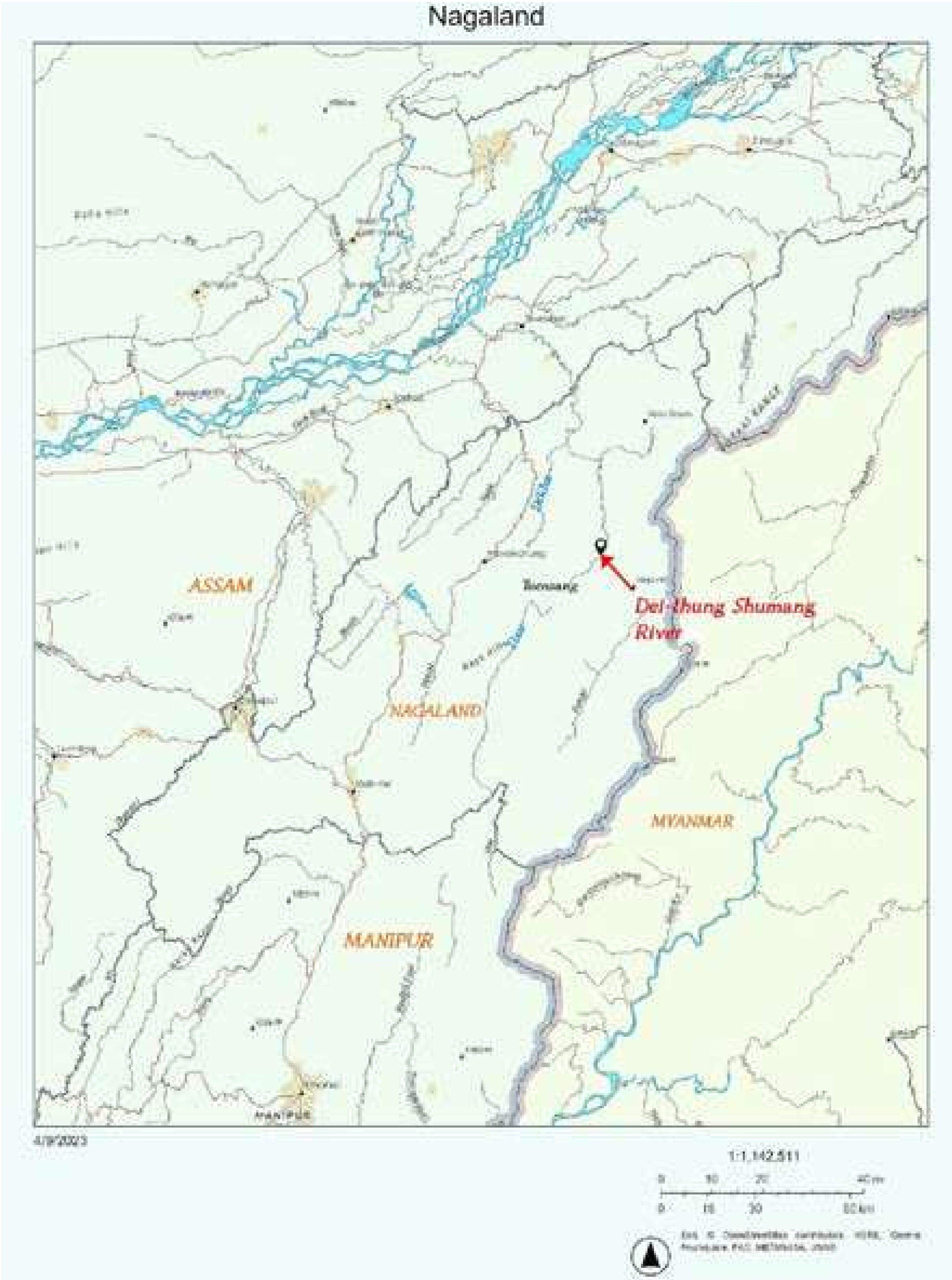
Nagaland
ASSAM
NAGALAND
MANIPUR
MYANMAR
Dei-Ihung Shumang
River
4/9/2023
1:1,142,511

Figure 1:

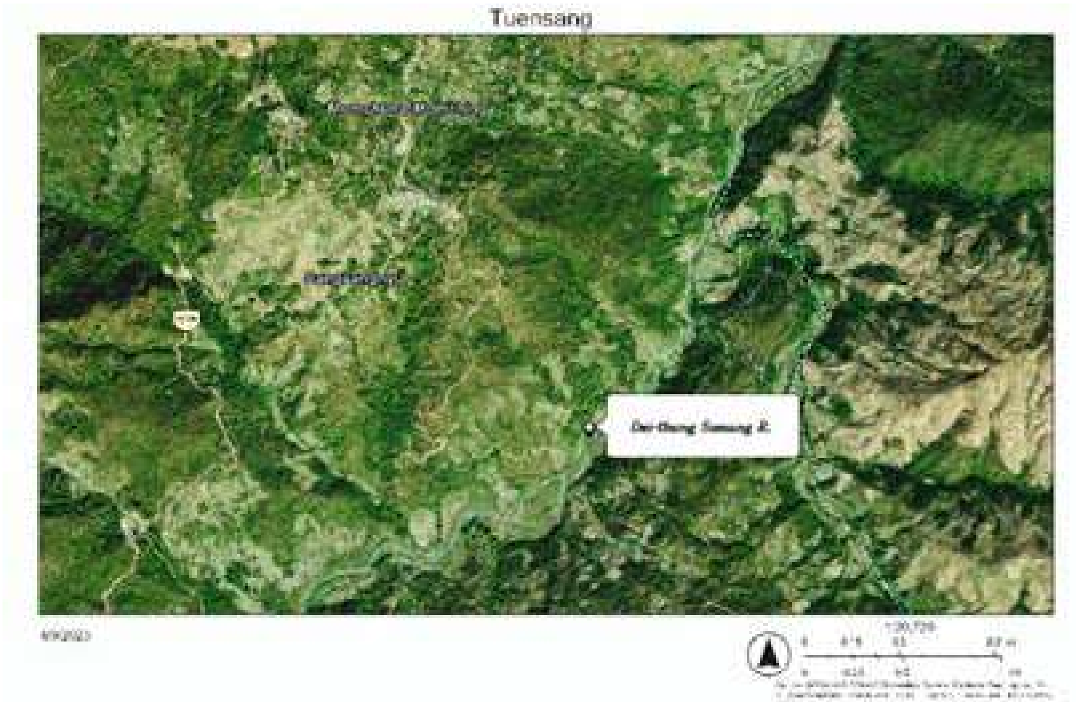

Figure 2(a)

Figure 2(b)

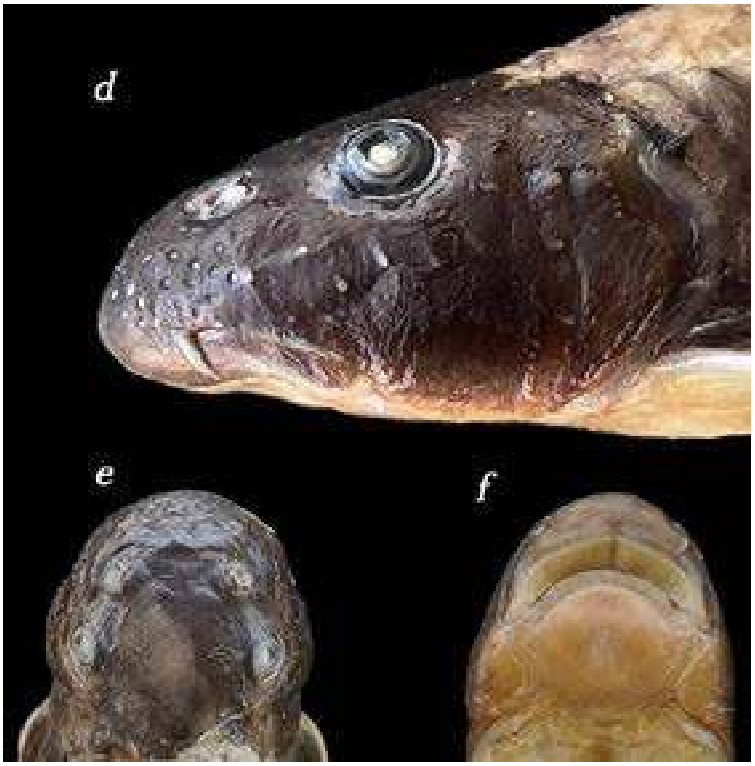

Figure 3

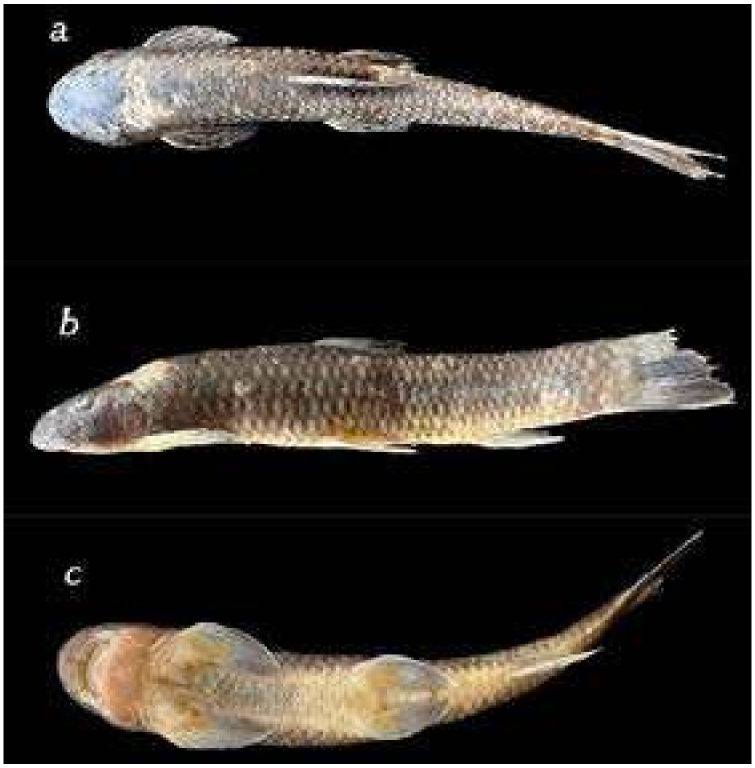

Figure 4

Acknowledgment:

We are extremely thankful Dr. Laishram Kosygin, Officer in Charge, Freshwater Fish Section Zoological Survey of India, Kolkata for giving access to type specimens.. We are grateful to the Head of Department of Zoology, Manipur University for giving access to Museum of fishes. We are also thankful to Dr. Y. Rameshwori, Fishery section, Department of Zoology for her encouragement and cooperation. The authors would like to sincerely thank Dr. Kh. Nebeshwar (Department of Zoology, Moreh College), Dr. B. Shangningam (ZSI) and Dr. A. Darshan (Department of Zoology, MU) for their constructive ideas, comments, and providing literature. We are thankful to ICAR-Directorate of Cold-water Fisheries and Research, Bhimtal for the financial assistance to carry out field surveys under the Mahseer Project, “Species and stock validation of mahseer species of genus *Tor* and *Neolissochilus* from central and eastern Himalayan region of India”. We are also grateful to the Department of Zoology, Dhanamanjuri University for providing lab facilities for the studies of new species.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

A new fish species of the genus *Garra* (Teleostei: Cyprinidae) from the Chalou River, Manipur, India

Thonbamliu Abonmai[1], Linthoingambi Irengbam[2], Catherine Ngangbam[3], Kalpana Thoidingjam[4], Kh. Rajmani Singh[5]

[1,2,3,4,5]D. M. College of Science, Dhanamanjuri University, Thangmeiband, Imphal-795001, Manipur, India.

Email:[1]thonabonmai7@gmail.com, [2]irengbamlinthoi78@gmail.com, [3]pipingangbam@gmail.com [4]abethoi.thoi@gmail.com. [5]rajmanikh@rediffmail.com

Abstract

A new species of the genus *Garra* is described from the Chalou River in Manipur, northeastern India. The new species, *Garra chingaiensis*, belongs to the "proboscis with a transverse lobe species group". It further belongs to the unilobed proboscis group and can be distinguished from its congeners in having a combination of the following characters: a prominent 3-4 unicuspid tubercles on the unilobed proboscis, a transverse lobe with an irregular 11-13 unicuspid tubercles, lateral surface of the snout with 2-3 minute tubercles; a narrow black 5 stripes, laterally more distinct towards caudal peduncle, 3 stripes below the lateral line and 2 stripes above lateral line; black stripes in the middle of caudal fin; chest and belly scaled; 12 circumpeduncular scales; 34-35 lateral scales; 8 ½ branched dorsal fin rays; and 5 ½ branched anal fin rays.

Keywords: Labeoninae, *Garra*, Taxonomy, new species, Chalou River, Manipur

Introduction

The cyprinid genus *Garra* Hamilton, 1822 includes elongated small to medium sized bottom-dwelling fishes, usually found in swift-flowing rivers or mountain streams and are distributed from the Sub-Saharan Africa to Borneo through the Arabian Peninsula, South Asia and Southern China (Zhang & Chen, 2002). It is diagnosed by the presence of a labial fold forming a gular disc that displays a variation in the snout (Kottelat, 2020). This genus is divided into five groups based on snout morphology: a smooth snout species group, a transverse lobe species group, a proboscis species group, a rostral flap species group, and a rostral lobe species group (Nebeshwar & Vishwanath, 2017).

Currently, 45 species of *Garra* that belongs to the "snout with proboscis group" are reported, out of which 11 are distributed in the Chindwin River Basin: *G. bispinosa* Zhang 2005, *G. chindwinensis* Premananda, Kosygin and Saidullah 2017, *G. cornigera* Shangningam and Vishwanath 2015, *G. elongata* Vishwanath and Kosygin 2000, *G. gravelyi* Annandale 1919, *G. litanensis* Vishwanath 1993, *G. moyonkhulleni* Moyon and Arunkumar 2018, *G. qiaojiensis* Wu and Yao 1977 (in Wu 1977), *G. rotundinasus* Zhang 2006, *G. surgifrons* Sun, Xu Li, Zhou and Fenglian 2018 and *G. trilobata* Shangningam and Vishwanath 2015. A collection of fishes from the Chalou River, a tributary of the Chindwin River in the Ukhrul District of Manipur, India included 6 undescribed specimen of *Garra* with proboscis on the snout, which herein described as *Garra chingaiensis,* new species.

Material and Methods:

The specimens were collected from streams of Chalou River at Chingai Village by means of hand picking after diverting part of a stream by damming. They were found along some shallow beds of the stream. Specimens obtained were not much greater in length. A planned expedition may perhaps obtain larger specimen. The fishes were fixed in 10% formalin. Measurements were made point to point with a digital calliper on the left side of specimens to the nearest

*Author for correspondence :
Article Received on: 02.04.2023

Accepted on: 24.04.2023

0.1mm. Counts, measurements and terminology follow Nebeshwar and Vishwanath (2013). Lateral line scales (scales on the body + scales on the caudal fin) were counted from the anterior most pored scale in contact with the shoulder girdle to the posterior most pored scales on the caudal fin. Fin rays were counted following Kottelat (2001), indicating the last two rays articulating on the same pterygiophore as "1 ½". The identification of the elements of the gular disc follows Kottelat (2020). Fin rays and the number of scales were counted under stereoscopic Zoom microscope. Holotype of the species have been deposited in Zoological Survey of India Kolkata and paratypes deposited in the Dhanamanjuri University, Museum of Fishes.

Results

Garra chingaiensis, sp. nov

(Figure1)

Material examined. Holotype: ZSI FF 9810 67.6 mm SL: India, Manipur, Ukhrul district: Chalou River, Chingai Village (Chindwin basin), 2586.05 31° N, 9453.45 49° E; coll. Rinchuiphy Rungsung, 4th January, 2020.

Paratype: DMUMF-TA02-DMUMF-TA06, 65.5-74.2 mm SL; same data as holotype.

Diagnosis: *Garra chingaiensis sp. nov.* belongs to the "proboscis with transverse lobe" group of Nebeshwar and Vishwanath, 2017. This group further consists of "incipient or weakly developed, unilobed, bilobed or trilobed proboscis". The new species belongs to the group with unilobed proboscis and can be distinguished from the congeners of the Chindwin-Irrawaddy drainage (except *G. litanensis, G. qiaojiensis, G. rotundinasus*) in having unilobed proboscis vs. weakly developed in *G. elongata*, incipient in *G. gravelyi,* bilobed in *G. bispinosa, G. chindwinensis, G. cornigera, G. moyonkhulleni* vs. trilobed in *G. surgifrons, G. trilobata.* It is closely similar to *G. elongata* and *G. litanensis,* however differs in presence (vs. absence) of scales on chest, presence (vs. absence) of black spot at the upper angle of gill opening. It further differs from *G. elongata* in having five stripes on body (vs. a stripe from the gill opening to caudal fin base); from *G. litanensis* in absence (vs. presence of a black spot at dorsal fin base). It further differs from *G. gravelyi* in entirely absence (vs. presence of a few indistinct black spots at the base of branched dorsal fin rays), presence (vs. absence of black band at the middle of caudal fin); from *G. qiaojiensis* in having fewer unbranched dorsal fin rays (2 vs. 4); from *G. rotundinasus* in having lesser lateral line scales (33-34 vs. 36-37), caudal fin with black band in the middle (vs. with a dark distal margin). It is similar to *G. substrictorostris* from the Barak drainage of Manipur in having unilobed proboscis however differs in having lesser transverse scale rows above lateral line (3½ vs. 5½) and circumpeduncular scales (12 vs. 16), absence (vs. presence) of black spot at dorsal fin base; from *G. paratrilobata* in having unilobed (vs. trilobed) proboscis, lesser transverse scales above lateral line (3½ vs. 4½). It also differs from *G. koladynenis* from the Koladan River drainage in having unilobed (vs. trilobed) proboscis. A detailed comparison is discussed herein.

Description: Morphometric data and counts are presented on Table 1. Body elongated, slightly compressed laterally, more compressed in caudal peduncle. Dorsal profile smoothly arched to dorsal- fin origin then gently sloping towards caudal peduncle. Ventral profile flattened from head to chest, then more or less round up to pelvic-fin origin and straight from pelvic to caudal-fin base. Head moderately large and depressed with slightly convex interorbital space, height less than length, width greater than height; Eyes small, dorso-laterally located, closer to posterior margin of opercle than to snout tip; snout moderately rounded with transverse lobe covered with 11-13 small to medium unicuspid acanthoid tubercles, demarcated posteriorly by deep transverse groove; a prominent unilobed proboscis, protruding forward, moderately elevated upwards, the anterior margin of proboscis sharply delineated from the depressed rostral surface by a narrow transverse groove; width smaller than the internarial space, each anterolateral marginal corner of the proboscis with one large unicuspid acanthoid tubercle, and one small tubercle in between (Figure1.d.). Depressed rostral surface flat. Sublachrymal groove deep, horizontally curved and confluent to lateral groove of rostral cap. Rostral lobe absent. Barbel two pairs; rostral barbel anteroventrally located, longer than eye diameter; maxillary barbel shorter than rostral barbel and at the corner of the mouth. Rostral cap long, well-developed, fimbriated, papillated ventral surface moderately wide. Upper lip present, with weakly developed papillae in one row, completely covered by rostral cap. Mental adhesive disc elliptical, shorter than wide and narrower than head through roots of maxillary barbel, and posteriorly positioned; torus of mental adhesive disc slightly arched, its lateral extension reaching slightly beyond imaginary vertical line through lateral margin of pulvinus; pulvinus relatively small (width 34.9-37.6% HL, length 27.2-29.01 % HL), its anterior and posterior halves equally rounded, width 1.3-1.4 times its length; Labellum convex with large distinct posterior margin, its upper marginal region covered slightly by rostral cap; anterior margin of Labrum extend upto level of posterior margin of eye; groove between torus and pulvinus narrow, moderately deep; pulvinus with a narrow, papillated transverse lobe at the anterior portion, demarcated posteriorly by a shallow transverse groove, anteriorly separated from the torus by a transverse grove (Figure 1.e.). Papillae on ventral surface of rostral cap, torus, labellum, and labrum rounded, evenly arranged.

Dorsal fin with ii simple and 8 ½ branched rays; last simple ray shorter than the head length; origin closer to snout tip than to caudal fin base, inserted anterior to vertical from pelvic fin origin; first branched ray longest, last branched ray not extending vertically to anal fin origin; posterior margin emarginate. Pectoral fin with i simple and 16 branched rays, reaching beyond midway to pelvic- fin origin when adpressed; fifth branched ray longest, shorter than head length; margin acuminate. Pelvic fin with i simple and 8 branched rays; second branched ray longest, reaching beyond midway to anal-fin origin, surpassing anus; origin closer to anal-fin origin than to pectoral-fin origin; inserted under based of third branched dorsal-fin ray; posterior margin straight. Anal fin short with ii simple rays and 5 ½ branched rays; first branched ray longest, reaching base of caudal fin; posterior margin straight; origin closer to caudal-fin base than to pelvic-fin origin. Anus to anal distance is 39.9-42.0 % of pelvic-anal fin distance. Caudal fin forked, lobe tips pointed; upper lobe with 10 and lower lobe with 9 rays respectively (10+9 lobes).

Lateral line complete with 32+2 or 32+3 scales. Transverse scale rows above lateral line 3 ½ and scales between lateral line and pelvic fin origin 3. Circumpeduncular scale rows 12. Pre dorsal scales 10; regularly arranged. Chest and belly scaled. One axillary scale at base of pelvic-fin reached the posterior end of pelvic-fin base. Preanal scales 4. Dorsal-fin base scales 6 of which last three to five connected to base of dorsal fin. Anal-fin base scales 5, of which last one or two connected to base of anal fin.

Colouration in Preservative: In formalin, the head, dorsum and lateral sides are dark grey. Mouth, chest and abdomen light brown. Dorsal, pectoral, pelvic, anal and caudal fins greyish. Faint greyish stripes over lateral line scales, more distinct posteriorly to the caudal fin. A faint blackish spot immediately anterior to the upper angle of the gill opening. A longitudinal black band in the middle of the caudal fin. Narrow black stripes on body, laterally more distinct towards caudal peduncle, 3 stripes below lateral line and 2 stripes above lateral line; black stripes in the middle of the caudal fin, occupying the 8^{th}, 9^{th}, 10^{th} fin rays of upper lobe and 6^{th}, 7^{th}, 8^{th}, 9^{th}fin rays of lower lobe (counting from the periphery of the lobes)

Distribution: *Garra chingaiensis* is known from the Chalou River at Chingai village in Ukhrul district, Manipur, India (Chindwin River basin).

Etymology: Named after its type locality, Chingai village. Noun.

Discussion

The genus *Garra* develops a modification on the snout to adapt to the running waters. Species are distinguished by their variation in morphology of proboscis, variation in the shape and structure of mental disc, the morphology and the pattern of distribution of tubercles. Nebeshwar &Vishwanath (2017) divided *Garra into* five groups based on snout morphology: a smooth snout species group, a transverse lobe species group, a proboscis species group, a rostral flap species group, a rostral lobe species group. Comparisons of *G. chingaiensis* is therefore, restricted to congeners of proboscis with transverse lobe from the Chindwin-Irrawaddy drainage. We have also compared *G. chingaiensis* with other similar congeners of proboscis with transverse lobe from the neighbouring Barak, Brahmaputra and Kaladan River drainages.

Garra chingaiensis is distinguished from its congeners except *G. chindwinensis* by the presence (vs. absence) of a narrow, papillated transverse lobe at the anterior portion of the pulvinus, which is demarcated posteriorly by a transverse groove. It is further distinguished from its congeners of the Chindwin-Irrawaddy drainage except *G. litanensis, G. rotundinasus, G. qiaojiensis* in having a unilobed proboscis (vs. weakly developed in *G. elongata* vs. incipient in *G. gravelyi* vs. bilobed in *G. bispinosa, G. cornigera, G. chindwinensis*; vs. trilobed in *G. surgifrons* and *G. trilobata*). It differs from *G. litanensis* in the presence (vs. absence) of scales on the chest, fewer scales above lateral line scales (3½ vs 5½), absence (vs. presence) of black spot along the base of dorsal fin, more lateral line scales (34-35 vs. 32); from *G. rotundinasus* in having a longer head (23.0-23.8% SL vs 19.9-21.7), fewer lateral line scales (34-35 vs. 36-37), more caudal peduncle depth (13.4-15.7% SL vs 10.8-11.5), larger eye diameter (20.1-24.6% HL vs. 13.8-18.6), longer rostral cap (vs. shorter), posterior region of labrum farther from the level of pectoral fin origin (vs. nearer); from *G. qiaojiensis* in having a fewer unbranched dorsal fin rays (2 vs. 4), smaller gular disc width (57.4-59.2 % HL vs. 65-70), more compressed body (body depth 18.4–20.2% SL vs. 20-5–26.0), presence (vs. absence) of a band in the middle of caudal fin. It further differs from *G. elongata* in having presence (vs. absence) of scales on chest, absence (vs. presence) of transverse black bar on dorsal fin, more longitudinal stripes on body (5 vs. one from the gill opening to caudal fin base), more branched pectoral fin rays (16 vs. 11-12), lesser lateral line scales (34-35 vs. 39-40) and pre dorsal scales (10 vs. 13); from *G. gravelyi* in having fewer lateral line scales (34-35 vs. 36-37), entirely absence (vs. presence) of a few indistinct black spots at the base of branched dorsal fin rays, presence (vs. absence) of a black band in the middle of caudal fin; from *G. bispinosa* in having unilobed proboscis (vs. bilobed), fewer unbranched dorsal fin rays (3 vs. 4), fewer circumpeduncular scale rows (12 vs. 16), more longitudinal stripes on the lateral sides of the body (5 vs. 3-4), longer disc length (50.6-52.7% HL vs. 38.1-43.8) and more forward position of anus (anus-anal distance 39.9-42.0% pelvic-anal distance vs. 25.9-30.6); from *G. chindwinensis* in having shallow head depth at eye (35.3-36.8% HL vs. 55-58), larger eye diameter (20.1-24.6 % HL vs. 14.0-15.0), longer mental disc length (50.6-52.7 % HL vs. 39.0-41.0), more anal fin base scales (5 vs. 3), pectoral fin branched rays 16 vs 13-14; from *G. cornigera* in having fewer circumpeduncular scale rows (12 vs.14), presence (vs. absence of anterolateral lobe; from *Garra moyonkhulleni* in having a fewer transverse scale rows above lateral line (3 ½ vs. 4 ½), fewer circumpeduncular scale rows (12 vs. 14), more predorsal scales (10 vs. 8), greater pulvinus width (54.5-59.3 % HL vs. 31.1-35.8), longer pulvinus length (50.6-52.7 % HL vs. 19.7-26.3), more forward position of anus (anus-anal distance 39.9-42.0% pelvic-anal distance vs. 26.3-32.5), more pectoral branched rays (16 vs. 14), lesser head depth at nape (28.6-30.5 % HL vs. 64.0-71.4) and at eye (35.3-36.8 % HL vs. 59.5-63.5); from *G. surgifrons* in having fewer circumpeduncular scales (12 vs. 16), more forward position of anus (anus-anal fin distance 39.9-40.2% pelvic-anal fin distance vs. 18.5-29.9), more branched pectoral fin rays (16 vs. 13), proboscis just reaching transverse lobe (vs. distance between proboscis and transverse lobe equal to eye diameter), presence (vs. absence) of stripes on the body, presence (vs. absence) of median black band on caudal fin; from *G. trilobata* in having a unilobed (vs. trilobed) proboscis, absence (vs. presence) of multicuspid acanthoid tubercles on snout, longer disc length (50.6-52.7% HL vs. 20-34), more lateral line scales (34-35 vs. 31-32), fewer circumpeduncular scales (12 vs. 14). *G. longchuanensis* Yu *et.al.*, 2013 is similar to *G. chingaiensis* in having unilobed proboscis, however, comparison amongst the two have not been studied since Sun *et.al.,* 2018 mentioned the former should be a junior synonym of *G. qiaojiensis.*

Garra chingaiensis differs from all its congeners of proboscis with transverse lobe from the Brahmaputra basin except *G. arunachalensis, G. bimaculacauda, G. binduensis, G. clavirostris, G. dengba, G. jaldhakaensis, G. kalpangi, G. langlungensis, G. magnacavus, G. parastenorhynchus, G. quadratirostris* in having a unilobed proboscis. *Ga. chingaiensis* can be easily distinguished from *G. arunachalensis* in having a shallower body depth at dorsal fin origin (18.4-20.2 % SL vs. 23.3-25.4), shorter head length (23.8 % SL vs. 24.6-27.1), longer dorsal fin length (20.8-24.7 % SL vs. 16.4-20.1), more forward position of anus (distance between anus and anal fin origin % Pelvic-anal distance 39.9-42.0 vs. 19-25), presence (vs. absence) of longitudinal stripes on the sides of body; from *G. bimaculacauda* fewer scales above lateral line (3½ vs. 6), labellum distinct with posterior margin (vs. fused with labrum), presence (vs. absence) of five stripes on the body, absence (vs. presence) of a conspicuous dark spot at caudal fin base, absence (vs. presence) of two distinct spots on tips of each lobe of caudal fin; from *G. binduensis* in having a shorter dorsal fin length (20.8-23.5% SL vs. 24.5-29.1), more pectoral-fin branched rays (16 vs. 13-14), smaller pulvinus length (6.1-7.0 % SL vs. 11.0-14.4), presence (vs. absence) of longitudinal stripes on the sides of body; from *G. clavirostris* in having a transverse lobe of only unicuspid tubercles (vs. multicuspid), longer caudal peduncle length (14.1-15.9 % SL vs. 10.1-14.6), more forward position of anus (distance between anus and anal fin origin % pelvic-anal distance 39.9-42.0 vs. 18.6-25.1), more pectoral-fin branched rays (16 vs. 14-15), having a proboscis moderately elevated upwards (club-shaped proboscis); from *G. dengba* in having lesser lateral line (34-35 vs. 42-44), predorsal scales (10 vs. 14-16) and axillary scale on pelvic fin base (1 vs. 2), more branched dorsal fin rays (8½ vs. 6), presence (vs. absence) of black stripes on the body; from *G. jaldhakaensis* in having transverse lobe with 11 unicuspid tubercles (vs. 16-25 multicuspid tubercles), fewer circumpeduncular scales (12 vs. 16), longer gular disc (50.6-52.7 % HL vs. 34.6-37.2), bigger pulvinus width (34.9-37.7%

HL vs. 27.1-30.4); from *G. kalpangi* in present (vs. absent) of transverse groove, fewer circumpeduncular scales (12 vs. 16), more branched pectoral fin rays (16 vs. 10-12), presence (vs. absence) of stripes on the body and present (vs. absent) of median black band on caudal fin; from *G. langlungensis* in having more lateral line scales (34-35 vs. 30-32), less circumpeduncular scale rows (12 vs. 13-15), bigger disc width (54.5-59.3 % HL vs. 46-54), more predorsal scales (10 vs. 8-9), more forward position of anus (39.9-42.0 % pelvic-anal distance vs 19-31), bigger disc width (54.5-59.3 % HL vs. 46-54); from *G. magnacavus* in having well-developed gular disc (vs. weakly developed), absence (vs. presence) of 15-19 rounded large pits on snout, fewer lateral line scales (34-35 vs. 42), predorsal scales (10 vs. 14-16), pre anal scales (4 vs. 6-7) and circumpeduncular scales (12 vs. 16); from *G. parastenorhynchus* in having more lateral line scales (34-35vs.31-32), fewer circumpeduncular scale rows (12 vs. 16), shorter head depth at eye (35.3-36.8 % HL vs. 57.4-62.9), bigger disc width (54.5-59.3 % HL vs. 46.0-52.3), longer disc length (50.6-52.7 % HL vs. 32.6-37.2), bigger pulvinus width (34.9-37.7 % HL vs. 24.4-27.4), longer pulvinus length (25.0-29.8 % HL vs. 15.7-21.1); from *G. quadratirostris* in having fewer lateral line scales (34-35 vs. 37), shorter dorsal fin length (20.8-23.5 % SL vs 24.1-27.1), shorter pelvic-fin length (18.7-19.2 % SL vs. 20.5-23.3), shorter anal-fin length (17.4-19.4 % SL vs 20.5-24.9), bigger disc width (54.5-52.7 % HL vs. 43-48).

Garra chingaiensis is further compared with *G. paratrilobata* and *G. substrictorostris* from the Barak drainage of Manipur and *G. koladynenis* from the Koladan River drainage. It differs from *G. substrictorostris* and from *G. paratrilobata* and *G. koladynenis* in having unilobed and protruding forward proboscis vs unilobed and club-shaped proboscis vs trilobed proboscis respectively; fewer circumpeduncular scales (12 vs. 16), fewer tubercles on transverse lobe (11 unicuspid tubercles vs. 14-20 multicuspid tubercles vs. 13-17 bi- to tetracuspid tubercles vs. 11-23 unicuspid to hexacuspid tubercles) and each on lateral surfaces (2 vs. 7-11 vs. 6-9 vs. 6-10) respectively. It further differs from *G. koladynenis* in absence (vs. presence) of tubercles on rostral surface; from *G. paratrilobata* in presence (vs. absence) of labellum; from *G. substrictorostris* in fewer scales above lateral line (3½ vs. 5½) and more forward position of anus (anus-anal fin distance 39.9-40.2% pelvic-anal fin distance vs. 15-27). The new species further differs from both *G. mutuoensis* and *G. yajiangensis* in having unilobed (vs. quadrate, slightly bilobed) proboscis, more pectoral fin rays (16 vs 13-14), median black band on caudal fin present (vs absent), more forward position of anus (anus–anal fin base distance 40.0-42.0 vs. 36-46 and 19-24) respectively % pelvic-anal fin base distance. It further differs from *G. motuoensis* in having 11 (vs. 16-20) unicuspid tubercles on snout, and further from *G. yajiansis* in absence (vs presence) of sub marginal band on distal half of dorsal fin.

Fishes of the genus *Garra* are well adapted to fast flowing rivers and streams by clinging to the rocky substratum, mainly by means of the suctorial mental disc modified from the lower lip (Menon, 1964; Shangningam and Vishwanath, 2015). *G. chingaiensis* like *G. chindwinensis* are a specialized rheophilic species among the species of the genus since it developed an additional papillated adhesive transverse lobe at the anterior region of the callous pad, which is demarcated posteriorly from the remaining portion by a transverse groove.

Nebeshwar & Vishwanath (2017) during their extensive report on snout and oromandibular structure of the genus *Garra* claimed that the shapes of proboscis in them may change during ontogeny and may differ between the sexes. *G. bimaculacauda* has its smallest reported size upto 66.2mm SL and is said to have weak proboscis with poorly developed tubercles. *G. parastenorhynchus* (57.0 mmSL) also has unilobed and well developed proboscis. Similarly *G. magnicavus* (68.0 mmSL) is also reported to have unilobed incipient proboscis. *G. gravelyi* too have weakly developed proboscis. During the present study not more than 74.2 mmSL specimen were obtained. However the proboscis in the species has well developed unilobed proboscis. An extensive collection of the species throughout the year may perhaps highlight the changes in the structure of the snout during ontogenic development.

Comparative material:

Garra arunachalensis - MUMF 4304, 121.0 mm SL; India: Arunachal Pradesh: Lower Divang valley district: Deopani River at Roing (Brahmaputra basin), 29°09’35” N 95°54’08” E; A. L. Bony, 9 Jan 2005.

Garra binduensis - ZSI/ FF 5623, 87.2 mm SL; India: North Bengal Darjeeling district, Jaldhaka River at Bindu near Jaldhaka Hydel complex, a tributary of Brahmaputra River basin; Collector Ujjal Das 22 August 2016.

Garra chindwinensis - ZSI FF 5906, 120 mm SL, India, Manipur, Senapati District, Laniye River near Laii, (Chindwin basin), 25´31´20´N 93´26´13´E, 05-xi-2015, coll. N. Premananda

Garra clavirostris - MUMF 22004, 117.5 mm SL, male; India: Assam: Dima Hasao District: Dilaima River at Boro Chenam Village below the confluence of Dilaima and Dihandi (Brahmaputra drainage); 25°18 03" N, 92°52 05" E, 401 m above sea level, Sarbojit et al, 19 April 2015.

Garra cornigera - MUMF 12061, 76.0 mm SL; India: Manip ur state: Ukhrul District: Sanalok River (Chindwin basin), 24°52'N 94°39'E; Shangningam *et al.*, 18 April 2011.

Garra elongata - MUMF 2311, 94.9 mm SL; Locality: INDIA:Manipur: Chindwin basin: hill stream near Tolloi, 25° 12' N, 94° 20' E, C. 2,016 m above msl; ColI. L. Kosygin, 12.xi.1997.

Garra gravelyi - ZSI F 11586/1, 107.5–112.4 mm SL; Myanmar, S. Shan States, Lawksawk Canal at Lwaksawk (Chindwin basin)

Garra jaldhakaensis - ZSI FF 8126, 97.2 mm SL, India, West Bengal, Kalimpong district, Jaldhaka River near Jhalong, Brahmaputra River Drainage, 27°02'39' N 88°52'71'E, elevation 1,220 ft. 09.iv.2018, coll. Ujjal Das.

Garra langlungensis - ZSI FF7152, 13.i.2017, 54.9mm SL, India, Nagaland, Langlung River near Zutovi Village, Dimapur District, Brahmaputra Basin; 25.7160 N, 93.6500 E, collected by Ezung *et al.*

Garra litanensis – MUMF-68/1, 92.5 mm SL, Litan stream, Litan, Manipur, female; 16.3.86 (collected by W. Vishwanath)

Garra magnacavus - ZSI FF 6010, 68.0 mm SL; India: Arunachal Pradesh: Lower Subansiri District, Ranga River, Brahmaputra River Basin, 27°20' N 93°48' E, 547 m above sea level, Bikramjit Sinha, 16 March 2013.

Garra paratrilobata - MUMF 22050, 137 mm SL, India: Manipur: Noney district: Leimatak River, a tributary of Irang River (Barak drainage), at Awangkhul Village, 24°49'07.20" N, 93°30'00.60" E; Chinglemba et al, 4 November 2017.

Garra quadratirostris - MUMF 4306, 108.0 mm SL; India: Sikkim: Tista River at Rangpo (Ganga basin), 27°10' 43" N 88°32'10" E; W. Vishwanath *et al.*, 2-9 January 2006.

Garra substrictorostris - MUMF 22034, 173 mm SL; India: Manipur: Churachandpur District: Leimatak River (Barak River drainage); 24°34'33" N, 93°40'01" E, 513 m above sea level, Nebeshwar *et al.*, 9 August 1999

Garra trilobata - MUMF 12051, 118.5 mm SL; India: Manipur state: Ukhrul District: Sanalok River (Chindwin basin), 24°52'N 94°39'E, Shangningam *et al.*, 18 April 2011.

Published information used for comparison:

Zhang, 2005 for *Garra bispinosa*; Thoni *et.al.*, 2016 for *Garra bimaculacauda* and *Garra parastenorhynchus*; Deng *et.al.,* 2018 for *Garra dengba*; Wu *et.al.*, 1977 for *Garra qiaojensis*; Zhang, 2006 for *Garra rotundinasus*; Chao *et al.*, 2018 for *Garra surgifrons*.

Table 1. Morphometric data of holotype and five paratypes *Garra chingaiensis* sp. nov.

Morphometrics	**Holotype**	**Range (n=5 paratypes)**	
		Min-Max	Mean±SD
Standard length (in mm)	67.6	65.5-74.2	
In percent of standard length			
Head length	24.0	23.0-23.8	23.2±0.2
Body depth at dorsal fin origin	20.1	18.4-20.2	19.2±0.7
Head width	19.5	17.9-20.3	19.1±0.7
Head depth at nape	7.24	6.7-7.8	7.1±0.3
Head depth at eye	8.57	8.4-9.0	8.6±0.2
Body width at anal fin origin	11.6	11.5-12.8	12.0±0.4
Body width at dorsal fin origin	17.7	16.0-18.3	17.2±0.8
Caudal peduncle length	14.9	14.1-15.9	14.8±0.6
Caudal peduncle depth	13.9	13.4-15.7	14.1±0.7
Dorsal fin base length	15.1	13.8-16.9	15.1±0.9
Dorsal fin length	22.6	20.8-23.5	21.3±1.3
Pectoral fin length	21.4	19.3-21.8	21.1±1.1
Pelvic fin length	19.2	18.7-19.2	19.0±0.2
Anal fin base length	6.7	5.8-7.2	6.6±0.4
Anal fin length	17.4	17.4-19.4	17.9±0.7
Pre-dorsal length	46.7	46.7-48.6	47.9±1.3
Pre-pectoral length	22.6	22.0-24.7	23.0±0.9
Pre-pelvic length	54.8	54.3-59.7	55.5±1.9
Pre-anal length	82.1	77.0-84.1	80.4±2.5
Pre-anus length	70.0	68.3-70.2	69.2±0.7
Pelvic anal distance	25.7	23.6-26.4	25.3±1.0
Disc width	14.2	12.7-14.2	13.5±0.5
Disc length	12.1	12.1-13.3	12.5±0.4
Pulvinus width	9.0	8.1-9.5	8.9±0.4
Pulvinus length	7.1	6.1-7.0	6.5±0.4
Anus anal fin distance	10.7	9.4-11.0	10.3±0.6

Morphometrics	Holotype	Range (n=5 paratypes)	
In percent of pelvic-anal distance			
Anus-anal distance	42.1	39.9-42.0	40.7±1.0
In percent of head length			
Head depth at nape	30.2	28.6-30.5	29.8±0.7
Head depth at eye	35.8	35.3-36.8	36.0±0.6
Head width	81.5	77.5-81.9	79.8±1.6
Snout length	51.2	48.5-53.3	51.8±1.6
Eye diameter	22.8	20.1-24.6	22.3±1.6
Interorbital distance	46.9	44.3-47.4	46.4±1.0
Disc width	59.3	54.5-59.3	56.2±1.7
Disc length	50.6	50.6-52.7	52.3±0.8
Pulvinus width	37.7	34.9-37.7	37.1±1.0
Pulvinus length	29.2	25.0-29.8	27.3±1.7

Figure legends:

Figure 1. *Garra chingaiensis,* sp. nov**.**, holotype, ZSI FF 9810, 67.6mm SL; **a.** dorsal view, **b.** lateral view, **c.** ventral view, **d.** dorsal view of head showing transverse lobe and proboscis, **e.** oromandibular structure **f.** lateral view of snout showing small tubercles, shape of proboscis and position of eye. India: Manipur: Ukhrul district: Chalou River (Chindwin basin).

Figure 2. Map showing type locality of *Garra chingaiensis,* sp. nov.

Figure 3. Chalouriver, Manipur, India; habitat of *Garra chingaiensis*. sp. nov.

Figure 1

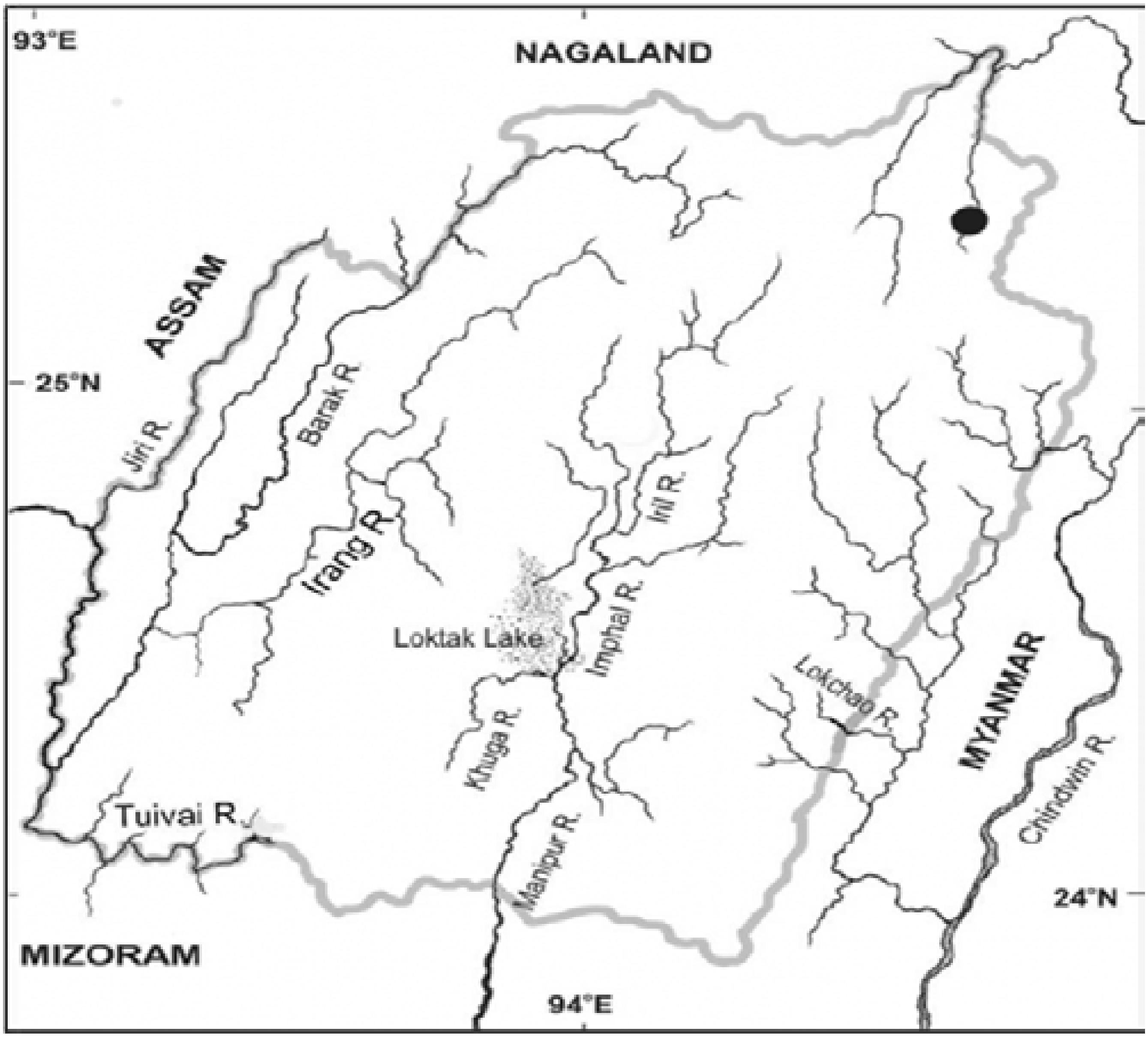
93°E
NAGALAND
ASSAM
25°N
Jiri R.
Barak R.
Irang R.
Iril R.
Loktak Lake
Imphal R.
Lokchao R.
MYANMAR
Khuga R.
Tuivai R.
Manipur R.
Chindwin R.
24°N
MIZORAM
94°E

Figure 2

Figure 3

Acknowledgments

We are grateful to Dhanamanjuri University, department of life science, zoology for providing lab facilities for the studies of new species (*Garra chingailensis*). We are extremely thankful Dr. Laishram Kosygin, Officer in Charge, Freshwater fish section Zoological Survey of India, Kolkata for giving access to type specimens. We are grateful to the Head of Department of Zoology, Manipur University for giving access to Museum of fishes. We are also thankful to Dr. Y. Rameshwori, Fishery section, Department of Zoology for her encouragement and cooperation. We also would like to extend our heartfelt gratitude to Dr. Achom Darshan, Dr. Nebeshwar Kongbrailatpam, and Dr. Bungdon Shangingam for providing literatures, valuable suggestions and constructive ideas.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

A new sisorid catfish of the genus *Glyptothorax* Blyth (Teleostei: Sisoridae) from Kasom Khullen of Manipur, India

Kongbrailatpam Babyrani Devi[1], I. Linthoingambi[2], Kh. Rajmani Singh[3]
[1,2,3]Department of Zoology, Dhanamanjuri University, Thangmeiband, Imphal -795001
E-mail: [1]kbabyrani1995@gmail.com, [2]irengbamlinthoi78@gmail.com,[3]rajmanikh@rediffmail.com

Abstract

Glyptothorax lairamkhullensis, new species, is described from the Taretlok River, a tributary of the Chindwin Basin in Kasom Khullen, Manipur, India. The new species is very similar to *G. ventrolineatus* but can be distinguished from it in having ventral surface of pectoral and pelvic fins pleated (vs not pleated or smooth) and dorsal-fin spine not serrated (vs finely serrated at tip). The new species has a U-shaped adhesive apparatus open caudally; broader than its length and not extending up to the gular region; interdorsal distance (22.7-26.9% SL); claspers present at anus. Congeners from the Chindwin basin of Manipur have the ventral surface of paired fins smooth. The present species is unique in having pleated skin on paired fins.

Keywords: New species, *Glyptothorax lairamkhullensis*, Manipur.

Introduction

Glyptothorax Blyth, 1860 is the most diverse species and widely distributed genus of sisorid catfishes (Ng and Kullander, 2013). The fish species is characterised by the presence of a thoracic adhesive apparatus bearing longitudinal folds or pleats of skin, a detached portion of the premaxilla, and lateral arms of the vomer extending under entire length of the articular process of the lateral ethmoid (de Pinna, 1996). Currently 10 species of *Glyptothorax* are known from Chindwin basin viz., *G. burmanicus, G. chavomensis, G. granulus, G. igniculus, G. minutus, G. ngapang, G. senapatiensis, G. trilineatus, G. ventrolineatus and G. waikhomi* Shangningam & Kosygin, 2022 from Chakpi River Manipur (Premananda *et al.* 2015, Arunkumar and Wanglar, 2017 and Ng and Kullander, 2013). While species reported from Koladyne basin includes *G. jayarami* Rameshori and Vishwanath 2012, *G. ater and G. chimtuipuiensis* Anganthoibi and Vishwanath 2010a, *G. caudimaculatus* Anganthoibi and Vishwanath 2010b, *G. gopii* Kosygin *et al.* 2019, *G. kailashi* Kosygin *et al.* 2020, *G. churamanii* Rameshori & Vishwanath 2012, *G. verrucosus* Rameshori & Vishwanath 2012. From Brahmaputra river basin includes 20 species viz., *G. cavia* (Hamilton 1822), *G. pantherinus* Anganthoibi & Vishwanath 2012, *G. radiolus* Ng & Lalramliana 2013, *G. alaknandi* Tilak 1969, *G. brevipinnis* Hora 1923, *G. botius* (Hamilton 1822), *G. telchitta* (Hamilton 1822), *G. conirostris* (Steindachner 1867), *G. garhwali* Tilak 1969, *G. gracilis* (Gunther 1864), *G. mibangi* Darsan *et al.* 2015, *G. distichus* Kosygin *et al.*2020, *G. manipurensis* Menon 1954, *G. rupiri* Kosygin *et al.* 2021, *G. pasighatensis* Arunkumar 2016, *G. pectinopterus* (McClelland 1842), *G. stolickae* (Steindachner 1867), *G. indicus* Talwar 1991, *G. dikrongensis* Tamang & Chaudhry 2011 *and G. striatus* (McClelland 1822).

During an ichthyological survey of the Taretlok River in Manipur, specimens of a species of *Glyptothorax* with distinctive features were obtained. Further study revealed this material to belong to an unnamed species, which is described here as *G. lairamkhullensis*, new species.

*Author for correspondence
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Material and Methods

Specimens were collected, preserved in 10% formalin and stored for further analysis. Dial calliper with nearest 0.1 mm in percentage of SL and HL was used for measurements of morphometric and meristic counts. General counts and measurements follow Hubbs and Lagler (1946) with measurements of thoracic adhesive apparatus as in Vishwanath and Linthoingambi (2005, 2007). Fin rays were counted under stereoscopic microscope. Asterisks after a meristic value indicates the condition for the holotype. The holotype and paratypes are deposited in the Freshwater fish section, Zoological Survey of India, Kolkata and Dhanamanjuri University Museum of Fishes, Manipur respectively. Four specimen were radiographed at Dr P. Shyamsunder Home Clinic, Imphal to count Veretebrae.

Glyptothorax lairamkhullensis, new species.

Material Examined: **Holotype**: ZSI Calcutta F 9797, 86.7 mm SL; India: Manipur: Kamjong District: Taretlok River at Lairam Khullen, Kasom Khullen, 24°38' N 16°94' E Altitude 1822 ft above sea level; 17-ii-2023, Coll: K. Babyrani and K. Shyamchandra.

Paratypes: DMUMF-KB002, (6), 66.3-91.4 mm SL; data same as holotype.

Diagnosis. *Glyptothorax lairamkhullensis* belongs to the group having pleated folds of skin on ventral surface of pectoral fin spine and first ray of pelvic fin. It is very similar to its Chindwin congener *G. ventrolineatus* in having three longitudinal lines on the body (Mid dorsal, mid ventral and mid lateral). However it differs in having nasal barbel short (vs long), inferior mouth (vs terminal), low head depth at occiput (50.2-57.0% HL vs 57.5-66.3). The species differs from *G. trilineatus* in having two longitudinal lines (mid ventral and lateral), non serrated dorsal spine (vs serrated) and undersurface of paired fins pleated (vs smooth). Species is similar to Indian subcontinent congeners from Brahmaputra and Koladyne basin viz., *G. ater, , G. churamanii, G. alaknandi, G. brevipinnis, G. pectinopterus, G. striatus, G. radiolus, G. sasii, G. stolickae, G. pantherinus, G. jayarami, G. verrucosus, G. gopii, G. chimtuipuiensis, G. rupiri and G. nelsoni* in having pleated folds of skin on the ventral surface of paired fins. However, it differs from them in having three stripes on body vs. two or no stripes. A detailed distinguishing character are discussed.

Description. Body medium sized, elongated and posteriorly compressed. Skin granulated, smooth on head. Ventral profile flattened till posterior base of pectoral fin, slightly elevated till posterior end of anal fin and tapers towards caudal fin; mouth inferior with fleshy papillated lips, upper jaw longer than lower with teeth on upper jaw in a single lunate shaped patch, those of lower jaw interrupted in the middle by slightly narrow gap. Premaxillary tooth band visible even with mouth open slightly. Eyes small in size and ovoid; orbital diameter greater than interorbital width; snout length greater than mouth width; anterior and posterior nares distinctly large, separated by base of nasal barbel; barbels four pair; nasal barbel longer than internarial space; maxillary barbel long, thick, slightly curved at the end, reaching posterior base of pectoral fin; inner mandibular lesser than interorbital; inner and outer mandibular barbel reach anterior region of thoracic adhesive apparatus when adpressed. Outer mandibular barbel longer than inner mandibular, extending and reaching pectoral spine base; occipital process not in contact with the first pterygiophore. Thoracic adhesive apparatus with longitudinal, uninterrupted (except at posterior base) continuous folds of skin or striae present with its edge almost reaching the posterior base of pectoral fin. Dorsal fin with *I, 6, i (5), I, 5, i (2) rays, distal region slightly concave its spine strong, hard and not serrated posteriorly. Pectoral fin positioned low, short, not reaching anterior origin of pelvic fin, with *I, 8, i (5), I, 9, i (2) rays its spine hard, smooth, broad, serrated posteriorly with 10-*17 serrae, its undersurface plicated with more number of plicae comparatively than that in pelvic fin (9-23). Pelvic fin soft, with *i, 5 (5), i, 4 (2) rays and lesser number of plicae (6-16), its origin vertically level of base of dorsal fin, its 2nd branched ray almost reaching anal fin origin surpassing anus and urogenital opening. Anal fin with *ii, 8, i (6), ii, 9, i (1) rays. Deep caudal peduncle. Caudal fin with i, 7+8, i (7) rays and deeply forked, lower lobe longer than upper lobe. Lateral line complete, midlateral. Clasper present. Vertebrae 32(4) (Fig 5).

Colouration. In 10 % formalin, body dark grey. Ventral and dorsal profile shows dusky black base in nasal, maxillary and outer mandibular barbel. Wherein maxillary barbel with faded black line at the base with cream or yellow edge; creamy inner mandibular barbel. Dusky black base with cream or yellow edge is also seen in dorsal and adipose fins. Dusky black stripes is also present on submarginal and half on proximal and distal portion of dorsal, pectoral, pelvic and anal fins with cream or yellow edges. Three prominent Creamy longitudinal lines at the region of mid dorsal, mid lateral and mid ventral of the body. Caudal fin base with black wide blotch.

Etymology. The species is named after the Lairam Khullen Village where the type series was collected from.

Distribution. Taretlok River of Lairam Khullen village of Kasom Khullen Sub-Division, Kamjong District, Manipur, India. Taretlok River flows in the natural boundary of Kasom Khullen Sub-Division to drain into the tributaries of Chindwin River of Myanmar.

Discussion. The *Glyptothorax* species are diagnosed with the following characteristic features: presence (vs absence) of pleated folds of skin on the ventral surface of paired fins, shape of thoracic adhesive apparatus (Ng & Kottelat, 2008), presence (vs absence) of longitudinal bands on the surface of body and thoracic adhesive apparatus reaching (vs not reaching) gular region, presence of furrow running on the ventral surface of the pectoral spine (Ng & Lalramliana, 2012). *G. lairamkhullensis* is unique in having plicae on undersurface of paired fins and presence of longitudinal bands on body. The genus is restricted to a particular river basin rarely extending to other basins (Ng and Rachmatika, 2005). *G. lairamkhullensis* differs from its congeners from the Chindwin river drainage viz., *G. granulus, G. burmanicus, G. ngapang, G. senapatiensis, G. igniculus, G. chavomensis, G. minutus* and *G. waikhomi* in having pleated undersurface of paired fins vs smooth and three longitudinal lines on body present vs absent. The new species further differs from *G. granulus* in having dorsal spine not serrated (vs serrated), thoracic adhesive apparatus U shaped (vs oval), longer head (30.4-33.3% SL vs 26.0-26.7), longer dorsal fin (16.7-20.3% SL vs 13.5-14.5); from *G. burmanicus* in having granulated skin (vs smooth); from *G. ngapang* in possessing U shaped (vs V shaped) thoracic adhesive apparatus, skin granulated (vs tuberculated), dorsal spine not serrated (vs serrated) ; longer head (30.4-33.3 % SL vs 22.2-25.0), pelvic, pectoral and anal fins dusky black (vs spotted brown); longer dorsal fin (19.4-22.2 % SL vs 11.9-12.9), from *G. senapatiensis* in possessing skin on body granulated (vs densely tuberculated), dorsal spine not serrated (vs serrated), body depth at dorsal fin origin (15.2-20.3 % SL vs 21.0-26.8); from *G. igniculus* in possessing thoracic adhesive apparatus U shaped (vs lanceolate), skin granulated (vs almost smooth with minute tubercles), body dark black, greyish (vs uniform brown), longer head (30.4-33.3 % SL vs 20.3-21.8); greater interdorsal distance (22.7-26.9 % SL vs 19.8-24.6); from *G. chavomensis* in possessing granulated (vs tuberculated) skin, absence (vs presence) of ridges or bumps in front of adipose dorsal fin, longer head (30.4-33.3 % SL vs 22.4- 24.3), deeper caudal peduncle (10.1-12.9 % SL vs 6.5-6.7); from *G. minutus* in possessing more serrae on pectoral spine (10-17 vs 6); dorsal spine smooth (vs serrated); from *G. waikhomi* in possessing thoracic adhesive apparatus U shaped (vs oblanceolate leaf-shaped), longer head (30.4-33.3% SL vs 22.0-23.4), dorsal spine not serrated (vs serrated), absence (vs presence) of dark brown blotches; presence of 3 (vs1) longitudinal band on the body; from *G. rugimentum* of Ataran, Salween and Sittang River drainages in Myanmar and Western Thailand in possessing Thoracic adhesive apparatus not extending (vs extending) upto the gular region; shorter predorsal (34.7-37.4 % SL vs 39.9-42.7); greater interdorsal (22.7-26.9 % SL vs 17.2-22.2); longer caudal fin (26.5-35.5 % SL vs 23.3-30.2); from the congener of Barak River drainage *G. scobiculus* in lacking (vs presence) of furrow running along the entire length of the ventral surface of the pectoral spine.

G. lairamkhullensis is also distinguished from its congeners Kaladan River drainage viz., *G. ater* , *G. churamanii* , *G. jayarami, G. verrucosus, G. gopii and G. chimtuipuiensis* and further distinguished from *G. ater* in possessing longer head (30.4-33.3 % SL vs 23.4-25.3), longer dorsal fin base(12.1-14.7 % SL vs 9.8-10.8), longer dorsal spine (15.3-18.2 % SL vs 8.3-13.7), deeper caudal peduncle (10.1-12.9 % SL vs 6.7-8.1) having (Ushaped vs rhomboidal) thoracic adhesive apparatus; without (vs with) central depression; not extending up to the gular region; from *G. churamanii* differ in possessing U shaped (vs V-shaped) thoracic adhesive apparatus, *having* (granulated vs tuberculated) skin; from *G. gopii* in possessing U shaped (vs elliptical) thoracic adhesive apparatus, deeper caudal peduncle (10.1-12.9 % SL vs 7.9-9.1); from *G. chimtuipuiensis* in possessing longer pectoral fin (20.0-23.8 % SL vs 16.8-21.9), longer dorsal spine (15.3-18.2% SL vs 5.1-8.9), longer caudal fin (26.5-35.5 % SL vs 17.7-23.4), caudal fin deeply forked (vs emarginate), U shaped (vs chevron) thoracic adhesive apparatus; longer interdorsal distance (22.7-26.9 % SL vs 11.9-21.5); From *G. jayarami* in having U shaped (vs elongate ovoid) thoracic adhesive apparatus; granulated (vs densely tuberculated) skin; longer head (30.4-33.3 % SL vs 24.8-27.0), deeper caudal peduncle (10.1-12.9 % SL vs 5.5-7.9); from *G. verrucosus* in possessing U shaped (vs elliptical) thoracic adhesive apparatus, nasal barbel not reaching vs reaching anterior margin of the eye; from *G. caudimaculatus* in possessing U shaped (vs rhomboidal shaped) thoracic adhesive apparatus; not extending(vs extending) upto gular region; ventral surface plaited (vs non plaited); from *G. kailashi*. in possessing shorter nasal barbel not reaching (vs reaching) anterior margin of the eye; dorsal fin spine (15.3-18.2 % SL vs 15.3-16.9). *G. alaknandi* (presence of 3 vs absence) of longitudinal strips on the body mid dorsal, mid lateral and mid ventral of body, bands extending towards the caudal fin, slender caudal peduncle (15.2-18.9 % SL vs 10.8), Greater interdorsal (22.7-26.9 % SL vs 18.6); *G. brevipinnis* (occipital process not in contact vs contact) with the first dorsal fin pterygiophore

Furthermore it is also compared with the species of the Indian subcontinent and Ganga-Brahmaputra River drainage viz., *G. pasighatensis, G. mibangi, G. distichus, G. cavia* , *G. manipurensis, G. rupiri, G. conirostris* , *G. gracilis, G. alaknandi, G. brevipinnis, G. radiolus* , *G. stolickae, G. pantherinus* ,*G. pectinopterus*, *G. pasighatensis* ,*G.garhwali* ,*G. striatus* and *G. telchitta* .From *G. garhwali* in possessing longer interdorsal (22.7-26.9 %SL vs 16.7-17.6), more slender body (body depth at anus 15.1-17.7%SL vs 15.8-20.1) ; caudal peduncle depth (10.1-12.9%SL vs 8.8-14.4). From *G. pasighatensis* in possessing smooth (vs tuberculated) skin on head ; nasal barbel not reaching (vs reaching) towards the anterior margin of orbit ; from *G. striatus* in possessing body black greyish (vs dark brown), presence of 3(vs 2) longitudinal bands on body, U shaped (vs wedge shaped) adhesive apparatus without (vs with) median depression, Nuchal plate elements distinctly visible (vs not distinct), dorsal spine not serrated (vs serrated), adipose fin slightly arched at the tip (vs not arched), adipose fin dusky black at the base (vs entirely brown), greater post adipose distance (14.03-17.3 % SL vs 7.4-9.9), deeper caudal peduncle (10.1-12.9 % SL vs 7.1-7.5), longer caudal fin (26.5-35.5%SLvs 23.6-33); head less depressed vs more depressed. Differs from *G. mibangi, G. distichus, G. cavia* and *G. manipurensis* in having plicae (vs smooth). Further from *G. mibangi* possessing deeper caudal peduncle (10.1-12.9 % SL vs 6.8-8.3); from *G. distichus* possessing 3 (vs 2) longitudinal strips; U shaped (vs chevron) adhesive apparatus; from *G. cavia* in having adhesive apparatus without central pit (vs presence); from *G. manipurensis* in body granulated (vs smooth); nasal barbel not reaching (vs reaching) anterior margin of orbit; absence (vs presence) of black spot at dorsal, adipose and caudal fin bases; From *G. rupiri* in possessing greater dorsal spine(15.3-18.2 % SL vs 11.3-12.2)); Ushaped (vs Vshaped) thoracic adhesive apparatus; greater pectoral fin length(20.0-23.8% SL vs 19.5-22.1), greater predorsal length (34.7-37.4 %SL vs 33.1-34.9); from *G. conirostris* in possessing Ushaped (vs Chevron shaped) thoracic adhesive apparatus ; plaited (vs non plaited) paired fins; dorsal spine not (vs serrated) from *G. gracilis* in possessing presence (vs absence) of 3 longitudinal strips on the body; granulated (vs smooth) skin. from *G. brevipinnis* in possessing greater pectoral fin length (20.0-23.8 % SL vs 19.9); from *G. pectonopterus* in possessing nasal barbel not reaching (vs reaching) to middle of pectoral fin base; *G. radiolus* in possessing U shaped (vs rhomboidal shaped) thoracic adhesive apparatus; From *G. stolickae* in possessing presence (vs absence) of pale mid dorsal stripe on the dorsal surface of body; nasal barbel (not reaching vs reaching anterior margin of orbit), but longer than internarial space; From *G. pantherinus* in possessing presence (vs absence) of 3 longitudinal bands on the body; longer adipose fin base (13.5-14.9 % SL vs 10.8-11.8) deeper caudal peduncle (10.1-12.9% SL vs 8.0-8.9); from *G. telchitta* in possessing deeper caudal peduncle (10.1-12.9 %SL vs 4.7-5.9). It also differs from *G. nelsoni* having more serrae (10-17 vs 10-11) on posterior margin of pectoral spine

Therefore, Ichthyofaunal study of Taretlok river of Kasom Khullen remain unexplored. Future Investigation will help for taxonomical study of diverse fish species found at the Taretlok river.

Comparative materials:

Glyptothorax verrucosus: ZSI FF 5272, 1 paratype, 60.0 mm SL; India: Mizoram: Lawntlai district : Kaladan River, Kolchaw, 22° 23' N 92° 57' E.

Glyptothorax churamanii: ZSI FF 5271, 1 paratype, 60.0 mm SL; India: Mizoram : Lawntlai district: Kaladan River, Kolchaw, 22° 23' N 92° 57' E.

Glyptothorax conirostre: ZSI F10382/1, 1 paratype, 102 mm SL; India ; Himachal Pradesh: Shimla.

Glyptothorax waikhomi: ZSI FF 8679, holotype, 85.0mm SL; India: Manipur; Chandel District: Chakpi River near Chakpikarong, headwaters of Chindwin drainage; ZSI FF 8680, paratype 1 , 74.2 mm SL; ZSI FF 8707, 1 paratype, 79.0 mm SL. Approximately 24° 11' N 93° 54' E .

Glyptothorax kailashi: ZSI FF 5010, holotype, 59.9 mm SL; India : Mizoram ; Champhai District: Tuipui River near Champhai (Kaladan River drainage).

Glyptothorax pectinopterus: ZSI F 216 /2,1, 61.0 mm SL ; India: Punjab : Kangra valley .

Glyptothorax brevipinnis: ZSI F 10134 / 1, 4 syntypes, 44.6-79.0 mm SL; India.

Glyptothorax garhwali: ZSI F 6152/ 2, 1 paratype, 86.6 mm SL, Alaknanda River, near Srinagar District , Pauri , Garhwal, Utter Pradesh, India.

Glyptothorax burmanicus: ZSI F 10877/ 1, holotype, 102 mm SL , Myanmar : Upper Myanmar : Myitkyina District : Sankha, a large hill stream between Kamaing and Mogaung.

Glyptothorax ater: MUMF 10044,4 paratypes , 48.3- 126.5 mm SL, Koladyne River at Kolchaw, Lawntlai District, Mizoram, India.

Glyptothorax alaknandi: ZSI F 6154/2, holotype, 57.5mm SL; India: Uttar Pradesh: Pauri Garhwal district: Alaknanda River, Srinagar.

Glyptothorax chindwinica: MUMF 6366, holotype, 145.4 mm SL; MUMF 6368 (5), paratypes, 115.6-14.5 mm SL; India; Manipur, Iril River.

Glyptothorax caudimaculatus: MUMF 10029, holotype,59.8 mm SL; MUMF 10030-10032 (3), paratypes, 41.5-58.9 mm SL; India: Mizoram, Kaladan River, Kolchaw, Lawntlai District, 22° 23› N 57°92› E.

Glyptothorax chimtuipuiensis: MUMF 10022, holotype, 57.8mm SL; MUMF 10023 (6), paratypes,33.7-55.3mm SL; India: Mizoram, Kaladan River at Kolchaw, Lawntlai District, 22° 23› N 57°92› E.

Glyptothorax granulus: MUMF 6151, holotype,76.6 mm SL; MUMF 6152 (10), paratypes, 61.7-76.6 mm SL; India; Manipur, Iril river, Ukhrul District.

Glyptothorax jayarami: MUMF 14012, holotype, 104.5 mm SL; India: Mizoram state, Kaladan River at Kolchaw, Lawntlai District.

Glyptothorax ngapang: MUMF 6131, holotype, 82.7mm SL; MUMF 6152 (10), paratypes, 80.5-89.8 mm SL; India: Manipur, Iril river, Imphal East District.

Glyptothorax pantherinus: MUMF 10047, holotype,131.2 mm SL; India: Arunachal Pradesh, Noa Dehing River at Deban-Namdapha, Brahmaputra basin, Additional data from Anganthoibi and Vishwanath (2012).

Glyptothorax ventrolineatus MUMF L0221, holotype, 85.8 mm SL; MUMF L0222(5), paratypes, 85.1-94.5mm SL India: Manipur, Iril River, Ukhrul District.

Published information used for comparison:

Anganthoibi and Vishwanath (2010) for *Glyptothorax ater*; additional data from Kosygin *et al.*, (2020) and Ng and Kullander (2013); for *Glyptothorax burmanicus;*;Anganthoibi and Vishwanath (2010) for *Glyptothorax chimtuipuiensis* and *Glyptothorax cavia;* Arunkumar, and Moyon (2017) for *Glyptothorax chavomensis* ;Vishwanath and Linthoingambi (2007) for *Glyptothorax manipurensis* ; Kosygin *et al.*, (2020) for *Glyptothorax distichus*; Ng and Kullander (2013) for *Glyptothorax igniculus* Rameshori and Vishwanath (2012) for *Glyptothorax jayarami* ;Darshan *et al.*, (2015) for *Glyptothorax mibangi;* Premananda *et al.*, (2015) for *Glyptothorax senapatiensis*; additional data from Vishwanath and Linthoingambi (2005) and Rameshwori *et al.*, (2012*)* for *Glyptothorax trilineatus* ; Shangningam *et al.*, (2022) for *Glyptothorax waikhomi ;Glyptothorax striatus*: uncat. DMUMF, collected from east Khasi hills Meghalaya. Data from Kosygin *et al.*,(2020) for *Glyptothorax Kailashi*, *Glyptothorax alaknandi, Glyptothorax saisii;* Arunkumar (2016) for *Glyptothorax pasighatensis;* Ng and Kottelat (2008) for *Glyptothorax rugimentum and G.dorsalis* additional data from Kosygin *et al.*,(2021*)* for *Glyptothorax brevipinnis, Glyptothorax conirostris, Glyptothorax garhwali,* and *Glyptothorax telchita*; Jayaram (2006) for *Glyptothorax stolickae* and *Glyptothorax pectinopterus*; from *Darsan et al.*,(2015*)* for *Glyptothorax gracilis, Glyptothorax rupiri* ; from Rameshwori and Vishwanath(2012b) for *Glyptothorax saisii*; Ng and Lalramliana (2013) for *Glyptothorax radiolus;* Kosygin *et al.*,(2019*)* for *Glyptothorax gopii;* Rameshwori and Vishwanath (2012) for *Glyptothorax churamanii* an*d Glyptothorax verrucosus;* Hora(1921) for *Glyptothorax minutus;* Ganguly *et al.*, (1972*)* for *Glyptothorax nelsoni.* Ng and Lalramliana (2012) for *Glyptothorax maceriatus* and *Glyptothorax scrobiculus.*

Table.1. Morphometric data of holotype (ZSI Calcutta F 9797) and 6 paratypes (DMUMF-KB 001-006) of *Glyptothorax lairamkhullensis*

	Holotype	Range	Mean	SD
Standard length (in mm)	86.7	66.3-91.4		
In % SL				
Head length	32.2	30.4-33.3	31.5	1.0
Body depth at dorsal fin origin	15.2	15.2-20.3	17.6	1.7
Body depth at anus	15.2	15.1-17.7	16.2	1.1
Pre dorsal length	37.4	34.7-37.4	36.0	1.1
Pre pectoral length	20.5	18.3-22.1	20.0	1.2
Pre pelvic length	49.4	45.5-51.0	49.2	1.8
Preanal length	67.2	64.1-71.9	68.4	2.6
Dorsal fin spine length	15.8	15.3-18.2	16.8	2.6
Dorsal fin height	20.6	19.4-22.2	20.9	1.0
Length of dorsal fin base	14.0	12.1-14.7	14.0	0.6
Inter dorsal distance	25.3	22.7-26.9	24.5	1.4
Post- adipose distance	17.3	14.03-17.3	16.1	1.3
Length of Adipose- fin base	13.9	13.5-14.9	14.2	0.6
Pectoral fin length	22.7	20.0-23.8	21.8	1.2
Pelvic fin length	16.3	15.7-18.8	17.2	2.3
Caudal peduncle length	18.3	15.2-18.9	18.0	1.3
Caudal peduncle depth	11.6	10.1-12.9	11.4	1.0
Caudal fin length	27.9	26.5-35.5	31.9	3.5
Adhesive apparatus length	14.4	10.6-14.6	12.8	1.5
Adhesive apparatus width	13.1	9.7-13.1	10.7	1.1
In % of head length				
Head depth at occiput	56.6	50.2-57.0	53.5	3.1
Head width (Maximum)	70.3	66.2-74.5	71.2	3.4
Orbital diameter	7.3	6.2-10.5	8.2	1.5
Snout length	42.4	38.0-42.4	39.5	1.4
Inter orbital width	26.5	21.2-28.3	25.6	2.4
Nasal barbel length	22.2	20.4-26.9	23.3	2.0
Maxillary barbel length	57.0	57.0-93.0	75.2	11.2

	Holotype	Range	Mean	SD
Inner mandibular barbel length	21.1	21.1-25.0	23.4	1.4
Outer mandibular barbel length	27.9	27.8-44.0	38.8	5.3
Mouth width	31.7	28.5-35.3	31.3	2.2
Internarial space	12.3	8.4-14.7	12.1	2.0

Figure legends:

Figure 1: Map of Ukhrul district showing Taretlok river, Kasom Khullen and Lairam Khullen, the collection site of *Glyptothorax lairamkhullensis*.

Figure 2 A. Showing **a.** dorsal, **b**. ventral and **c.** lateral views **B**. Thoracic adhesive apparatus Holotype 86.7mm SL of *Glyptothorax lairamkhullensis*.

Figure 3 A and B: Showing the ventral surface of pleated and plicae on pectoral spine and pelvic fin ray.

Figure 4. Type locality: Habitat of *Glyptothorax lairamkhullensis*, Taretlok river of Lairam Khullen, Kasom Khullen, Manipur.

Figure 5. Radiograph of *G. lairamkhulensis* showing vertebrae

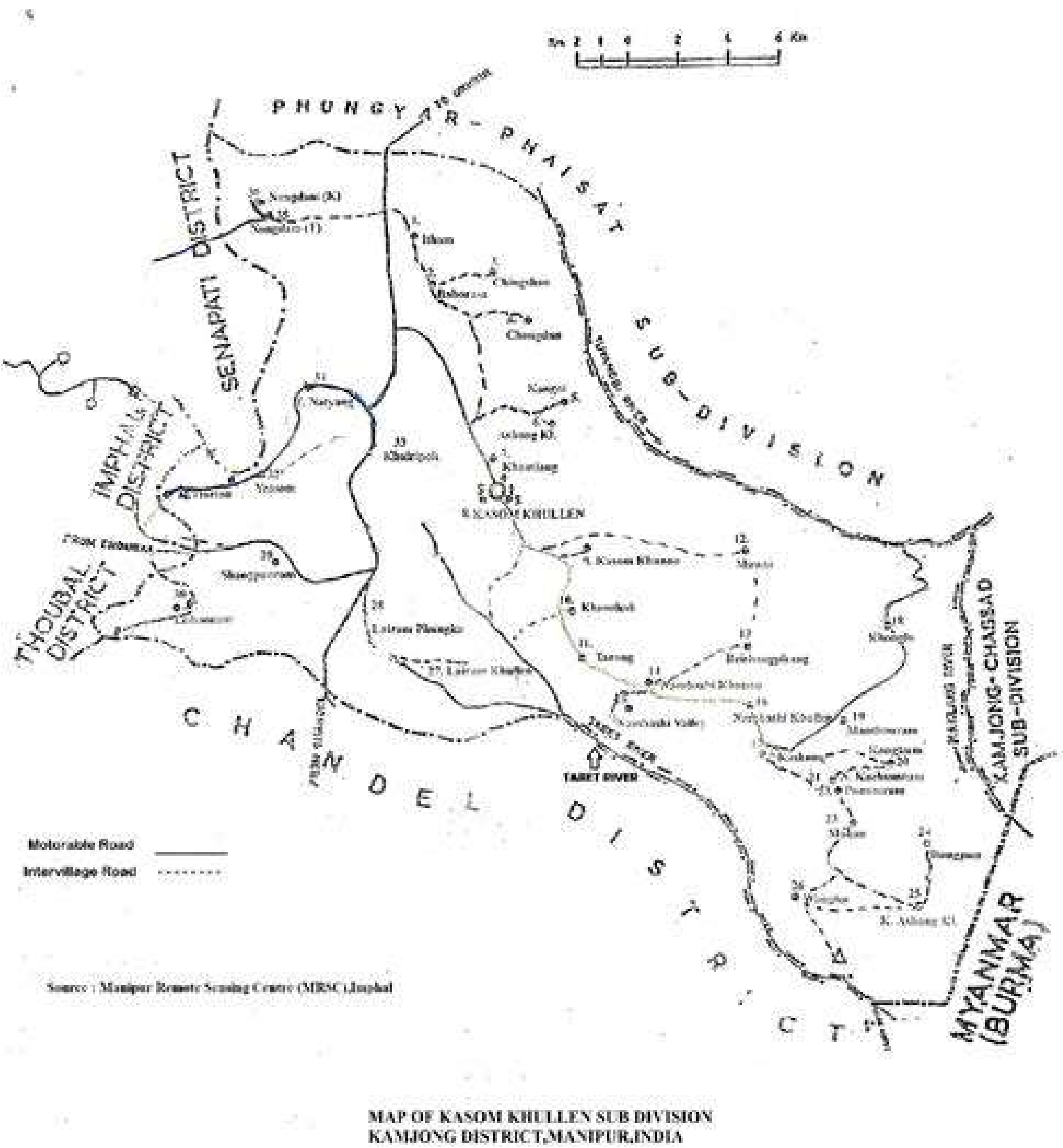
PHUNGYAR - PHAISAT SUB-DIVISION
SENAPATI DISTRICT
IMPHAL DISTRICT
THOUBAL DISTRICT
CHANDEL DISTRICT
KAMJONG-CHASSAD SUB-DIVISION
MYANMAR (BURMA)
8. KASOM KHULLEN
TARET RIVER
Motorable Road
Intervillage Road
Source : Manipur Remote Sensing Centre (MRSC),Imphal
MAP OF KASOM KHULLEN SUB DIVISION
KAMJONG DISTRICT,MANIPUR,INDIA

Figure 1

Figure 2A

Figure 2B

Figure 3A

Figure 3B

Figure 4

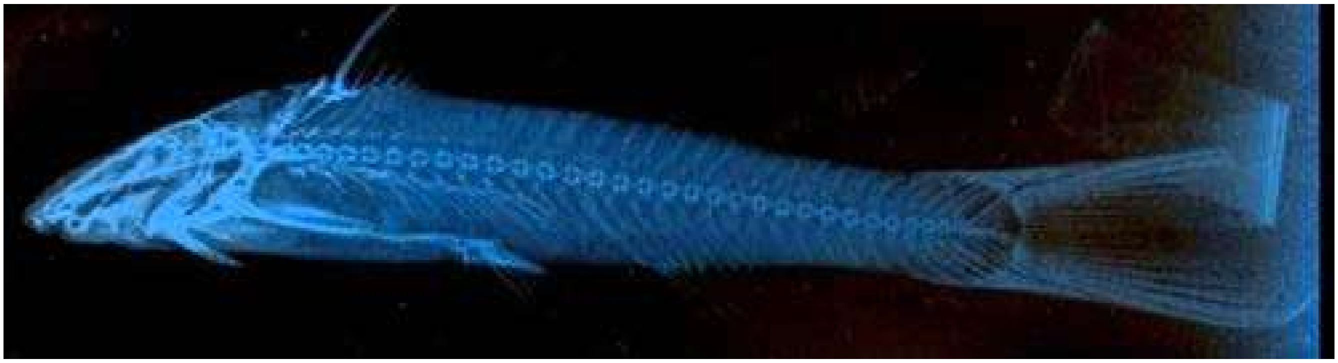

Fig 5 showing radiograph

Acknowledgements

We are grateful to Dhanamanjuri University, Department of life sciences, Zoology for providing laboratory facilities of the new species *Glyptothorax lairamkhullensis.* We also would like to extend our heartfelt gratitude to Dr Laishram Kosygin Officer In Charge, Fresh water Fish Section Zoological Survey of India Kolkata for giving access to type specimen; Dr. Nebeshwar Kongbrailatpam Moreh College, Dr. Achom Darshan Dr Y. Rameshwori Fishery section Department of Zoology Manipur University, Dr. Bungdon Shangingam ZSI Kolkata, providing literatures, valuable suggestions and constructive ideas, their cooperation and encouragement. We are thankful to Larima from Shillong for helping in collection of fishes from Khasi Hills.

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Map Source: DRDA, Ukhrul & District Election Office, (Ukhrul /Election Commission of India).

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Description of *Talanema dhritiae* sp. n. (Qudsianematidae : Dorylaimida) from West Bengal, India

Viswa Venkat Gantait* and Olivia Das
Zoological Survey of India, M-Block, New Alipore
Kolkata-700053, West Bengal, India

Abstract

In the present manuscript, a new species *Talanema dhritiae* sp. n., collected from vineyard in Chhatna village of Bankura district, West Bengal, India is described based on characters: having shorter body (L=0.71-0.97 mm), a=15.5-20.5, b=3.4-4.6, c=28.4-35.4, c'=0.9-1.1, V=44.6-48.2, transverse vulva, small spherical cardia and digitate tail. It shows similarities with *T. avolai* (L=0.85-0.99 mm) and *T. salinae* (L=0.7-0.8 mm) in having small slender body, but differs from both of them in odontostylet length (15.7-17 µm in *T. avolai* and 12-14 µm in *T. salinae*), width of lip (11-14 µm in *T. avolai* and 12-14 µm in *T. salinae*), oesophageal length (251-263 µm in *T. avolai* and 210-243 µm in *T. salinae*) and position of vulva (V=55.3-61.3 in *T. avolai* and 56.8-58.4 in *T. salinae*), pre-rectum length (52-58 µm in *T. avolai* and 23-39 µm in *T. salinae*) and shape of cardia (spherical *vs* conical). The species key of the genus is also provided.

Keywords: *Talanema dhritiae* sp. n., species key, vineyard, West Bengal.

Introduction

Andrassy (1991) proposed the genus *Talanema* belonging to the family Qudsianematidae under the order Dorylaimida by transferring four species from the genus *Labronema* Thorne, 1939 *viz. Labronema digitatum* Sukul *et al.*, 1975, *L. mauritiense* Williams 1959, *L. pararapax* Ahmad and Jairajpuri, 1982 and *L. pygmaeum* Heyns, 1963. He differentiate the genus from *Labronema* depending upon three important characters i.e. transverse vulva (*vs* longitudinal), digitate tail (*vs* rounded) and non-contiguous supplements (*vs* contiguous); from *Takamangi* Yeates, 1967 in having a double guiding ring, a sub-digitate tail and higher number of supplements. He selected *T. mauritiense* (Williams, 1959) as the type species of the genus. Vinciguerra and Clausi described two new species *T. avolai* and *T. salinae* in 1995. *T. nicaraguaense* was described by Shaheen and Ahmad (2005). Andrassy (2011) again transferred *L. ibarakiense* Khan and Araki, 2002 to the genus. *L. baqrii* Khan *et al.* 1989, *L. malagasi* Furstenberg *et al.*, 1993 and *L. sphinctum* Mohilal and Dhanachand, 2001 were shifted to *Talanema* by Imran *et al.* (2021). They regarded *L. neodiversum* (Mondal, Manna and Gantait, 2012) as junior synonym of *T. baqrii* (=syn. *L. neodiversum* Mondal *et al.*, 2012). Imran *et. al.* (2021) provided the first molecular (18S, D2-D3 and 28S rDNA) study of *T. baqrii*. They discussed its evolutionary relationships and also presented a compendium of the main morphometrics for a total of 11 species of the genus. *T. saccatum* was described by Jabberi *et al.* (2021). *T. ibericum* was described by Pena Santiago *et al.* in 2023. He represented molecular trees to establish the evolutionary relationships of their described species.

During a faunistic survey in 2017 to the Chhatna village in Bankura district of West Bengal, India, nematode specimens were collected from the rhizospheric soil of vineyard which is being described and illustrated. *Talanema dhritiae* sp. n. is characterized by having shorter body length, short odontostylet, transverse vulva that is located at anterior half of the body, small spherical cardia and digitate tail. It shows close similarities with *T. avolai* and *T. salinae* having small body; values of b, c´ and length of pharyngeal bulb; transverse vulva and absence of male. But the proposed new species strongly differs from both the species in values of a, c,

*Author for correspondence : vvgzsi123@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

V, lip diameter; length of odontostylet, pharynx, pre-rectum and tail; shape of cardia. A species key to the genus is also provided.

Materials and Methods

Specimens were collected from rhizospheric soil of vineyard from Chhatna village in Bankura district of West Bengal, India. Nematodes were extracted using the Cobb's sieving technique (Cobb, 1918) and decanting method followed by Modified Bearmann's funnel technique (Christie & Perry, 1951). They were then processed by Seinhorst's slow dehydration method (Seinhorst, 1959), mounted on slides in anhydrous glycerin and sealed with paraffin. Specimens were identified (up to subfamily) following the taxonomic key, made by Jairajpuri and Ahmad (1992) and genus identified following Andrassy, 1991. Dimensions were presented in accordance with De Man's formula (De Man, 1884). Positions of the oesophageal gland nuclei were presented according to Andrássy's formula (Andrássy, 1998). Drawings were made with the help of camera lucida using Olympus research microscope with a drawing tube attached, model no. BX 41. Measurements and photographs were taken with Nikon Eclipse Ni Research Microscope Y-TV55.

Systematic Accounts

ORDER : DORYLAIMIDA Pearse,1942

SUBORDER : DORYLAIMINA Pearse, 1936

SUPERFAMILY : DORYLAIMOIDEA De Man, 1876

FAMILY : QUDSIANEMATIDAE Jairajpuri, 1965

SUBFAMILY : QUDSIANEMATINAE Jairajpuri, 1965

Genus : ***Talanema*** Andrassy, 1991

***Talanema dhritiae* sp.n.** (Table-1; Figs. 1 & 2)

Materials examined : Holotype and 6 Paratypes : Female : India, West Bengal, Bankura district, Chhatna village, 23.3085°N, 86.9649°E, 4-vii-2017, coll. V.V. Gantait (Reg. No. NZC/ZSI/WN 3913).

Measurements : Shown in Table-1.

Description : Female : Small sized nematode, moderately slender body more or less straight to ventrally arcuate upon fixation. Body slightly tapering towards both the extremities. Cuticle smooth, when observed under light microscope 1.6-1.8 μm thick at midbody and 1.9-2.2 μm at anterior portion and 2.3-2.4 μm on dorsal side of the tail, but possess fine striations when observed under high magnification. Lip region well offset with a distinct constriction, 2.2-3.0 times as wide as high and about one-fifth (21-24%) of body diameter. Amphid fovea stirrup shaped, 7.8 μm wide, its aperture occupying more than one-half of lip region diameter. Odontostylet strong, 1.2 times longer than lip region diameter; aperture one-half of its length. Guiding ring double, situated at 8.4-11.0 μm from anterior end. Odontophore rod-like, 1.3-0.9 times longer than odontostylet. Pharynx entirely muscular, gradually enlarging into the basal expansion which occupies less than one-half (42-48%) of the total neck length. Gland nuclei located as follows: D=61-67%, AS_1 =30.4-32.4%, AS_2= 36.7-37.7%, PS_1= 55.3-57.3%, PS_2=67.1-69.1%. Nerve ring located at 44.6 – 47.0% of the total neck length from anterior end. Pharyngo-intestinal junction consisting of a short and spherical cardia measuring 8.6-9.1×8.5-8.7 μm. Genital system amphidelphic with equally-developed branches; the anterior gonad 156.7-174.1 μm long or 18-22% of body length, the posterior one 173.0-191.6 μm or 18-27% of the body length. Ovary reflexed with oocytes arranged in a single row. Vulva, a transverse slit 4.1-5.6 μm long with sclerotized lips. Vagina extending inwards 23.4-32.2 μm or 49-70% of body diameter. Pars proximalis 16-22×12-15 μm, with well-developed musculature, pars refringes consisting of sclerotized pieces measuring 4.0-5.8×3-6 μm and pars distalis 3.3-4.1 μm long. Sphincter present between oviduct and uterus. Uterus 103.4-104.1 μm long or 2.2-1.9 times body diameter. Uterine eggs 50.4-48.5 × 34.2-33.5 μm. Pre-rectum about 1.5 times anal body width. Rectum slightly smaller than anal body diameter. Tail short, 2.8-6.4% of body length, digitate with small concavities.

Male : Not found.

Differential diagnosis and relationships: The genus *Talanema* possesses 13 species under it. *Talanema dhritiae* sp.n. is strongly differentiated from all other species of the genus having shorter body length (*vs* more than 1 mm), except *T. avolai* (0.8-0.9 mm) and *T.salinae* (0.7-0.8 mm). It also differs from all of them in the values of **a** (*vs.* 18.0-34.6), **c** (*vs* 26.4-77.0), narrower lip region (*vs.* 11-16 μm), short odontostylet (*vs.* long 15-27 μm), length of pharynx (*vs.* 202-488 μm), pharyngeal bulb length (*vs.* 89-251 μm), small spherical cardia (*vs.* conical), pre-rectum length (*vs.* 24-231 μm) and vulva at anterior half of the body (*vs.* posterior half).

The proposed new species shows close resemblances with *Talanema avolai* and *T. salinae* with small slender body (L=

0.85-0.99 mm in *T. avolai* and 0.70-0.80 mm in *T. salinae*), in the values of **b** (3.4-3.9 and 19.5-22.7) and **c'** (1.0-1.2 and 1.1-1.3), length of pharyngeal bulb (93-100 µm and 89-108 µm), transverse vulva , tail length (22-27 µm and 21-26 µm) and absence of male. But it differs from *T. avolai* in the values of **a** (*vs* 25-31), **c** (*vs* 36.3-36.9), **V** (*vs* 55.3-61.3), odontostylet length (*vs* 15.7-17.0µm), neck length (251-263µm), length of pre-rectum (*vs* 52.7-58.0 µm) and long conical cardia (*vs* small spherical).

Talanema dhritiae sp. n. also differs from *T. salinae* in the values of **a** (*vs* 19.5-22.7), **V** (*vs* 56.8-58.4), lip diameter (*vs* 12-14 µm), odontostylet length (*vs* 15.5-17.0 µm), pharyngeal length (*vs* 210-243 µm) anal body diameter (*vs* 23.5-39.0 µm) and cardia conical in shape (*vs* small spherical). Therefore, the present species holds significant and substantial differences from all other valid species of the genus *Talanema* and can be considered as a new species under this genus.

Etymology: The species epithet, *dhritiae*, is a Latin term which is given after Dr. Dhriti Banerjee, the eminent scientist and the first lady Director of Zoological Survey of India, Kolkata, West Bengal, India.

Key to species of the genus *Talanema* Andrassy, 1991

1. Male present---2

 Male absent ---9

2. Cardia rounded, enveloped by conical intestinal tissue -------------------------- ***T. ibericum*** Pena-Santiago *et al.,* 2023

 Cardia conical, not enveloped by conical intestinal tissue---3

3. Female tail conoid, without digitations***T. malagasi*** (Furstenberg, Heyns and Swart, 1993) Imran, Abolafia and Ahmad, 2021

 Female tail digitate--4

4. Tail dissimilar in sexes, female tail digitate, male tail without digitation ---5

 Tail similar in sexes, both female and male tail digitate --6

5. Male tail convex conoid with rounded terminus, lip region offset by deep constriction -***T. baqrii*** (Khan, Jairajpuri and Ahmad, 1989) Imran, Abolafia and Ahmad, 2021

 Male tail convex conoid with more thickened terminus, lip region slightly offset -- ***T. digitatum*** (Sukul, Das and Mitra 1975) Andrássy, 1991

6. Males with hiatus, odontostylet 25-27 µm long ------------ ***T. pararapax*** (Ahmad and Jairaipuri 1982) Andrássy, 1991

 Males without hiatus, odontostylet 17.5-22.4 µm long --7

7. Tail 30.4-36µm long; male with 8 ventromedian supplements --- ***T. sphinctum*** (Mohilal and Dhanachand, 2001) Imran, Abolafia and Ahmad, 2021

 Tail length < 30 µm; ventromedian supplements 19-23 in numbers---8

8. Tail slightly digitate, anal body diameter 27-33 µm, prerectum 72-85 µm long-- ***T. mauritiense*** (Williams, 1959) Andrássy, 1991

 Tail digitate, anal body diameter23-26 µm, prerectum 50-63 µm long --- ***T. ibarakiense*** (Khan and Araki, 2002) Andrássy, 2011

9. Tail with saccate bodies at ventral and sometimes both sides---------------------------- ***T. saccatum*** Jabberi *et al.*, 2021

 Tail without saccate bodies at ventral or dorsal sides --- 10

10. Body length more than 1.1 mm-- 11

 Body length less than 1.1 mm--- 12

11. Body length >1.5 mm, c=66-77, female tail length 25-27 µm -------------- ***T. nicaraguaense*** Shaheen and Ahmad, 2005

Body length<1.5 mm, c = 54-66, female tail length 17 µm --- ***T. pygmaeum*** (Heyns 1963) Andrássy, 1991 = ***Labronema pygmaeum*** Heyns, 1963

12. Odontostylet length11-12.4 µm, lip width 9.91-10.71 µm, vulva pre-equatorial (V=44.61-48.17%) ---------------------- ***T. dhritiae* sp. n.**

Odontostylet length>12.4 µm, lip width >10.71 µm, vulva post-equatorial (V>55%) ----------------------------------- 13

13. Body length ≤ 1.06 mm, L = 0.85-1.06 mm, a=23.4-33.4, c = 31-44.9, prerectum length 51-78 µm ------------ ***T. avolai*** Vinciguerra and Clausi, 1994

Body length < 1.06 mm, L < 0.81mm, a=18.4-22.7, c = 26.4-32.8, prerectum length 23.5-39 µm ------------------------- ***T.salinae*** Vinciguerra and Clausi, 1994

Table 1. Morphometric data of *Talanema dhritiae* sp. n; all measurements in µm, except L in mm

Morphometric characters	Holotype (n=1)	Paratypes (n=6)	Mean±SD
L	0.97	0.71-0.97	(0.85±0.1)
a	20.5	15.5-20.5	(17.2±2.8)
b	4.6	3.4-4.6	(4.1±0.6)
c	35.4	28.4-35.4	(32.4±3.6)
c’	1.1	0.9-1.1	(1.0±0.1)
V	44.6	44.6-48.2	(46.8±1.8)
V’	51.5	49.9-51.5	(50.6±0.8)
G1	18	17.9-22.2	(19.7±2.2)
G2	17.9	17.9-27.2	(21.7±4.8)
Lip region width	9.9	9.9-10.7	(10.4±0.4)
Lip region depth	4.6	3.6-4.6	(4.2±0.6)
Maximum body width	47.4	45.4-47.4	(46.4±1.0)
Body width at base of lip region	15.3	14.3-15.3	(14.5±0.7)
Body width at base of oesophagus	38.6	38.6-40.0	(39.4±0.7)
Body width at anus	24.0	24.0-25.8	(25.2±1.0)
Odontostyle length	12.4	11.2-12.4	(11.9±0.6)
Odontophore length	17.0	12.1-17.0	(14.7±2.5)
Amphid from anterior end	5.4	4.4-5.4	(4.6±0.7)
Guiding ring from anterior end	8.4	7.4-8.4	(7.8±0.6)
Nerve ring from anterior end	94.3	94.3-97.4	(96.0±1.6)
Oesophageal length	211.0	207.2-211.0	(209.4±2.03)
Expanded part of oesophagus	97.4	94.3-97.4	(96.0±1.6)
Glandularium	87.1	87.1-88.0	(87.5±0.5)

Morphometric characters	Holotype (n=1)	Paratypes (n=6)	Mean±SD
Vulva from anterior end	432.7	339.9-432.7	(405.1±56.6)
Anterior gonad	174.1	156.7-174.1	(166.9±9.1)
Posterior gonad	173.0	173.0-191.6	(181.7±9.3)
Prerectum	35.6	28.8-35.6	(31.7±3.5)
Rectum	22.9	17.1-22.9	(19.9±2.9)
Tail length	27.4	27.4 – 45.3	(36.1±9.0)

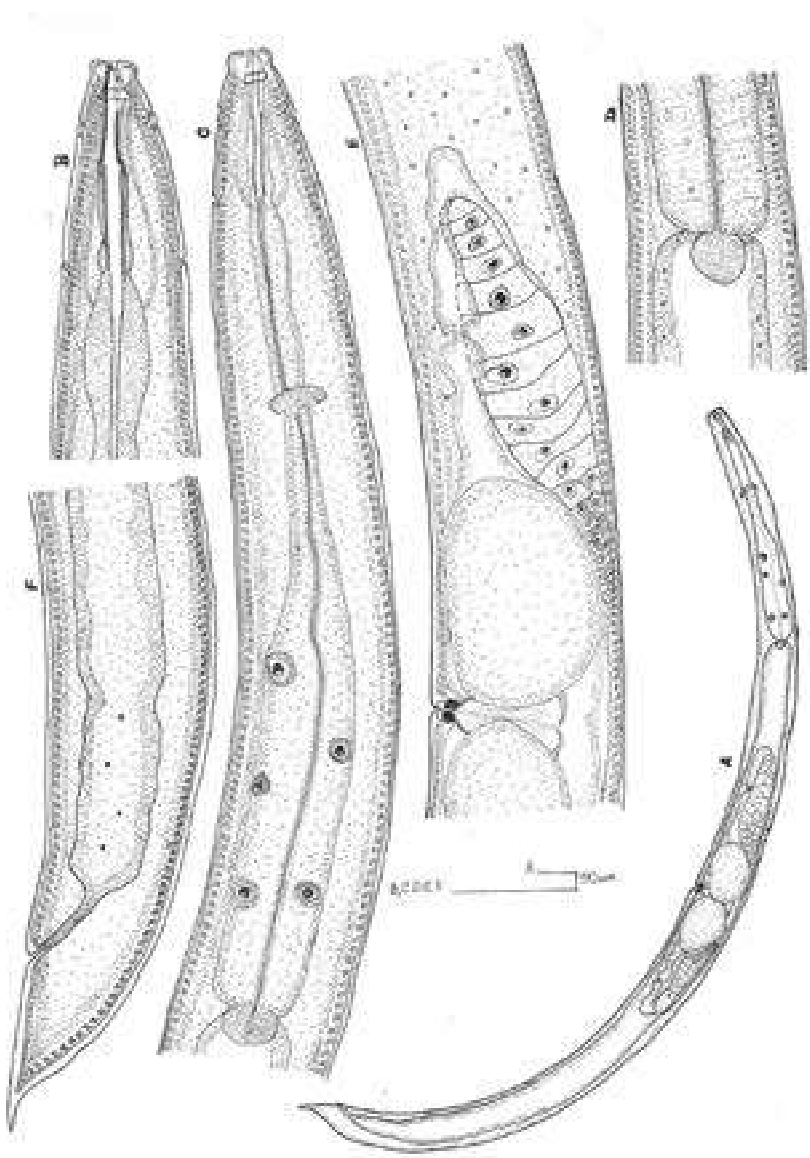

Fig 1. *Talanema dhritiae* sp.n. A. Entire female, B. Anterior region, C. Pharynx, D. Pharyngo-intestinal junction, E. Vulva and anterior gonad, F. posterior region

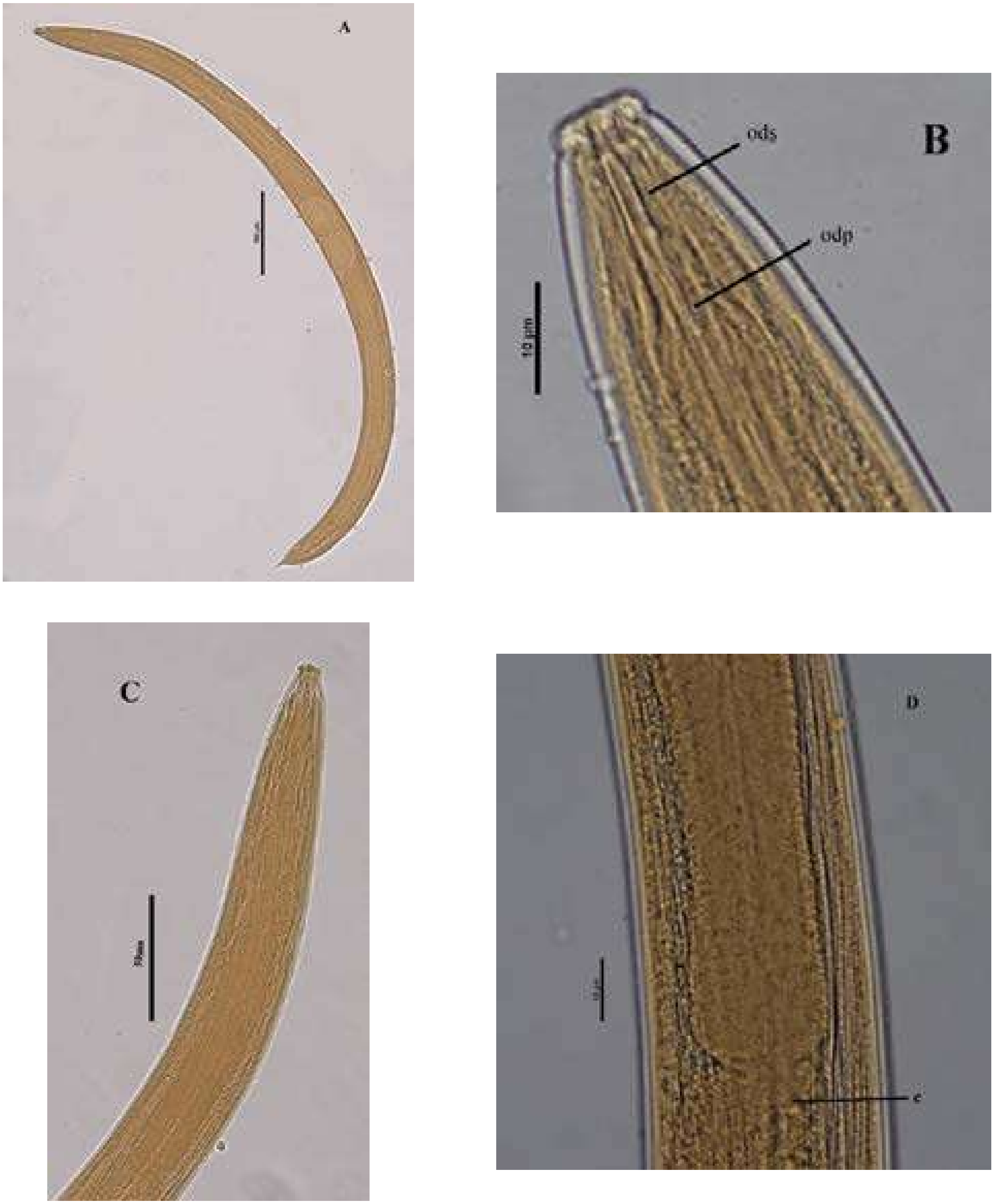

Fig 2. Photomicrographs of *Talanema dhritiae* sp. n. A. Entire female, B. Head region, C. Pharynx, D. Pharyngo-intestinal junction,

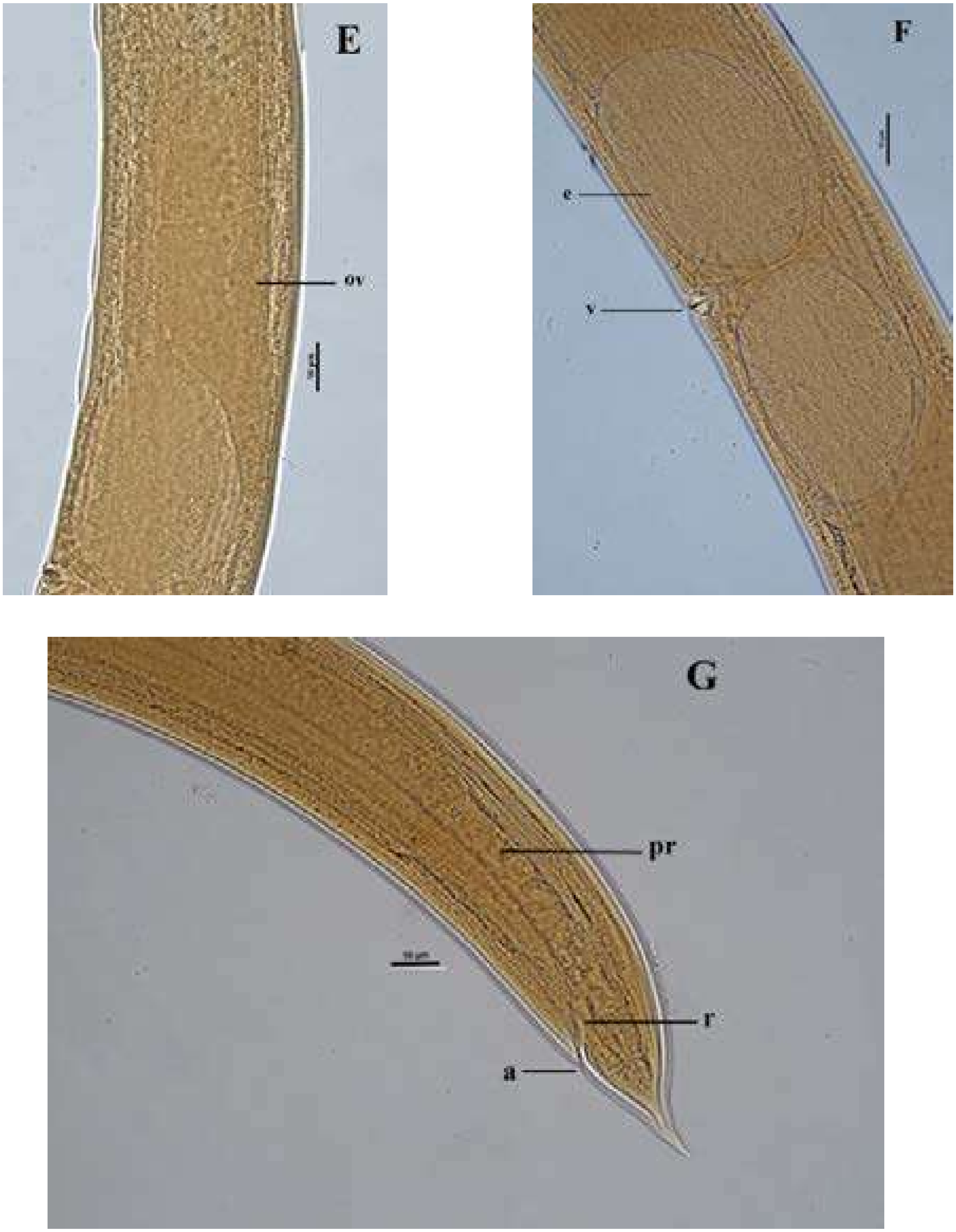

Fig 2. Photomicrographs of *Talanema dhritiae* sp. n. E. Vulva and egg, F. Anterior gonad, G. Posterior region.
Ods : Odontostylet ; Odp : Odontophore ; c : cardia ; ov : ovary ; e : egg ; v : vulva ; pr : pre-rectum ; r : rectum ; a : anus

Acknowledgments

The authors are very much grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India, Kolkata, West Bengal, India for providing all kinds of facilities to do the present work. We are also thankful to Dr. Anjum Nasreen Rizvi, Scientist-E and O/C- Nemathelminthes Section of Zoological Survey of India, Kolkata for her constant support during the work.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

New species and records of tribe Sericini of Manipur, India (Coleoptera: Scarabaeidae: Melolonthinae)

Debika Bhunia[1,2], Devanshu Gupta[1], Subhankar Kumar Sarkar[2] and Dirk Ahrens[3]

[1]Zoological Survey of India, M Block, New Alipore, Kolkata, 700053, West Bengal, India.
dbhunia92@gmail.com, debikazoo22@klyuniv.ac.in, https://orcid.org/0000-0002-7957-0334
devanshuguptagb4102@gmail.com, https://orcid.org/0000-0001-9188-4689;
[2] Entomology Laboratory, Department of Zoology, University of Kalyani, Kalyani -741235, West Bengal, India
sksarkarzoo18@klyuniv.ac.in, https://orcid.org/0000-0002-4129-2148
[3] Zoologisches Forschungsmuseum Alexander Koenig Bonn, Adenauerallee 127, 53113 Bonn, Germany.
E-mail: ahrens.dirk_col@gmx.de , https://orcid.org/0000-0003-3524-7153

Abstract

Here we describe one new species from Manipur, India: Maladera *bezdeki* Bhunia, Gupta, Sarkar & Ahrens. Moreover, *Maladera drescheri* (Moser, 1913), *M. freyi* Ahrens & Fabrizi 2016, *M. rufotestacea* (Moser, 1915), and *Maladera satrapa* (Brenske, 1898), are recorded from Manipur state of India for the first time. Diagnostic morphology of the new species is described and illustrated, and the updated species distribution is shown on a map.

Keywords: Biodiversity hotspots, morphology, Northeast region, taxonomy

Introduction

Beetles of the tribe Sericini (Coleoptera: Scarabaeidae: Melolonthinae) are herbivores in adult life stages and are known with nearly 4,600 described species globally. Of these, over 682 species are known from India (Ahrens & Fabrizi 2016; Sreedevi *et al.* 2018, 2019; Chandra *et al.* 2021; Bhunia *et al.* 2021; Bhunia *et al.* 2022), accounting for 16% of their global diversity. Most of the Indian species are reported from the Himalayas (Ahrens 2004) and the southern areas of the country alsi Ahrens & Fabrizi 2016. However, in many regions, such as the north-eastern states, the tribe remain largely unexplored or represented only by old collection records which have too imprecise data to be geo- localized. While working on unidentified Sericini beetles of Manipur state, we have found five interesting species, of which we describe one new species of the *Maladera thomsoni* group. Moreover, four species belonging to two genera are recorded from Manipur state for the first time: *Maladera drescheri* (Moser, 1913), *M. freyi* Ahrens & Fabrizi 2016, *M. rufotestacea* (Moser, 1915), and *M. satrapa* (Brenske, 1898). These new data show that there is continued urgent need to further explore the diversity of the species in the unexplored, white spots in India that will help to get insights on systematics, distribution, and biodiversity of Indian Sericini. The morphology of the new species is described and illustrated and its distribution is illustrated.

Material and methods

Manipur is biogeographically located in the north-eastern part of India, covering an area of 22,327 km^2. It is bounded by the Indian states of Nagaland to the north, Mizoram to the south, Assam to the west, and by Myanmar in the east.

The unidentified pinned and dry preserved collections of NZC of ZSI, Kolkata were studied. The aedeagus was dissected by softening the specimens; after dissection it was kept in 10% KOH for 10 minutes to clear the hard sclerotised structures. For identification of the species, the male genitalia of all the specimens were examined. All the specimens were examined either using a Nikon SMZ–25

*Author for correspondence
Article Received on: 02.04.2023

Accepted on: 24.04.2023

stereo zoom microscope, and illustrations were taken through the microscope using the software NIS–Elements BR 5.10.00 or with a Leica M125 stereo microscope with a Leica DFC420Cdigital camera using the Leica Application Suite (ver. 3.3.0). The resulting images were subsequently digitally edited to remove reconstruction errors and to obtain a white background. The type material is deposited as indicated along the material examined. A distribution map was prepared using the software QGIS 2.8.1.

The following code identifies the collection housing the examined material:

NZSI—Zoological Survey of India, Kolkata, India.

Results

Systematic account

Order **Coleoptera** Linnaeus, 1758

Suborder **Polyphaga** Emery, 1886

Superfamily **Scarabaeoidea** Latreille, 1802

Family **Scarabaeidae** Latreille, 1802

Subfamily **Melolonthinae** Leach, 1819

Tribe **Sericini** Kirby, 1837

Diagnostic Characters: Genus *Maladera* Mulsant & Rey, 1871 is one of the diverse genus of tribe Sericini (Coleoptera: Scarabaeidae: Melolonthinae) consisting of many subgenus and group under it. Genus *Maladera* can be distinguished with other genera by having protibia with two teeth, Antennal club in male with three or four antennomeres. More than, 400 species of Sericini are currently known from the Indian subcontinent.

New species

***Maladera bezdeki* Bhunia, Gupta, Sarkar & Ahrens**, **new species**

(Figs. 1–5)

Type locality. India: Manipur, Churachandrapur, Circuit House, 24.3429N, 93.7005E.

Type material. Holotype, male: "India: Manipur, Churachandrapur, Circuit House, 24.3429N, 93.7005E, 19.v.1993, leg. B. Mitra" (NZSI).

Description of the holotype, male. Body. Length: 9.21 mm, length of elytra: 5.28 mm, width: 4.38 mm. Body oblong-oval, yellowish brown, dorsal surface dull, dorsal surface glabrous.

Head. Labroclypeus subtrapezoidal, distinctly wider than long, widest at base, lateral margins nearly straight, convergent anteriorly, anterior angles strongly rounded, anterior margin weakly sinuate medially, margins weakly reflexed; lateral margin and ocular canthus produce an indistinct angle; surface flat, finely, densely punctate, with a very few single setae; twice as wide as long; ocular canthus short and moderately narrow (1/3 of ocular diameter), finely densely punctate, with a terminal seta. Frons with sparse punctures, with many long, erect setae beside eyes. Eyes moderately large, ratio diameter/interocular width: 0.68. Antenna with ten antennomeres, club with three antennomeres and straight, as long as the remaining antennomeres combined. Mentum elevated and slightly flattened anteriorly.

Pronotum moderately transverse, widest at the base, lateral margins moderately and evenly convex and more strongly convergent anteriorly; anterior angles distinctly produced and sharp; posterior angles blunt and weakly rounded at tip; anterior margin straight, with robust marginal line, base without marginal line; surface moderately densely and finely punctate, with minute setae in punctures; anterior and lateral margin finely sparsely setose; hypomeron carinate, not produced ventrally. Scutellum wide, triangular, with fine, moderately dense punctures, impunctate on midline.

Elytra widest at middle, apex truncated, striae finely impressed, finely and densely punctate, intervals nearly flat, with fine, moderately dense punctures concentrated along striae and with minute setae in punctures; epipleural edge robust, ending at blunt external apical angle of elytra, epipleura sparsely setose; apical border of elytra membraneous, with a fine rim of microtrichomes (visible at ca 100x magnification).

Ventral surface dull, finely and densely punctate, nearly glabrous, metasternal disc sparsely covered with fine, short setae; metacoxa with a few longer setae laterally. Abdominal sternites finely and densely punctate, punctures with minute setae, each sternite with a transverse row of punctures each bearing a fine seta. Mesosternum between mesocoxae as wide as mesofemur. Ratio of length of metepisternum/metacoxa: 1/1.75. Pygidium strongly but evenly convex, dull, finely and densely punctate, without smooth midline, with long setae along apical margin.

Legs short and wide, dull; femora with two longitudinal rows of setae, finely and sparsely punctate. Anterior margin of shiny metafemur acute, without adjacent serrated line, anterior row of setae completely reduced; posterior ventral margin smooth, strongly widened at ventral apex, dorsal posterior edge smooth, neither serrate, glabrous. Metatibia short and very wide, widest at middle, ratio of width/length: 1/2.5, sharply carinate dorsally, with two groups of spines, basal group at middle, apex finely serrate, shallowly sinuate interiorly near tarsal articulation. Tarsomeres dorsally impunctate, glabrous, neither laterally nor dorsally carinate, moderately setose ventrally; metatarsomeres with a strongly serrated ridge ventrally and a smooth subventral longitudinal carina, glabrous; first metatarsomere slightly shorter than following two tarsomeres combined and slightly longer than dorsal tibial spur. Protibia moderately long, bidentate; anterior claws symmetrical, basal tooth of both claws bluntly truncate at apex.

Aedeagus: Fig. 1–4. Habitus: Fig. 5.

Diagnosis. *Maladera bezdeki* Bhunia, Gupta, Sarkar & Ahrens, new species is in its shape of the genitalia and its external appearance very similar to *M. balphakramensis* Ahrens and Fabrizi, 2016. From *M. balphakramensis* the new species differs by the shorter and curved parameres, having a long dorsal lobe at the left paramere instead at the right one. *Maladera bezdeki* differs from all other so far known species of the *M. thomsoni* group by the strongly curved parameres which are in all other species usually straight; and the dorsal lobe which is strongly reflexed and bent laterally, while it is only weakly curved in the other taxa.

Etymology. This new species (noun in the genitive case) is dedicated to Dr Aleš Bezděk, curator, Institute of Entomology, Academy of Sciences of the Czech Republic, in honor and gratitude for his relentless effort to study and catalogue the Oriental and Palearctic Melolonthinae.

Distribution. The species is only known from the type locality in Mizoram (Fig. 22)

New records

***Maladera drescheri* (Moser, 1913)**

(Fig: 6-9)

Autoserica drescheri Moser, 1913: 294.

Maladera drescheri: Ahrens 2004b: 278; Krajcik 2012:154.

Autoserica dalatensis Frey, 1969b: 107; syn. by Ahrens 2004b: 278. *Maladera drescheri:* Ahrens& Fabrizi 2016: 263

Material examined. 2 males: India: Imphal, West Imphal Valley, 24.7828° N, 93.8859° E, 04.vi.1945, coll. M.L. Roonwal. (NZSI).

Remarks. This is the first state record for Manipur state of India (Fig. 22). Previously recorded from Meghalaya (Ahrens & Fabrizi 2016).

Maladera freyi Ahrens & Fabrizi, 2016

(Fig: 10-13)

Cephaloserica opaca Frey, 1975b: 229.

Maladera opaca: Ahrens 2004b: 238; Krajcik 2012: 155.

Maladera freyi (replacement name): Ahrens & Fabrizi 2016: 167; Chandra *et al.* 2021: 503.

Material examined. 1 male: India: Manipur, Churachandpur, Boumba, 24.3429N, 93.7005E, 15.iv.1992, coll**.** S. K. Saha (NZSI).

Remarks. This is the first state record for Manipur state of India (Fig. 22). Previously recorded from India (West Bengal, Meghalaya), Bhutan, and Nepal (Ahrens & Fabrizi 2016, Chandra et al 2021).

Maladera rufotestacea (Moser, 1915)

(Fig: 14-17)

Maladera rufotestacea: Ahrens & Fabrizi 2016: 210

Material examined. 1 male: India: Manipur, Tamenglong, 24.990 N, 93.5006 E, 26.v.1981, coll. Radhakrishnan (NZSI).

Remarks. This is the first state record for Manipur state of India (Fig. 22). So far the species is known from India (Meghalaya), China, Thailand, Myanmar, Vietnam (Ahrens & Fabrizi 2016).

***Maladera satrapa* (Brenske, 1898)**

(Fig: 18-21)

Autoserica satrapa Brenske, 1898: 341.

Maladera satrapa: Krajcik 2012: 155. : Ahrens & Fabrizi 2016: 137

Material examined. 1 male: India: Manipur, Bishnupur, Keibul- Lamjao National Park, 24.4788° N, 93.8395° E, 02.iii.1994, coll. S.K Saha. (NZSI).

Remarks. This is the first state record for Manipur state of India (Fig. 22). Previously recorded from Meghalaya (Ahrens & Fabrizi 2016).

Discussion

The present study is very much relevant as it closes some important gaps in the knowledge of the distribution of Indian Sericini. As a result, one new species of the *Maladera thomsoni* group, *Maladera bezdeki* Bhunia, Gupta, Sarkar & Ahrens, new species, has been added, including four new records to the state of Manipur, India. All the three reported *Maladera drescheri* (Moser, 1913), *M. rufotestacea* (Moser, 1915), and *Maladera satrapa* (Brenske, 1898), seem to be endemic to north eastern region of India, except *Maladera freyi* Ahrens & Fabrizi, 2016 which has recently been reported from West Bengal (Chandra et al 2021), although a lot more vigorous study will unveil the actual figure. This study which provides some ideas that a there is always a pressing need to update the species distribution, particularly in the unexplored parts of India, is very important since many of the local endemic and autochthonous species are potential crop pests as they are phytophagous (Ahrens *et al.* 2009). Thus, these new records in these underexplored areas encourage further sampling with light traps there despite their high population density for further faunistic and taxonomic investigations, which hopefully will also help to further explore the ecology of the species.

Figure captions:

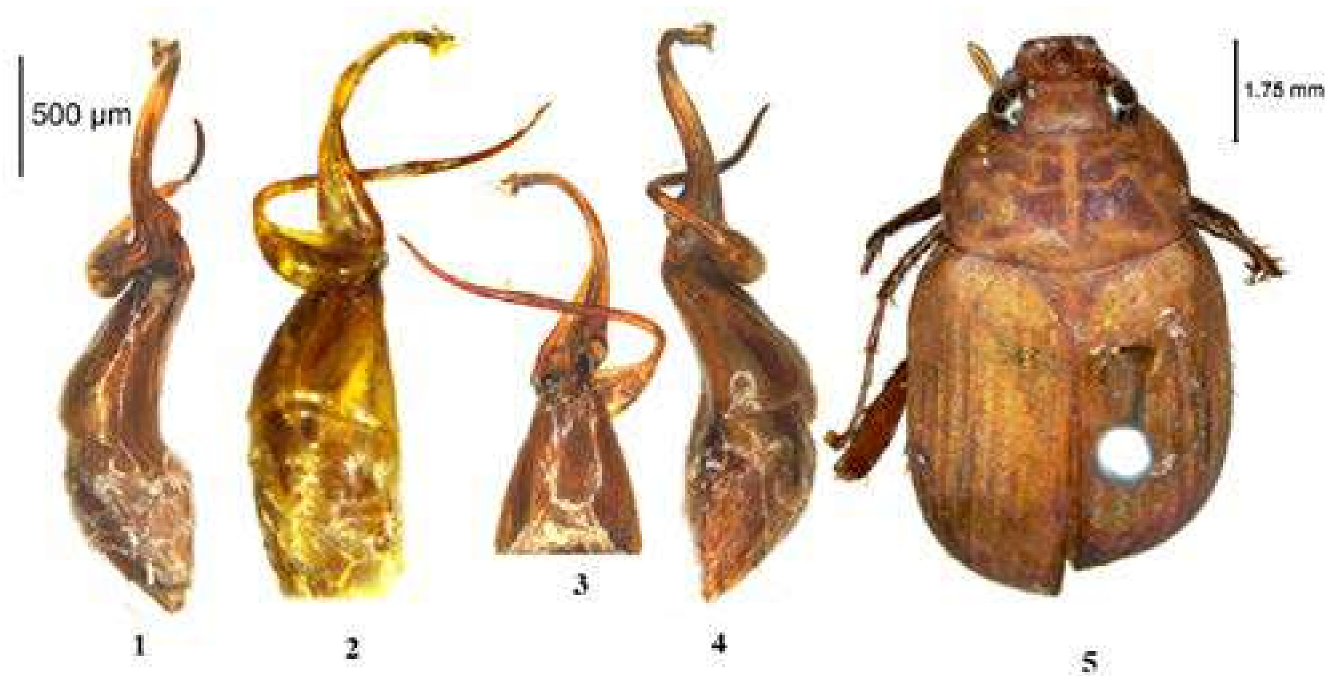

FIGURE 1-5. *Maladera Bezdeki* Bhunia, Gupta, Sarkar & Ahrens, new species (holotype); **(1)** aedeagus in lateral view (left); **(2)** aedeagus in dorsal view; **(3)** aedeagus in ventral view; **(4)** aedeagus in lateral view (right); **(5)** habitus, dorsal view. aedeagus (1-4), scale 0.5 mm.

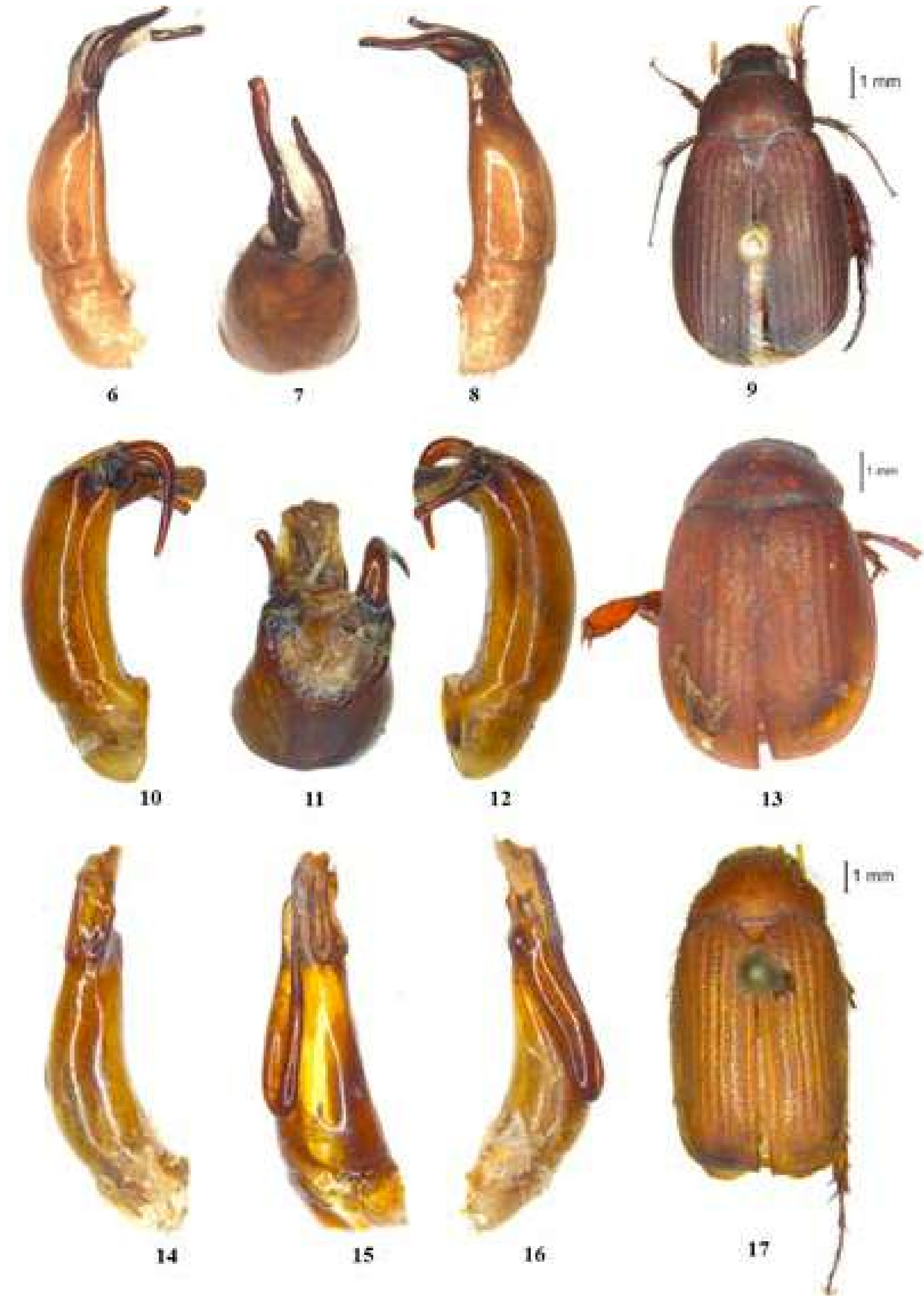

FIGURE 6-17. 6-9. *Maladera drescheri* (Moser, 1913); **(10-13).** *Maladera freyi* Ahrens & Fabrizi, 2016; **14-17.** *Maladera rufotestacea* (Moser, 1915); (6, 10, 14) aedeagus in lateral view (left); (7, 11, 15) aedeagus in dorsal view; (8, 12, 16) aedeagus in lateral view (right); (9, 13, 17) habitus, dorsal view. scale 0.5 mm.

FIGURE 18-21. *Maladera satrapa* (Brenske, 1898), **(18)** aedeagus in lateral view (left); **(19)** aedeagus in dorsal view; **(20)** aedeagus in lateral view (right); **(21)** habitus, dorsal view. aedeagus (1-4), scale 0.5 mm.

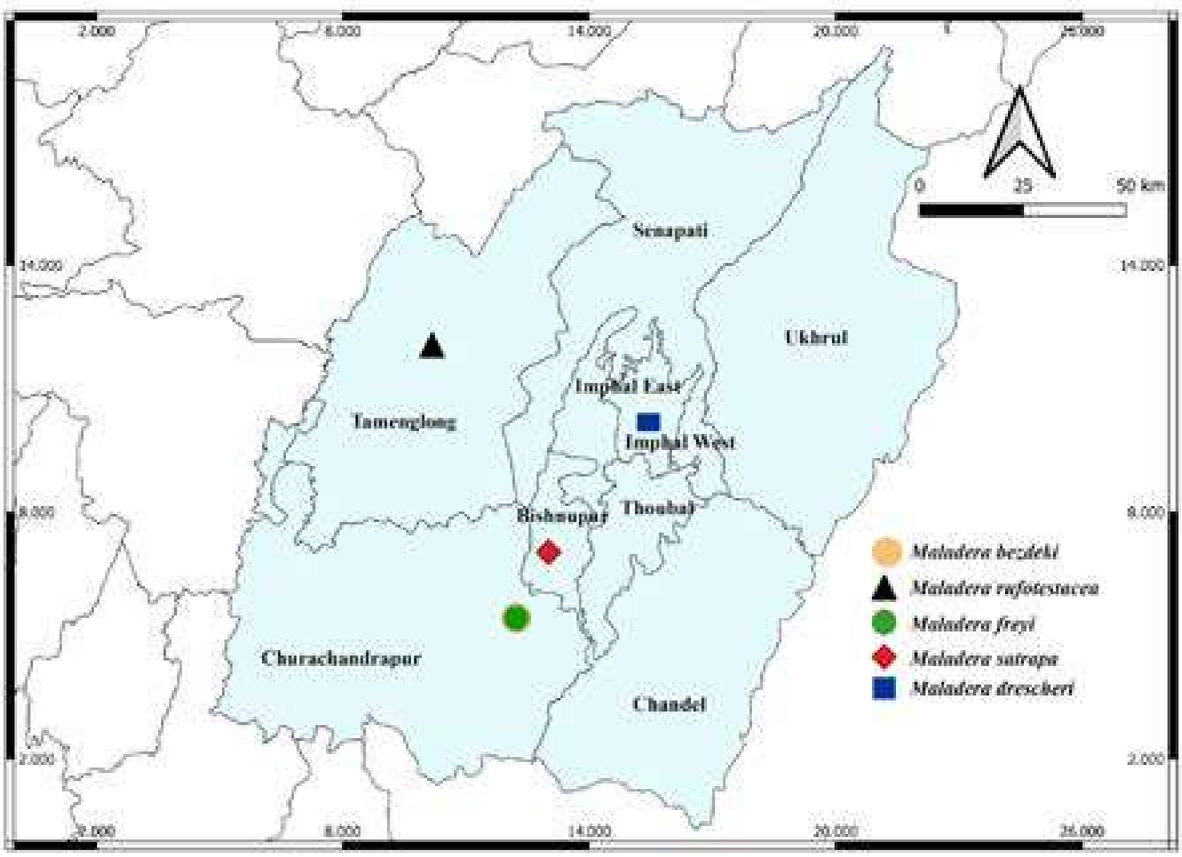

FIGURE 22. Map of Manipur showing the location of the type locality of the new species, *Maladera bezdeki* Bhunia, Gupta, Sarkar & Ahrens, sp. nov., as well as the new state records of *Maldera rufotestacea* Ahrens & Fabrizi, 2016, *M. freyi* Ahrens & Fabrizi, 2016, *M. satrapa* (Brenske, 1898), and *Maladera drescheri* (Moser, 1913).

Acknowledgements

The authors are thankful to the Dr. Dhriti Banerjee, Director, Zoological Survey of India, for providing necessary facilities for the work. We also thank Dr. C. Raghunathan, Scientist-F & Division-in-Charge, Entomology A&B, for his continued support. DG, SKS and DB are thankful to the Vice Chancellor to the University of Kalyani for his support. In addition, we would like to thank the past and present members of multiple survey teams and staff of the Coleoptera section (ZSI, Kolkata) for collecting and maintaining specimens. Authors extend their thanks to O/C, Microscopy Section. This paper is part of the annual research programme "Taxonomic studies of Tribe Sericini of India (Coleoptera: Scarabaeidae: Melolonthinae) of Zoological survey of India, Government of India.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Description of two new species of *Eulophus* Geoffroy, 1762 (Hymenoptera: Chalcidoidea: Eulophidae) from India

Mohd Tanjeem Raza and Shahid Bin Zeya*
Department of Zoology, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India.

Abstract

Two new species of *Eulophus* Geoffroy (Eulophidae: Eulophinae), namely *Eulophus orientalis* Raza & Zeya, sp. nov. and *E. almoriensis* Raza & Zeya, sp. nov. are described from India. A revised key to Indian species of *Eulophus* is also given.

Keywords: Hymenoptera, Eulophinae, new species.

Introduction

Eulophus Geoffroy generally similar to *Necremnus* Thomson by having the funicle 3-segmented and notauli incomplete, but is distinguished from it by having reduced mandibles with teeth not reaching each other and basitarsus of mid leg shorter than second. The species are gregarious larval parasitoids of insects belonging to the orders Lepidoptera, Hymenoptera, Diptera and Coleoptera (Narendran, 2011). The genus is represented by 79 species from the world (Noyes, 2019), of which only 4 species are known from India viz., *E. razaki* Narendran, *E. velosus* Narendran, *E. abdominalis* Nees and *E. chennaicus* Narendran and eight are currently unavailable names. In the present paper we describe two new species, *Eulophus orientalis* Raza & Zeya sp. nov. and *E. almoriensis* Raza & Zeya sp. nov. from Uttarakhand, India.

Material and Methods

The specimens were collected by a sweep-net from the Nainital and Almora districts of Uttarakhand. All collected specimens were transferred in 80% alcohol and mounted the specimen on rectangular cards using water soluble glue. Body colour was noted from the card-mounted specimens. The wings and antennae were mounted on slides following methods provided by Noyes (1982). The terms and body sculpture followed Hayat (2006) and Narendran (2011). Body length is given in millimetres. Other measurements are relative taken mainly from the carded specimens at 80× magnification by using stereozoom binocular (Nikon SMZ 1000) except the relative measurements of antenna and wings, which were mounted on slides and taken at 100× magnification with the help of linear divisions of an ocular micrometres placed in the eye piece of compound microscope (Nikon Eclipse E200). The card-mounted parts were photographed with digital camera (Nikon DS-Fi2) attached to a stereo-zoom binocular (Nikon SMZ25) and for slide-mounted body parts were photographed with digital camera (Nikon DS-Fi1c) attached to compound microscope (Nikon Eclipse Ci). The photographs were further enhanced using Adobe Photoshop®.

The following morphological abbreviations are used in the text:

AOL = Minimum distance between a posterior ocellus and the anterior ocellus.

C1, C2, etc. = Claval segments 1, 2, etc.

F1, F2, etc. = Funicle segments 1,2, etc.

OCL = Minimum distance between a posterior ocellus and the occipital margin.

*Author for correspondence : drsbz1966@gmail.com Mob/WhatsApp +91 9690236032
Article Received on: 02.04.2023
Accepted on: 24.04.2023

OOL = Minimum distance between a posterior ocellus and the corresponding eye margin.

POL = Minimum distance between the posterior ocelli.

T1, T2, etc = Tergites 1, 2, etc. of gaster.

WIOS = Width of inter-ocular space.

The following acronym is used for the depository:

ZDAMU – Insect Collection, Department of Zoology, Aligarh Muslim University, Aligarh, India.

Results and Discussion

Genus *Eulophus* Geoffroy

Eulophus Geoffroy, 1762*:* 312. Type species *Ichneumon ramicornis* Fabricius, by monotypy.

Comedo Schrank, 1802: 308. Type species *Ichneumon larvarum* Linnaeus, by monotypy 195. Synonymy by Peck, 1951:430.

Cratotechus Thompson, 1878*:* 208, 219. Type species *Ichneumon larvarum* Linnaeus; designated by Ashmead 1904. Synonymy by Bouček & Askew, 1968:60.

Onychocomedo Graham, 1959: 183. Type species *Eulophus thespius* Walker;designated by Graham, 1959. Synonymy by Bouček, 1959: 160.

Diagnosis: *Female* :Antennae with funicle 3-segmented; mandibles reduced, not meeting medially; notauli incomplete or indistinct; basitarsus, at least of mid leg shorter than second tarsal segment; gaster rounded or sub-rounded (Narendran, 2011).

Key to Indian species of *Eulophus* Geoffroy, females

1. Gaster with a pale yellow patch on gaster.. 2
-. Gaster without any pale yellow patch on gaster.. 5
2. Gaster with a pale yellow patch covering T1 and T2 medially (Fig.7) 3
-. Gaster with a pale yellow patch covering more than two basal tergites of gaster (Narendran 2011: fig.179) 4
3. Antennal scape reaching level of the vertex; clava 2.7–2.8× as long broad , slightly shorter than F2 & F3 combined (Fig. 5) .... *E.orientalis* **sp. nov**.
-. Antennal scape not reaching level of the vertex; clava 3.3–3.6× as long broad, distinctly longer than F2 & F3 combined (Fig.9) .... *E. almoriensis* **sp. nov**.
4. Metasoma with petiole distinctly longer than broad .... *E. velosus* Narendran
-. Metasoma without petiole or petiole indistinct.. *E. abdominalis* Nees
5. Fore and mid coxae and all femora yellow; body black with strong metallic green refringence .... *E. razaki* Narendran
-. All coxae black and femora brownish black with bases and apices pale; body black with very slight metallic green refringence.. *E. chennaicus* Narendran

Description of new species

1. *Eulophus orientalis* Raza & Zeya, sp.nov.

(Figs 1–7)

Diagnosis. *Eulophus orientalis* sp. nov. apparently looks similar to *E. velosus* Narenran, but it differs as follows: head and mesosoma metallic dark brown to black; fore wings subhyaline with a brown infuscate patch in the middle of the disc; gaster with a large pale yellow patch covering T1 and T2 medially; POL 1.71× OOL; fore and hind coxae brown; petiole broader than long. In *E. velosus*: head and mesosoma black and without metallic refringence; fore wings subhyaline without any infuscate patch; gaster with a large pale yellow patch covering T1, T2 and T3 medially; POL 3.5× OOL; all coxae black; petiole distinctly longer that broad (Narendran, 2011). Furthermore, the following features are taken to distinguish the species from other Indian species. These are: head dark brown with frontovertex metallic brown with green luster; F1 & F2 subequal in length; clava 2.7 – 2.8×

as long as broad, slightly shorter than F2 & F3 combined; fore wing with submarginal vein+parastigma 1.16× as long as marginal vein; marginal vein at most 1.8× as long as post marginal vein.

Description.

Female. Holotype. Length, 2 mm (Paratype, 2 mm). Head dark brown with frontovertex metallic brown with green luster; ocelli reflecting white; mandible and palpi brown. Antennal scape pale white, slightly darker at apex; pedicel and flagellum brown (Fig.5). Mesosoma metallic dark brown to black; tegula brown. Fore wings subhyaline with a brown infuscate patch in the middle of the disc; venation brown. Fore leg with coxa brown, femur brown with pale brown apically; mid leg with coxa pale yellow, femur in basal half pale yellow, rest brown to pale brown; hind leg with coxa brown, femur in basal half pale yellow, rest brown; tibiae and tarsi of all legs pale yellow. Metasoma with petiole pale yellow; gaster brown with a large pale yellow patch covering T1 and T2 medially.

Head. Head in dorsal view, 1.1× as broad as high (Fig.4); POL as long as 1.71× OOL (12:7); AOL 0.57× OOL (4:7); WIOS as broad as 2.5× POL (30:12); eye height 2.5× as long as malar space; Antennal toruli situated just little below the lower ocular line and scape reaching level of the vertex, 6.60× (paratype 4.6×) as long as broad; pedicel 2.25× (paratype 1.8×) as long as broad; funicle with 2 anelli, F1and F2 subequal; F3 is the shortest; clava 3-segmented, 2.8× (paratype 2.7×) as long as broad, slightly shorter than F2& F3 combined.

Mesosoma. Mesosoma (Fig. 6) gibbous, 1.2× (paratype 1.3×) as long as broad, 1.07× (paratype 0.85) as long as metasoma with raised polygonal reticulate sculpture; prepectus with reticulate sculpture; pronotum shorter and broad; mesoscutum transverse, 0.63× (paratype 0.64×) as long as broad, and 1.75× (paratype 1.6×) as long as scutellum; scutellum oval and gibbous, 1.25× as broad as long; propodeum with a strong median carina; spiracle round touching the anterior margin of propodeum. Fore wing (Fig. 2) 2.3× as long as broad; submarginal vein + parastigma 1.16× as long as marginal vein; marginal vein 1.8× as long as post marginal vein and 2.30× as long as stigmal vein, setation as in figure 2. Hind wing (Fig. 3) 4.0× (paratype 5.1) as long as broad. Legs with fore and hind coxae reticulated.

Metasoma. (Fig.7). Petiole 3.3× (paratype 2×) as broad as long, gaster little shorter than mesosoma; ovipositor not exerted beyond apex of gaster.

Relative measurements. (Holotype): Head (card) in dorsal view , head length: width, 20:55; eye height, 30; malar space, 12. Antennal segments (slide): Length: width – scape, 33:5; pedicel, 9:4; F1, 15:6; F2,15:8; F3, 13:8; C1, 10:6; C2, 10:8 ; C3, 5:5. Mesosoma length: width, 70:55; mesoscutum length: width, 35:55; scutellum length: width, 20:25. Fore wing length: width, 220:95; marginal vein length, 60; submarginal length, 50; parastigma length, 20; stigmal vein length, 26; postmarginal vein length, 32. Hind wing length: width, 160:40; Metasoma length: width, 55:30. Petiole length: width, 3:10.

Male. Unknown.

Material examined: Holotype: Female (one antenna and right wings on slides under two coverslips, slide No. EULT212, rest of the body on card), INDIA: Uttarakhand: Nainital, Kathgodam, 7.xi.2020; Coll: T. Raza, M. Ahmad (ZDAMU).

Paratype: 1female (one antenna and right wings on slides under two coverslips, slide No. EULT235, rest of the body on card), data as for holotype (ZDAMU).

Host. Unknown.

Distribution. India: Uttrakhand.

Etymology. The name of species is derived from the Oriental region as the Indian subcontinent is a sub-region of Oriental realm.

2. *Eulophus almoriensis* Raza & Zeya, sp.nov.

(Figs. 8–15)

Diagnosis. *Eulophus almoriensis* sp. nov. comes close to *E. orientalis* sp. nov. in having more or less similar body colour and antennal configuration and a patch of infuscation on the fore wing, but differs from the later by the character as follows: POL as long as 2.3–3× OOL; AOL 1 –1.1× OOL; (POL as long as 1.71× OOL; AOL 0.57× OOL in *orientalis*); marginal vein 1.5× as long as post marginal vein (marginal vein 1.8× as long as post marginal vein in *orientalis*) and also by the characters given in the key. Furthermore, *E. almoriensis* sp.nov. is distinguished from other Indian species in the following characters: head dark brown to black with frontovertex coppery bluish shine; POL as long as 2.3 –3× as long as OOL; clava more than 3× as long as broad, longer than F2 & F3 combined; fore wing with submarginal vein+parastigma 1.3× as long as marginal vein; marginal vein at most 1.5× as long as post marginal vein.

Female. Holotype (Fig. 8). Body length, 1.7 mm (paratype, 2.2 mm). Head dark brown to black; frontovertex with coppery and bluish shine; gena and area around mouth metallic black; ocelli dark brown; mandible brown and palpi dark brown. Antenna with scape pale brown, dorsal margin and apex with brown infuscation; pedicel brown; flagellum and clava dark brown. Mesosoma black; tegula pale brown. Fore wing subhyaline with a brown infuscate in middle of the disc; hind wing subhyaline. Legs with fore coxa black, fore femur brown with pale apices; mid coxa pale yellow; mid femur in basal third pale yellow, rest dark brown; hind coxa dark brown; hind femur in basal half pale yellow, rest dark brown, tibiae and tarsi and trochanters of all legs pale yellow. Metosoma with petiole pale yellow; gaster dark brown to black, with a large pale yellow patch covering T1 and T2 medially.

Head. Head in dorsal view, 1.1× (paratype 1.3×) as broad as high, with reticulate sculpture (Fig. 12); POL as long as 2.3× (paratype, 3×) OOL (14:6), AOL 1.1× (paratype, 1×) OOL (7:6) ; WIOS as broad as 2.2× (paratype 2.3×) POL (32:14); eye height 3× (paratype, 2×) as long as malar space. Antennal toruli situated just below the lower ocular line; scape not reaching level of vertex, scape 6× (paratype, 6.4×) as long as broad, 3.7× (paratype, 3.2×) as long as pedicel; pedicel 1.6× as long as broad; funicle with 2 distinct anelli; F1 longer than F2 and F3 individually; F3 the shortest; clava 3-segmented, 3.3× (paratype, 3.6×) as long as broad; clava longer than preceding two funicle segments combined.

Mesosoma. Mesosoma gibbous (Fig.13), 1.2× (paratype, 1.6×) as long as broad, 0.8× (paratype, 1×) metasoma; mesosoma with polygonal reticulate sculpture; prepectus strongly reticulated; pronotum transverse; mesoscutum with notauli indistinct, 1.5× as broad as long, 1.6× (paratype, 1.5×) as long as scutellum; scutellum gibbous, 0.9× as broad as long; propodeum (Fig. 14) with a raised median carina; spiracle separated from metanotum from its own diameter. Legs with fore and hind coxae reticulated. Fore wing (Fig. 10) 2.3× as long as broad; submarginal vein + parastigmal 1.3× as long as marginal vein; marginal vein 1.5× as long as post marginal vein, and 2× as long as stigmal vein. Hind wing (Fig.11). 4.4× (paratype, 4×) as long as broad, setation as in figure 11.

Metasoma (Fig.15). Petiole 2× (paratype, 1.5×) as broad as long; gaster 2.3× (paratype, 1.1×) as long as broad; ovipositor not exerted beyond apex of gaster.

Relative measurements (holotype). Head (card), in dorsal view, height: width, 45:50; eye height, 30; malar space, 10. Antennal segment (slide) length: width – scape, 30:5; pedicel, 8:5; F1, 14:8 ; F2,13:8; F3, 10:8 ; C1, 10:8; C2, 10:9; C3, 7:5. Mesosoma (card): mesosoma length: width, 60:50; pronotum length: width, 5:45; mesoscutum length: width, 32:50; scutellum length: width, 20:18. Fore wing (slide) length: width, 200:85; marginal vein length, 50; submarginal vein length, 45; parastigma length, 20; stigmal vein length, 25; postmarginal vein length, 32. Hind wing (slide) length: width, 150:34. Metasoma (card) length: width, 70:30; petiole length: width, 3:10.

Material examined: Holotype: Female (one antenna and right wings on slides under two coverslips, slide No. EULT218, rest of body on card), INDIA: Uttarakhand: Almora, Ranikhet, 15.vi.2022; Coll: T. Raza, M. Ahmad (ZDAMU).

Paratype: 1female (one antenna and right wings on slides under two coverslips, slide No. EULT219, rest of body on card), data as for holotype. (ZDAMU).

Host. Unknown.

Distribution. India: Uttarakhand.

Etymology. The species name is derived from the name of the district Almora in Uttarakhand, from where the holotype was collected.

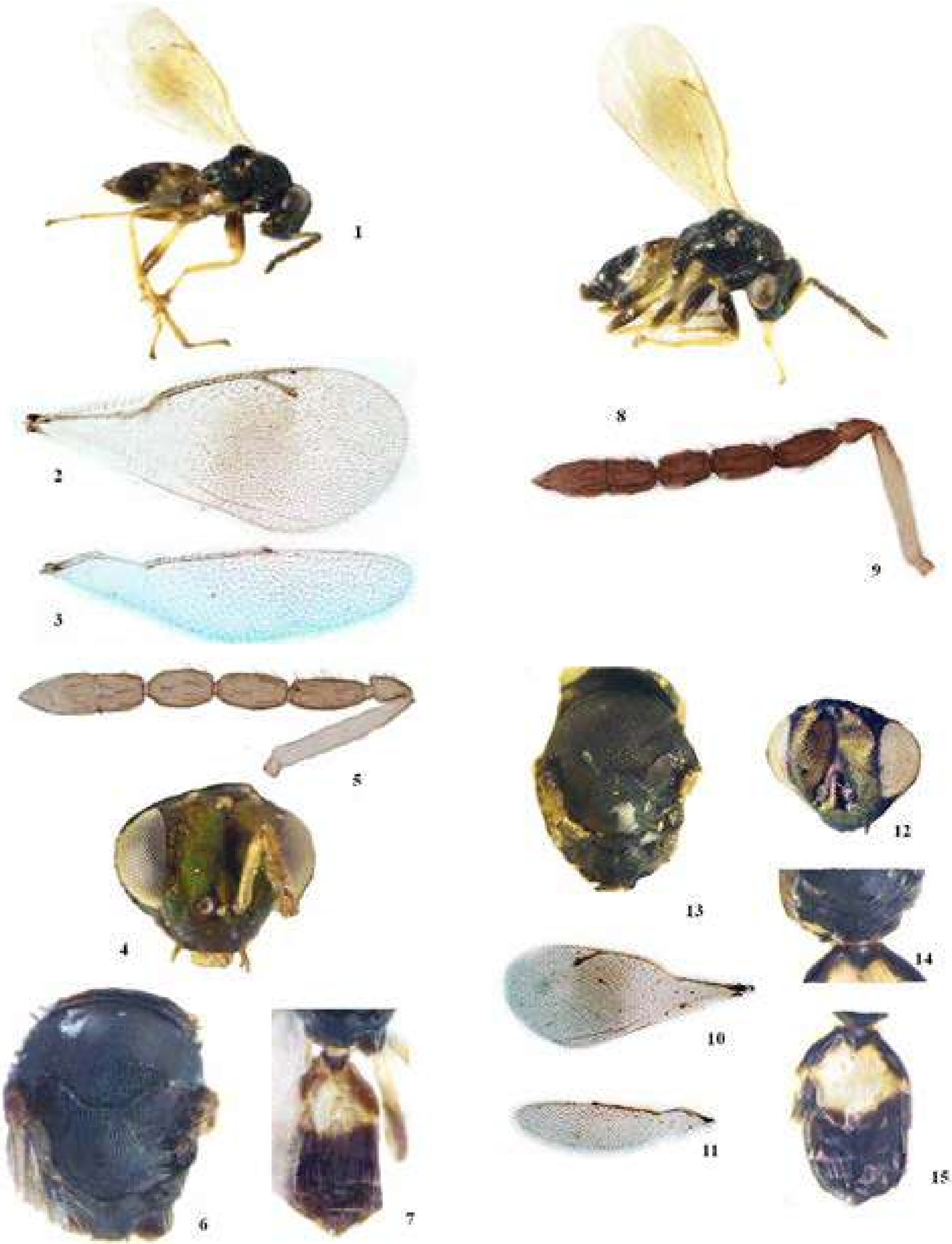
Legends

Figs 1–3: *Eulophus orientalis* sp. nov. female (holotype). 1. habitus; 2. fore wing; 3. hind wing.

Figs 4–7: *Eulophus orientalis* sp. nov. female (holotype). 4. head; 5. antenna; 6. mesosoma; 7. metasoma.

Figs 8–9: *Eulophus almoriensis* sp. nov. female (holotype). 8. habitus; 9. antenna;

Figs 10–15: *Eulophus almoriensis* sp. nov. female, (10–11, holotype). 10. fore wing; 11. hind wing; (12–15, paratype). 12 –head; 13. mesosoma; 14. propodeum; 15. metasoma.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Acknowledgments.

We thank the chairman, Department of Zoology, Aligarh Muslim University, Aligarh, for providing research facilities. TR gratefully acknowledges the Council of Scientific & Industrial Research, New Delhi for providing fellowship in the form of JRF. SBZ acknowledges the SERB-DST, New Delhi for financial assistance.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

A new species of the genus *Acaropsella* (Acari: Trombidiformes: Cheyletidae) from Kerala, India

Neeraj Martin[1]* & Sachin P James[2]

[1&2] P.G & Research Department of Zoology, Malabar Christian College, Kozhikode- 673001, India

Abstract

A new species, *Acaropsella strioreticulata* sp. nov. is described and illustrated herein from wheat semolina of Kerala state, South India. Additionally, this is first record of genus *Acaropsella* from India. Descriptions are based on the morphology of adult females.

Keywords: Acari, *Acaropsella*, new species, Kerala, India

*Corresponding author email: neeraj.martin@yahoo.com.

Introduction

Cheyletidae is a large family which presently includes 75 genera and over 440 species (Zhang *et al.* 2011; Beron 2021; Bochkov and Abramov2016). Genus Acaropsella comprises relatively large cheylitids and was created by Volgin (1969) for those species of the genus Acaropsis Moquin-Tandon 1863 in which acicular humeral setae is absent. Genus Acaropsella can be characterized by having a single palp comb, two dorsal shields, a pair of propodosomal eyes, all legs with paired claws, elongate and narrowly expanded or spatulate dorsal setae (L.A Corpuz-Razos, 1998). According to Gerson *et al.* (1999), Acaropsella included nine species. Later Fain and Bochkov, (2001) synonymized Acaropsella aegyptiaca Wafa et Soliman, 1968 with A. volgini Gerson, 1967; A. filippina Corpuz-Raros and A. konoi Tseng, 1977 with *A. kinshasensis* Fain, 1972. Consequently the species number of *Acaropsella* reduced to six. In 2007, Akbar *et al.* added two new species to this genus which resulted in the total of eight species of mite in the *Acaropsella*. This genus is been reported from India so far. Thus, the present work describes a new species *Acaropsella strioreticulata* sp. nov from India, which is also a new record to India.

Materials And Methods

Samples of wheat semolina infested with mites were collected from Kozhikode district of Kerala state, South India (11° 22' 3.54" N, 75° 47' 35.74" E) and extracted using Berlese-Tullgren funnels equipped with 60 watt bulbs. and picked out under a stereo microscope. Extracted mites were kept temporarily in lactic acid for clearing. Hoyer's medium was used for making permanent slides. Illustrations and measurements were made using Olympus CX31 bright field microscope equipped with a drawing tube. Illustrations were scanned and redrawn using Adobe Illustrator® program (vector-based graphics software, Adobe Systems Incorporated, San Jose). Measurements were done with Lynx Biolux (Lawrence and Mayo) image analysis software. All body measurements presented as ranges (minimum to maximum), in micrometers (μm). The type materials are preserved as permanent slides and deposited in the Western Ghat Field Research Centre- Zoological Survey of India, Kozhikode,Kerala, India.

*Author for correspondence
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Systematic Accounts

Material Examined: Holotype, Female, India, Kerala, Kozhikode. 23 September 2021. Paratype: four, four females. 11° 22' 3.54" N, 75° 47' 35.74" E, Altitude 13 m, 23-ix-2021, coll. Neeraj Martin (deposited at the Western Ghat Field Research Centre- Zoological Survey of India, Kozhikode, Kerala, India)

Description

***Acaropsella strioreticulata* sp. nov.**

Female (Fig.1-4)

Gnathosoma: (Fig. 3). Length 125 (122-127) and width 81 (79-82). Rostral shield has coarse robust pentagonal or hexagonal reticulation pattern. Rostrum tappers to blunt end. Tegmen is broader than protegmen. Palp femur have one spatulate dorsal setae of length 26 (25-26), two ventral setae and one dorsolateral seta. Transverse striations seen on palp femur. Palp tibia with one comb like seta with 13 teeth, two sickle like setae, palp claw with four teeth. Horse- shoe shaped periteme with six links on each side.

Idiosoma: (Fig. 1) Body ovoid, length 360 (352-366) and width 250 (244-254). Two dorsal shields are separated by transverse striation membrane of 34 (33-35) width. Both shields have prominent coarse pentagonal or hexagonal reticulation pattern. All dorsal setae are broadly spatulate and barbed. Propodosomal shield length 149 (146-151), width 166(162-169) and is trapezoidal. One pair of eyes are present which is placed off propodosomal shield. Propodosomal shield has four pairs of lateral setae Vi (25, 24-25), Ve (31, 30-32), Sci (29, 28-29) and Sce (31, 30-32) and three pairs of median setae d1(26, 25-26), d2 (26, 25-26) and d3 (25, 24-25) within the shield. Humeral setae of length 35(34-36) is similar to dorsal setae and is seen laterally on the membrane off the propodosomal shield. Hysterosomal shield of length 149(146-151) and width 166(162-169) bears four pairs oflateral setae L1 (31, 30-32), L2 (31, 30-32), L3 (31, 30-32), L4 (32, 31-33) and four pairs of median setae d4 (26, 25-26), d5 (26, 25-26), d6 (26, 25-26) and d7 (32, 31-33). Lateral setaL5 (34, 33-35) is placed caudally on membrane off the shield. Membranous area around the shield with striations seen.

Venter: (Fig. 2) All setae in the genital region are acicular. Genital setae g1 14(14), g2 16(16) and g3 16(16). Anal setae a1: 16(16) , a2: 26(25-26) and a3: 20(20) . Striations can be seen in the genito-anal region (fig. 2)

Legs: (Fig.4) Length of leg I (from coxae to tip of tarsi): 228 (223-232) , leg II: 195 (191-198) , leg III: 206 (201-209) and IV: 275 (269-280) . Ratio of leg I/ idiosoma= 0.63 (0.63-0.65), leg II/ idiosoma =0.54 (0.52-0.54), leg III/ idiosoma = 0.57 (0.56-0.58) and leg IV / idiosoma= 0.76 (0.73-0.76). Length of solenidion ω1 on tarsus I is 30 (29-30) μm and is supported by a small guard seta. Setae and solenidion in leg segments I-IV: coxae 2-1-2-2, trochanter 1-2-2-1, femur 2-2-2-1, genu 2-2-2-2, tibia 6-4-4-4 and tarsi 11-8-7-5. All leg segments except tarsi I- IV have transverse striation whereas tarsi I-IV have longitudinal striation. Tarsal claws have a terminal fork-like eupathidia.

Male: Not came in collection.

Diagnosis: *Acaropsella strioreticulata* **sp. nov.** is closely similar to *Acaropsella kinshasensis* Fain, 1972 and *A. filipina* Corpuz-Raros, 1998. The species *A. filipina* Corpuz- Raros, 1988 and *A. konoi* Tseng, 1977 are not different from *A. kinshasensis* Fain, 1972. All morphological the characters of these species, described by Corpuz-Raros (1988) and Tseng (1977) as "unique", i.e. the reticulate pattern on the stylophore and on the dorsal shields and also the fan-like dorsal seta of the palpal femur, are also present in *A. kinshasensis*. Hence, Fain and Bochkov (2001) considered *A. filipina* and *A. konoi* as junior synonyms of *A. kinshasensis*. A. strioreticulata sp. nov is similar to A. kinshasensis by having reticulation on rostrum and idiosoma, membranous separation between propodosomal and idiosomal shields, a total of 16 dorsal setae, L5 placed off the shield, comb seta with 13 processes and all anal setae simple acicular. *Acaropsella strioreticulata* sp.nov. clearly differs from *A. kinshasensis* by the presence of 4 palp teeth and by having propodosomal and hysterosomal shield of same length (ratio between the lengths of propodosomal shield and hysteriosomal shield is 1 in *A. strioreticulata* sp.nov and 0.78 in *A. kinshasensis*). Whereas, in *A. kinshasensis* 5-6 palp teeth present and hysterosomal shield is longer than propodosomal shield. All setae of tibia I is hair-like in *A. kinshasensis* whereas, in *A. strioreticulata* sp.nov all setae on tibia I is simple except one thickened setae (immature form of fan-like setae). *A. kinshasensis* possesses one fan-like seta on tibia III, while, *A. strioreticulata* sp.nov does not have such fan-like setae on tibia III. Three sickle setae are found in *A. filipina* whereas only 2 sickle setae is observed in *A. strioreticulata* sp. nov. Chaetotaxy of femur I-IV is 2-2-2-1 in *A. strioreticulata* sp.nov but it is 2-2-1-1 in *A. filipina*. In *A. strioreticulata* sp.nov, eyes are placed off propodosomal shield whereas in *A. filipina*, eyes are located within the antero-lateral margins of propodosomal shield.

Chaetotaxy of tarsi I-IV (including solenidion) is 11-8-7-5 in *A. strioreticulata* whereas it is 6-5-4-4 in *A. filipina*. All leg segments are transversely striated except tarsi which is longitudinally striated in *A. strioreticulata* **sp. nov**. and *A. shaziai*. This morphological feature is absent in other *Acaropsella* species. *A. strioreticulata* sp.nov. can be separated from *A. schmidtmanni, A.rohdendorfi* and *A.volgini* by the presence of coarse robust pentagonal or hexagonal reticulation on rostral and idiosomal shield , whereas it is absent in *A. schmidtmanni* , *A.rohdendorfi* and *A.volgini*. This specimen can be separated from *A.nobilis* and *A.kulagini* by the presence of four palp teeth whereas *A.nobilis* and *A.kulagini* have six palp teeth. *Acaropsella strioreticulata* sp.nov. differ from *A.shazai and A. walli* by the presence of 13 processes on comb seta and dorsal seta L5 out of theshield. In *A. shazai and A. walli* 16 processes present on comb seta and dorsal setae L5 is out of the shield along with L1 and L4.

Etymology: The specimen has been named after their morphological features.

Key to females species of the genus Acaropsella

1. Total number of dorsal setae equal or more than 17 ----------------------- *A. nobilis* Rasool, Chaudhri &Akbar, 1980
   -total number of dorsal setae less than 17 ---2

2. Setae d2 situated off from propodosomal shield --- *A. schmidtmanni* Price, 1972
   -setae d2 situated on propodosomal shield --3

3. Peritreme with more than 6 links --4
   -Peritreme with less than 6 links---5

4. Peritreme with 7 links--- *A. rohdendorfi* Volgin,1962
   -Peritreme with 8 links --- *A. shaziai* Akbar, Jahan & Mughal, 2008

5. Hysteriosomal shield longer than propodosomal shield, palpal teeth equal or more than 5 in number---------------------6
   -Hysterisomal shield and propodosomal shields almost similar in length, Palpal teeth less than 5 in number.-------------8

6. Propodosomal and hysteriosomal shields are separated by membranous area Dorsal setae on genu I-II fan like ----------7
   - Propodosomal and hysteriosomal shields are not separated by membranous area Dorsal setae on genu I-II hair like--*A . kulagini* Rohdendorf, 1940

7. Rostral and idiosomal shield with network pattern --- *A. kinshasensis* Fain, 1972
   -Rostral and idiosomal shield without network pattern ---*A. volgini* Gerson,1967

8. Comb setae with 13 process, setae L1 and L2 situated on hysteriosomal shield, striation pattern present on membranous area around propodosomal and hysteriosomal shield, femur IV with one setae………………………..…….***A. strioreticulata* sp.nov**

   -Comb setae with 16 process, setae L1 and L2 situated off hysteriosomal shield,striation pattern absent on membranous area around propodosomal and hysteriosomal shield, femur IV without setae…………………………..*A. walii* Akbar, Jahan & Mughal, 2008

FIGURES

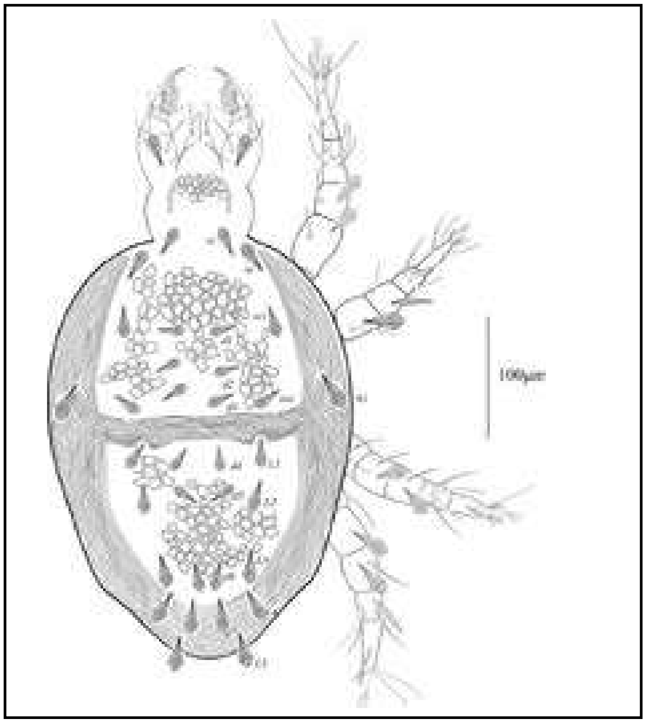

Figure 1: *Acaropsella strioreticulata* sp.nov. holotype female. Dorsal idiosoma

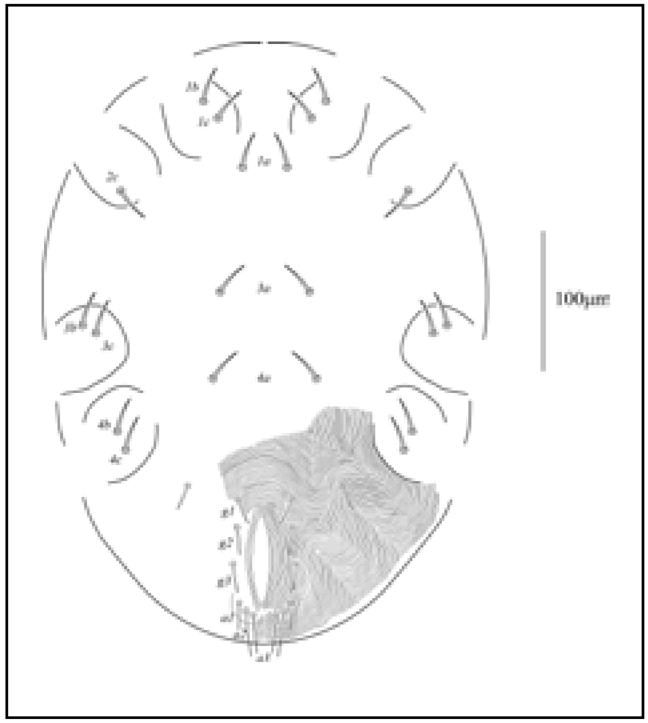

Figure 2: *Acaropsella strioreticulata* sp.nov. holotype female. Ventral idiosoma.

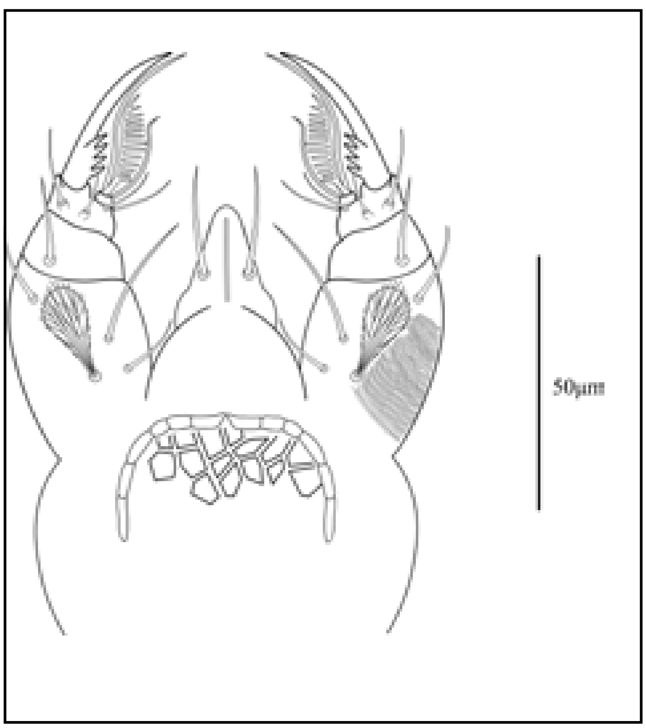

Figure 3: *Acaropsella strioreticulata* sp.nov. holotype female. Gnathosoma

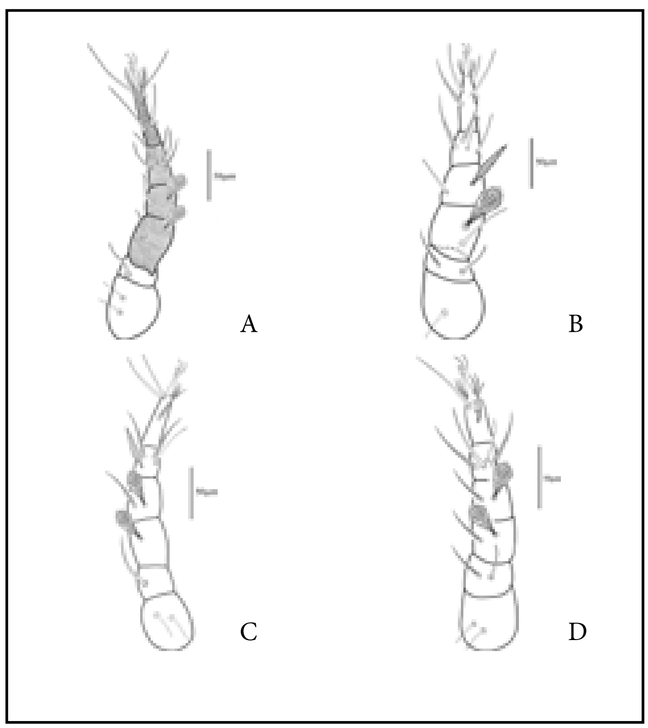

Figure 4: *Acaropsella strioreticulata* sp.nov. holotype female. A. leg I, B. leg II, C. legIII, D. leg IV.

Acknowledgements

First author thankfully acknowledges CSIR for the financial support by means of CSIR- JRF. Authors are also thankful to Jurgen C. Otto (Australian Quarantine and Inspection Service, Entomology, Rosebery, Australia) for helping with the identification of species and DST-FIST-2014 for providing financial support to adequately equip the laboratory.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Two New Records of Free-living Marine Nematodes (Nematoda: Enoplida: Ironidae and Plectida: Leptolaimidae) from India

Ritika Datta[1,2], Anjum N. Rizvi[1*] & C. Raghunathan[1]

[1]*Zoological Survey of India, New Alipore, Kolkata-700053, West Bengal, India*
[2]*University of Calcutta, 87/1, College Street, Kolkata-700 073, India*

Abstract

We report two new records of free-living Marine Nematodes from India, viz. *Trissonchulus provulvatus* Orselli and Vinciguerra, 1997 and *Antomicron quindecimpapillatus* Holovachov, 2012. Sediment samples were collected from Coastal regions of Puducherry. Morphological data along with description and distribution for both the species are provided here. Both the species reported here have been recorded previously only from their type locality: *T. provulvatus* Orselli and Vinciguerra, 1997 from the Mouth of River Simeto, Catania, Italy, while, *A. quindecimpapillatus* Holovachov, 2012 from Gullmarn Fjord near Fiskebackskil, Sweden.

Keywords: *Trissonchulus provulvatus, Antomicron quindecimpapillatus,* new records, nematoda.

Introduction

Free-living marine nematodes belonging to the phylum Nematoda are highly abundant to the extent that four out of five-bottom dwelling metazoans are nematodes (Bongers and Ferris, 1999). Considering both the terrestrial and the marine nematodes, about 25% of them are free-living marine forms (Du *et al.*, 2014). The order Enoplida Filipjev, 1929, consist of 7 suborders, amongst which the suborder Ironina Siddiqi, 1983, consist of one superfamily Ironoidea de Man, 1876, which further comprises of 3 families; Ironidae de Man, 1876, Leptosomatidae Filipjev, 1916 and Oxystominidae Chitwood, 1935. The genus *Trissonchulus* Cobb, 1920 belongs to the family Ironidae de Man, 1876. Furthermore, there are 16 valid species belonging to genus *Trissonchulus* Cobb, 1920. The species *Trissonchulus provulvatus* Orselli and Vinciguerra, 1997 is being reported for the first time from India. The order Plectida Malakhov, Ryzhikov and Sonin, 1982, consists of 2 suborders, namely Ceramonematina Cobb, 1933 and Plectina Malakhov, Ryzhikov and Sonin, 1982. Suborder Plectina consists of superfamily Leptolaimoidea Örley, 1880 and has two families Aphanolaimidae Chitwood, 1936 and Leptolaimidae Örley, 1880. Genus *Antomicron* belongs to the family Leptolaimidae Örley, 1880 and comprises 10 valid species. *Antomicron quindecimpapillatus* Holovachov, 2012 is being reported here for the first time from India.

Material and Methods

Sediment samples were collected from Pondy Marina (11°54'25.32"N; 79°49'41.39"E) and Kodikkarai (10°16'31.83"N; 79°49'9.49"E), both located in Puducherry, India. After collection, the sediment samples were fixed with 4% Formalin in filtered sea water. Rose Bengal stain was used to stain the samples after fixation (Williams and Williams, 1974). The stained samples were brought to the laboratory and were sieved using 2 mm Coarse sieve with the purpose to remove the larger particles and then passed in 53 µm mesh sieve to retain the meiofauna. The sieved residue was then examined under SZX-16 Olympus Microscope and free-living marine nematode specimens were picked out in cavity blocks containing Glycerin-Alcohol. The specimens were kept in desiccator containing anhydrous Calcium chloride for dehydration, following which permanent slides were prepared and identified under BX-53 DIC Olympus research

*Author for correspondence :
Article Received on: 02.04.2023 Accepted on: 24.04.2023

microscope. The specimens were photomicrographed using DP27 camera.

Abbreviations used: *a*= Body Length/ maximum body diameter; *b*= Body length/ pharynx length; *c*= Body length/ tail length; c'= Tail length/anal body diameter

Systematic Accounts

Phylum NEMATODA Cobb 1932

Class ENOPLEA Inglis, 1983

Order ENOPLIDA Filipjev, 1929

Suborder IRONINA Siddiqi, 1983

Superfamily IRONOIDEA de Man, 1876

Family IRONIDAE de Man, 1876

Genus ***Trissonchulus*** Cobb, 1920

Trissonchulus provulvatus Orselli and Vinciguerra, 1997

Class CHROMADOREA Inglis, 1983

Subclass CHROMADORIA Pearse, 1942

Order PLECTIDA Malakhov, Ryzhikov and Sonin, 1982

Suborder PLECTINA Malakhov, Ryzhikov and Sonin, 1982

Superfamily LEPTOLAIMOIDEA Örley, 1880

Family LEPTOLAIMIDAE Örley, 1880

Subfamily LEPTOLAIMINAE Örley, 1880

Genus ***Antomicron*** Cobb, 1920

Antomicron quindecimpapillatus Holovachov, 2012

Results and Discussion:

Trissonchulus provulvatus Orselli and Vinciguerra, 1997

(Figure 1; Table 1)

Materials examined: 2 Females and 3 Males: India, Puducherry, Pondy Marina, 11°54'25.32" N, 79°49'41.39" E, 16-ix-2021, coll. R. Datta (Reg. No. ZSI–HQ/NZC/WN.3574).

Description: *Male:* Body long and slender, the total body length varies from 3250.04-3296.87 µm. Smooth cuticle without any striations. The maximum body length varies from 47.54-51.5 µm. The head and the lip region are slightly set off. Labial and cephalic setae are absent, however six labials and ten cephalic papillae observed. Pocket-shaped amphids present, situated at a distance of 11.98-15.25 µm from the anterior most end and just posterior to the head region. The buccal cavity is in the form of a sclerotized tube, the anterior most region of which consist of three solid teeth. The two subventral teeth are curved and larger than the dorsal one. The pharynx without any prominent anterior or posterior bulb, however the posterior end is slightly thickened. Prominent heart shaped cardia present. Nerve ring is present, almost at a position half the length of the pharynx. The reproductive system in males is composed of paired and opposed testes. Spicules (Fig 1e) are 42.01-48.82 µm in length, curved ventrally and are cephalate at the proximal end, small sized gubernaculum present, 20.52-23.71 µm. Tail not very long, the terminal end is blunt and with the presence of ventrally opening caudal glands. Post cloacal papillae, six pairs in number have been observed (Fig 1g).

Female: Body is long and slender shaped, varying from 2781.5-3391.6 µm and with a maximum body width of 54.2-70.85 µm. Cuticle smooth. The head and the lip region are set off by a constriction and the internal surface of the lip region constitutes of minute denticles. Six labial and ten cephalic papillae are present. The region posterior to the lips constitutes of pocket-shaped amphid. Sclerotized tube-shaped buccal cavity present, (Fig 1d). Three solid teeth are present at the anterior end of the tube, the two sub ventral teeth (Fig 1b) are equal in shape and are bent, the dorsal tooth is smaller in size. Pharynx without any prominent bulb in anterior or posterior end, however the posterior end is slightly broadened, heart shaped cardia present beneath the posterior end of the pharynx (Fig 1c). Nerve ring is situated at almost a position half the length of the pharynx. Reproductive system is didelphic and opposed in females. Vulva situated at 1333.5-2485.3 µm from anterior end (Fig 1f). In comparison to males, females possess more rounded shaped and slightly longer tail (Fig 1h), Presence of ventrally opening caudal glands.

Remarks: The genus *Trissonchulus* under the family Ironidae was first erected by Cobb in 1920. The head sensilla is mostly papilliform, in case it is setiform it is very short, these characters differentiate this genus from the other genus under the family Ironidae. Presently 16 valid species represent this genus (Website Nemys: World Database of Nematodes; Bezerra *et al.*, 2022). The valid species are *T. acuticaudatus* Gagarin, Nguyen Vu Thanh, Nguyen Dinh Tu and Nguyen

Xuan Phuong, 2012*; T. acutus* (Gerlach, 1953) Gerlach and Riemann, 1974; *T. benepapillosus* (Schulz, 1935) Gerlach and Riemann, 1974; *T. dubius* Orselli and Vinciguerra, 1997; *T. janetae* Inglis, 1961; *T. latispiculum* Chen and Guo, 2015; *T. latus* (Wieser, 1953) Inglis, 1961; *T. littoralis* Yeates, 1967*; T. mangrovi* Nguyen Vu Thanh and Gagarin, 2015*; T. minor* Gagarin *et al.*, 2012*; T. obtusus* (Schuurmans Stekhoven, 1935) Inglis, 1961*; T. oceanus* Cobb, 1920*;T. provulvatus* Orselli and Vinciguerra, 1997*; T. quinquepapillatus* Yeates, 1967*; T. raskii* (Chitwood, 1960) Inglis, 1961*; T. reversus* Chitwood, 1951.

T. provulvatus was first described by Orselli and Vinciguerra, 1997 from Mouth of River Simeto (Catania, Italy) on the basis of reduced anterior female genital tract region and the anterior vulva. The species also differed from the other species in the shape of spicules and gubernaculum and also it did not consist of any precloacal papillae. The species described here conforms well with the first description of the species, almost same amphid and buccal cavity width. However, the body length of the species reported here is slightly smaller than the original description (2781.5-3391.6 µm vs 3570-3750 µm) with slightly greater tail length (74.06-92.09 µm vs 57.5- 65 µm).

Antomicron quindecimpapillatus Holovachov, 2012

(Figure 2; Table 2)

Materials examined: 3 Males: India, Kodikkarai, Puducherry; 10°16'31.83" N, 79°49'9.49" E, 19-ix-2021, coll. R. Datta (Reg. No. ZSI–HQ/NZC/ WN.3416). 1 Females and 2 Males: India, Pondy Marina, Puducherry; 11°54'25.32" N, 79°49'41.39" E, 16-ix-2021, coll. R. Datta (Reg. No. ZSI–HQ/ NZC/ WN.3575).

Description: Male: The male body is slightly tapering in the anterior region and appears curved after fixation (Fig 2a). The male body size varies from 921.4- 1173.95 µm. The maximum body diameter is 25.13- 35.42 µm in the mid body region. Cuticle is completely annulated. The head and the labial region are not set off and the anteriormost end is slightly rounded. The anterior most annule starts from the base of the amphid (Fig 2b). Labial setae (2.47-3.59 µm) observed and smaller than the prominent cephalic setae, 8.82- 11.94 µm (Fig 2c). At the anterior most part of the isthmus, nerve ring is present. The secretory-excretory system is present. Buccal cavity is minute and tubular with undifferentiated cheilostom and gymnostom. The pharynx is heavily muscular, the anterior part is cylindrical without any bulb and the posterior region is with distinct oval basal bulb (Fig 2d). Anterior part of the pharynx is divided into procorpus, metacorpus, both cylindrical and a narrow isthmus. Cardia is small. The reproductive system in males composed of two testes. Spicules short (30.15- 38.07 µm) and symmetrical, the shaft is arcuate subcylindrical and the manubrium is ovoid in shape (Fig 2e). Plate-like gubernaculum present, 17.91-20.82 µm. A total of fifteen midventral tubular supplements are present anterior to the spicule. Two pairs of precloacal setae (Fig 2f) and four pairs of caudal setae have been observed. Tail is small and elongate-conoid shaped. The tail tip is unstriated and do not possess swollen tip (Fig 2h). Three caudal glands present.

Female: Body short and tapering in the anterior region. The whole body is completely annulated except in the anterior most part and tail tip region. In the anterior end, annules begin just posterior to the amphid. The head is not set off, labial setae is small 3.2 µm. The cephalic setae larger in size than the labial setae, 6.99 µm. Amphid present almost at the anterior end. Nerve ring is present at 79.8 µm from anterior end. The anterior most part of the pharynx is without bulb and is divided into procorpus, metacorpus and isthmus, the posterior end consists of a basal ovoid bulb. The bulb is 45.6 µm in length. Small cardia present beneath the pharyngeal bulb. The reproductive system is didelphic (Fig 2g). The tail is not very long, elongate-conoid in shape, and lack annulations towards the tip.

Remarks: The genus *Antomicron* under the family Leptolaimidae was first erected by Cobb, 1920. Presently a total of 10 species are considered valid under this genus (Website Nemys: World Database of Nematodes; Bezerra *et al.*, 2022), namely *A. alveolatum* Villares and Pastor de Ward, 2011; *A. chinensis* Zhai, Wang and Huang, 2020; *A. elegans* (de Man, 1922) De Coninck, 1965; *A. holovachovi* Zhai, Wang and Huang, 2020; *A. intermedius* Gagarin and Nguyen Vu Thanh, 2005; *A. lorenzeni* Holovachov, 2012; *A. pellucidum* Cobb, 1920; *A. pratense* Lorenzen, 1966; *A. profundum* Vitiello, 1971; *A. quindecimpapillatus* Holovachov, 2012.

A. quindecimpapillatus Holovachov, 2012 was described as a new species from, Gullmarn Fjord near Fiskebackskil, Sweden, on the basis of its difference in body length and number of tubular supplements. This species consists of 15 tubular supplements whereas the other consists of a smaller number of supplements, 2-10 in number. The species being reported here for the first time from India, conforms well with the original description, except in having slightly smaller body length and pharynx length (869.37-1173.95 vs 1390-1459 μm and 108.81- 137.21 μm vs 150-151 μm respectively). All the male specimens consist of 15 tubular supplements.

Discussion

The two species *Trissonchulus provulvatus* Orselli and Vinciguerra, 1997 and *Antomicron quindecimpapillatus* Holovachov, 2012 are being reported here or the first time from India. Both the species have been collected from Puducherry. Both the species have been recorded previously only from their type locality: *T. provulvatus* Orselli and Vinciguerra, 1997 from the Mouth of River Simeto, Catania, Italy, while, *A. quindecimpapillatus* Holovachov, 2012 from Gullmarn Fjord near Fiskebackskil, Sweden.

Table 1: Morphometrics of *Trissonchulus provulvatus* Orselli and Vinciguerra, 1997(measurements in μm). Mean values in parenthesis.

Characters	Male	Female
n	**2**	**3**
Body Length	3250.04-3296.87 (3273.45)	2781.5-3391.6 (3021.5)
Maximum body diameter	47.54-51.5 (49.52)	54.2-70.85 (60.19)
Head diameter	20.6-24.2 (22.4)	22.99-23.89 (23.36)
Amphid from anterior end	11.98-15.25 (13.61)	9.76-12.62 (10.93)
Amphid diameter	9.55-11.89 (10.72)	7.54-10.5 (9.38)
Amphid length	4.93-5.54 (5.235)	5.56-8.04 (6.41)
Amphid cbd	17.87-30.03 (23.95)	25-27.1 (25.9)
Buccal cavity length	43.67-48.01 (45.84)	50.09-54.09 (52.03)
Nerve ring from anterior end	132.28-149.95 (141.11)	143.94-162.6 (152.55)
Nerve ring cbd	37.04-45.81 (41.42)	43.2-55.56 (49.21)
Pharynx length	345.03-366 (355.81)	335-382.6 (351.42)
Pharynx cbd	38.52-47.14 (42.83)	48.09-61.06 (53.94)
Anal body diameter	38.54-46.16 (42.35)	41.9-46.6 (44.14)
Tail length	74.06-82.52 (78.29)	84.9-92.09 (90.85)
Spicule length as chord	45.03-53.71 (49.37)	-
Spicule length as arc	42.01-48.82 (45.415)	-
Gubernaculum length	20.52-23.71 (22.11)	-
Vulva from anterior end	-	1333.5-2485.3 (1799.63)
a	64.01-68.36 (66.19)	47.87-53.34 (50.43)
b	8.99-9.41 (9.21)	8.26-8.86 (8.59)
c	39.95-43.88 (41.92)	29.10-34.05 (30.89)
c’	1.78-1.92 (1.85)	2.02-2.46 (2.22)

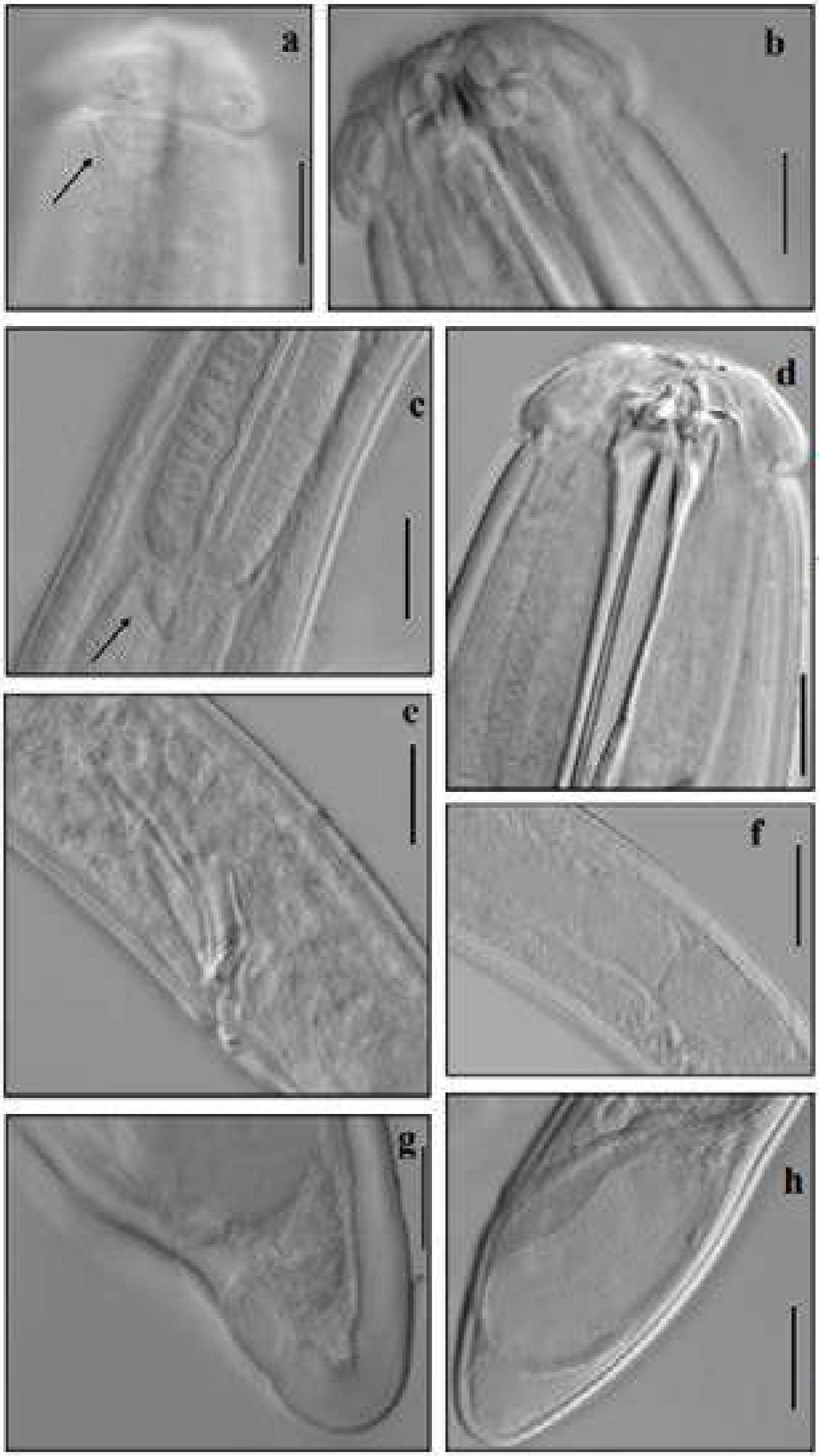

Figure 1: *Trissonchulus provulvatus* Orselli and Vinciguerra, 1997 (WN.3574 *Trissonchulus provulvatus*) (LM photographs) a: Female, amphid. b: Female, head and sub ventral teeth. c: Female, cardia. d: Female, buccal cavity e: Male, spicule. f: Female, genitalia. g: Male, post cloacal papillae. h: Female, tail. Scale bars: a, b, c, d, e, f, g and h: 5 µm.

Table 2: Morphometrics of *Antomicron quindecimpapillatus* Holovachov, 2012 (measurements in µm). Mean values in parenthesis.

Characters	Male	Female
n	**5**	**1**
Body length	921.4- 1173.95 (1016.72)	869.37
a	26.01- 39.01 (34.52)	27.68694268
b	7.21- 8.9 (7.95)	7.989798732
c	10.68- 13.02 (12.08)	9.249601021
c’	2.51- 4.04 (3.37)	3.356785714
Body diameter	25.13- 35.42 (29.86)	31.4
Labial setae	2.47-3.59 (3.09)	3.2
Pharynx length	115.33- 137.21 (127.88)	108.81
Tail length	73.75- 92.02 (84.21)	93.99
Anal or cloacal body diameter	21-29.8 (25.48)	28
Labial region diameter	8.06-16.84 (12.02)	12.5
Cephalic setae length	8.82- 11.94 (10.37)	6.99
Amphid length	5.23- 6.58 (6.29)	8.11
Amphid width	5.33- 7.39 (6.73)	11.61
Procorpus length	23.85 -30.06 (25.61)	21.9
Metacorpus length	22.1- 26.2 (24.26)	22.87
Isthmus length	37.35- 60.88 (48.25)	43.2
Bulbus length	39.41- 49.41 (43.99)	45.6
Nerve ring from anterior end	46.49- 82.4 (58.366)	79.8
Excretory pore from anterior end	79.1- 87.6 (81.62)	81.2
Spicule length	30.15- 38.07 (34.46)	-
Gubernaculum length	17.91- 20.82 (19.14)	-
Tubular supplements	15	-

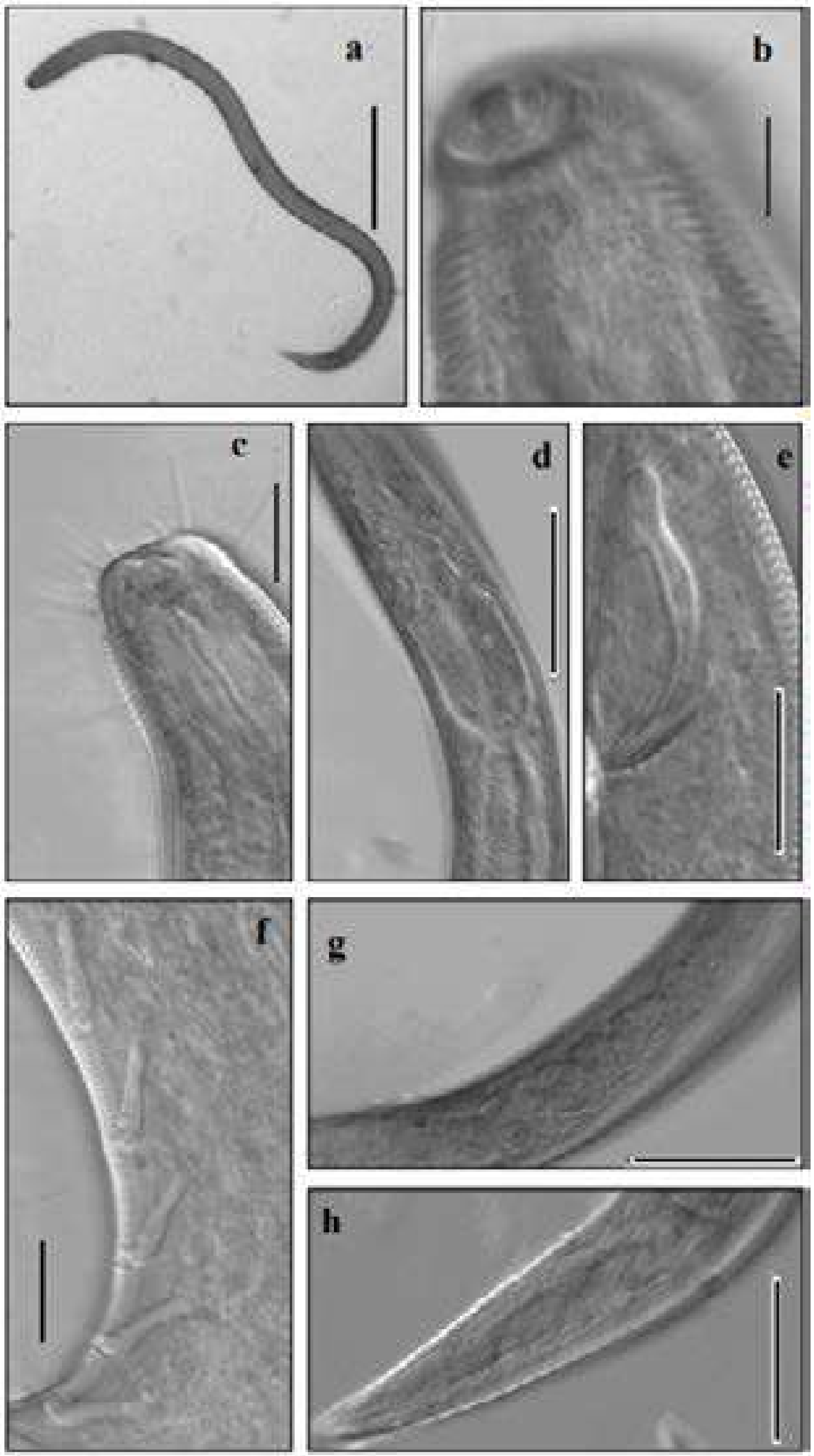

Figure 2: *Antomicron quindecimpapillatus* Holovachov, 2012. a: Male, whole body b: Male, amphid. c: Male, labial and cephalic setae. d: Male, posterior pharyngeal bulb. e: Male, spicule. f: Male, precloacal supplements. g: Female, genitalia. h: Male, tail. Scale bars: a= 200 µm; d and g= 50 µm; b, c, e, f and h= 5 µm.

Acknowledgements

The authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India (ZSI) for providing facilities. The first author is highly grateful for being supported with the Junior Research Fellowship of ZSI. Special thanks are also conveyed to Dr. Seepana Rajendra for the help extended during the collection of sediment samples.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

New Records and New Combinations of Ladybird Beetles from India (Coleoptera: Coccinellidae)

Priyanka Das[1], Dhriti Banerjee[2] and Devanshu Gupta[3]
Zoological Survey of India, M Block, New Alipore,
Kolkata, 700053, West Bengal, India
*[1]priyankajan03@gmail.com,[2]dhritibanerjee@gmail.com, [3]*devanshuguptagb4102@gmail.com*

Abstract

On examination of a collection of specimens from the Indian states of Arunachal Pradesh, Bihar, Gujarat, Jharkhand, Odisha and Telangana, we identified 10 species of ladybird beetles (Coleoptera: Coccinellidae). Of these, *Afissa langpingensis (*Zeng & Yang) and *Jauravia albidula* Motschulsky are new records for India. *Afissa langpingensis (*Zeng & Yang), *Illeis indica* Timberlake, *I. bistigmosa* (Mulsant), *Propylea dissecta* (Mulsant), *P. luteopustulata* (Mulsant), *Nephus tagiapatus* (Kamiya), *Micraspis univittata* (Hope), *Phrynocaria circumusta* (Mulsant) and *Jauravia albidula* Motschulsky comprise new distributional records to different states. While, *Epilachna langpingensis* Zeng & Yang, and *E. sureilica* (Kapur) are transferred to the genus *Afissa* Dieke, hence new combinations are proposed for *Afissa langpingensis (*Zeng & Yang), **comb. nov.** and *Afissa sureilica* Kapur **comb. nov.**

Keywords: Epilachnini, diversity, morphology, taxonomy.

Introduction

Ladybird beetles (Coleoptera: Coccinellidae) are recognized as the biological control agents predating aphids, mites and other minute insects. A few others are phytophagous particularly in the tribe Epilachnini. Their body design and tangible mandibular shape make them successful natural predators. Over 6000 species are established worldwide and almost 550 species have been documented in India (Poorani, 2002, Jadwiszczak and Wegrzynowicz, 2003, Robertson *et al.*, 2015, Das *et al.* 2023). Apart from the widely spread species, the majority of the species in this family are known from their narrow distributional ranges and not much has been documented. While examining a collection of specimens from the Indian states of Arunachal Pradesh, Bihar, Gujarat, Jharkhand, Odisha and Telangana, housed at Zoological Survey of India, Kolkata, we identified 10 species of ladybird beetles (Coleoptera: Coccinellidae). Of these, *Afissa langpingensis (*Zeng & Yang) and *Jauravia albidula* Motschulsky are new records for India. *Epilachna langpingensis* Zeng & Yang, and *E. sureilica* (Kapur) are transferred to the genus *Afissa* Dieke, hence new combinations are proposed for *Afissa langpingensis (*Zeng & Yang), **comb. nov.** and *Afissa sureilica* Kapur **comb. nov..** *Afissa langpingensis (*Zeng & Yang), *Illeis indica* Timberlake, *I. bistigmosa* (Mulsant), *Propylea dissecta* (Mulsant), *P. luteopustulata* (Mulsant), *Nephus tagiapatus* (Kamiya), *Micraspis univittata* (Hope), *Phrynocaria circumusta* (Mulsant) and *Jauravia albidula* Motschulsky comprise new distributional records to different states. The photographs for species are provided along with maps and taxonomic remarks.

Methodology

Samples were collected during various surveys from unexplored areas including some protected areas. They are deposited at National Zoological Collection of Zoological Survey of India, Kolkata [NZSI]. These specimens were examined using Nikon SMZ25 stereo zoom–microscope and the photos were taken using DS–Ri2 camera attached with it and they were processed with NIS Elements BR 5.10.00 imaging software. Minor image corrections were conducted using Adobe Photoshop 7 software.

*Author for correspondence
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Systematic Account

Family COCCINELLIDAE Latreille, 1807

Subfamily COCCINELLINAE Latreille, 1807

Tribe **Coccidulini** Mulsant, 1846

1. *Nephus tagiapatus* (Kamiya, 1965) (Fig. I-A)

   Scymnus (*Nephus*) *tagiapatus* Kamiya, 1965: 104.

   Nephus tagiapatus: Sasaji, 1968: 122.

   Nephus roonwali Kapur, 1966: 163.

   Material examined: India: Gujarat, Bharuch, Asuria, (21˚47.478 N 73˚01.934 E), 14-xii-2020, 1 ex., leg. Kaushik Deuti & team [NZSI-29675/H4A].

   Distribution: India: Andaman and Nicobar Islands, Gujarat (new record), and West Bengal. **Elsewhere**: China, Japan, Malaysia and Thailand.

Tribe **Coccinellini** Latreille, 1807

2. *Illeis bistigmosa* (Mulsant, 1850) (Fig. I-B)

   Psyllobora bistigmosa Mulsant, 1850: 168.

   Thea bistigmosa: Crotch, 1874: 135.

   Illeis bistigmosa: Bielawski, 1961a: 366.

   Illeis bielawskii Ghorpade, 1976: 579.

   Psyllobora simplex Mulsant, 1866: 128.

   Material examined: India: Telengana, Umamaheshwaram, 21-ix-2019, 1 ex., leg. Deepa Jaiswal & team [NZSI-29433/H4A].

   Distribution: India: Andaman and Nicobar Islands, Goa, Karnataka and Telangana (new record). **Elsewhere**: Celebes, Indonesia, Sri Lanka, Malaysia, Philippines, Nepal and Thailand.

3. *Illeis indica* Timberlake, 1943 (Fig. I-C)

   Illeis indica Timberlake, 1943: 61.

   Material examined: India: Bihar, Gaya, Sone Khap, Sherghati, 23-xii-2021, 1 ex., leg. Devanshu Gupta & Team [NZSI-29140/H4A].

   Distribution: India: Arunachal Pradesh, Assam, Bihar (new record), Himachal Pradesh, Jammu & Kashmir, Meghalaya, Odisha and Uttar Pradesh. **Elsewhere**: Pakistan and Thailand.

4. *Micraspis univittata* (Hope, 1831) (Fig. I-D)

   Coccinella univittata Hope, 1831: 3.

   Alesia univittata: Mulsant, 1850: 357.

   Tytthaspis univittata: Korschefsky, 1932: 384.

   Micraspis univittata: Iablokoff-Khnzorian, 1982: 511.

   Material examined: India: Telengana, Umamaheshwaram, 21-ix-2019, 1 ex., leg. Deepa Jaiswal & Party [NZSI-29434/H4A].

   Distribution: India: Arunachal Pradesh, Andhra Pradesh, Bihar, Karnataka, Nagaland, Odisha, Tamil Nadu, Telangana (new record) Tripura and Uttarakhand. **Elsewhere**: China and Nepal.

5. *Phrynocaria circumusta* (Mulsant, 1850) (Fig. I-E)

   Artemis circumusta Mulsant, 1850: 389.

   Coelophora circumusta: Crotch, 1874: 150.

   Lemnia (*Artemis*) *circumusta*: Iablokoff-Khnzorian, 1982.

   Coelophora westermanni Mulsant, 1850: 391.

   Material examined: India: Odisha, Ganjam, Bahadapalli, Katikata, 25-xi-2021, 1 ex., leg. Devanshu Gupta & team [NZSI-29786/H4A].

   Distribution: India: Andhra Pradesh, Assam, Jammu and Kashmir, Kerala, Odisha, Telangana (new record) and Uttarakhand. **Elsewhere**: China, Nepal, Taiwan and Thailand.

6. *Propylea dissecta* (Mulsant, 1850) (Fig. I-F)

   Lemnia (*Vola*) *dissecta* Mulsant, 1850: 377.

   Lemnia dissecta: Mulsant, 1866: 249.

   Propylea japonica ab. *dissecta*: Korschefsky, 1932: 531.

   Propylea dissecta: Crotch, 1874: 158.

   Lemnia mystacea Mulsant, 1853: 50.

   Harmonia feliciae Mulsant, 1866: 57.

   Propylaea fallax Yablokov-Khnzoryan, 1977: 61

   Material examined: India: Bihar, Gaya, Sone Khap, Sherghati, 23-xii-2021, 10 ex., leg. Devanshu Gupta & party [NZSI-29133/H4A]. India: Jharkhand, Palamau Tiger Reserve, Belta National Park, Koyal River, 2 exs., collector (no data) (NZSI-29244/H4A].

   Distribution: India: Arunachal Pradesh, Assam, Bihar (new record), Jharkhand (new record), Karnataka, Tamil Nadu and Uttar Pradesh. **Elsewhere**: Bangladesh and Nepal.

7. *Propylea luteopustulata* (Mulsant, 1850) (Fig. I-G) synonyms refer to (Das *et al.* 2023)

   Material examined: India: Telengana, Ambagiri, 19-ix-

2019, 1 ex., leg. Deepa Jaiswal & party (NZSI-29442/ H4A].

Distribution: India: Andaman and Nicobar Islands, Assam, Himachal Pradesh, Manipur, Meghalaya, Sikkim, Telangana (new record), Uttar Pradesh and West Bengal). **Elsewhere**: Bhutan, China, Myanmar, Nepal, Sri Lanka, Thailand, Tibet and Vietnam.

Tribe **Epilachnini** Mulsant, 1846

8. *Afissa langpingensis (*Zeng & Yang, 1996) **comb. nov**. (Fig. II-A-B)

Epilachna langpingensis Zeng & Yang, 1996: 195, fig. 3A-G (type locality: Tianlin Langping, Guangxi, 1300 m); Jadwiszczak and Węgrzynowicz, 2003: 82.

Material examined: India: Arunachal Pradesh, Anjaw, Manchila, 22-xi-2022, 1 ex., leg. Gurumayam & team [NZSI-29843/H4A].

Distribution: India: Arunachal Pradesh (new record). **Elsewhere**: China.

Remarks: *Epilachna langpingensis* was described by Zeng & Yang (1996) from Guangxi, China, subsequently recorded by Jadwiszczak and Węgrzynowicz (2003) and Ren *et al.* (2009). The world revision of the Epilachnini genera, based on phylogenetic analysis revealed that the genus *Epilachna* is not distributed in the old world (Tomaszewska and Szawaryn, 2016). Based on the diagnostic characters proposed by Tomaszewska and Szawaryn (2016), *Epilachna langpingensis* is transferred to the genus *Afissa* Dieke, 1947; hence new combination is proposed for *Afissa langpingensis (*Zeng & Yang, 1996) **comb. nov**. Further the species is recorded for the first time from India.

9. *Afissa sureilica* Kapur, 1961 **comb. nov.** (Fig. I-H)

Afissa sureilica Kapur, 1961: 136, fig. 3. a-c (type locality: Sureil, "Mangpu" [Mongphu], Darjeeling district, northern West Bengal).

Afissa sureilica var. *marginotata* Kapur, 1961: 138.

Epilachna sureilica: Jadwiszczak and Węgrzynowicz, 2003: 120.

Material examined: India: West Bengal, Buxa Tiger Reserve, Jayanti, 23-iii-2018, 3 exs., leg. A. Ramesh Kumar, [NZSI-29552/H4A].

Distribution: India: West Bengal. **Elsewhere**: Myanmar.

Remarks: *Afissa sureilica* was described by Kapur (1961) from Sureil, West Bengal, India, which was later shifted to genus *Epilachna* by Jadwiszczak and Węgrzynowicz (2003). The world revision of the Epilachnini genera based on phylogenetic analysis revealed that the genus *Epilachna* is not distributed in old world (Tomaszewska and Szawaryn, 2016). Based on the diagnostic characters proposed by Tomaszewska and Szawaryn (2016), *Epilachna sureilica* is again transferred to the genus *Afissa;* hence new combination is proposed for *Afissa sureilica* Kapur, 1961 **comb. nov**.

Tribe **Sticholotidini** Weise, 1901

10. *Jauravia albidula* Motschulsky, 1866 (Fig. III-A-B)

Clanis pubescens Weise, 1892: 25

Material examined: Female: India: Telengana: Nagarkurnool: Mallela, 29-xii-2021, 1 ex., leg. D. Jaiswal & Party, [NZSI-29331/H4A].

Distribution: India: Telengana (new record). **Elsewhere**:Sri Lanka.

Remarks: Motschulsky (1866) described this species from Ceylon, currently Sri Lanka. Kapur (1946) studied this species from Sri Lanka as well. After 75 years this species was collected from Telengana and identified as a new record from India.

Results and Discussion

A total of 26 specimens of ladybird beetles were studied, which resulted in the identification of 10 species. Of them, *Afissa langpingensis (*Zeng & Yang, 1996) and *Jauravia albidula* Motschulsky, 1866 have been recorded for the first time from India. Rest of the seven species are reported first time from different states of India viz; *Illeis indica* Timberlake (from Bihar), *I. bistigmosa* (Mulsant) (from Telangana), *Propylea dissecta* (Mulsant) (from Bihar and Jharkhand), *P. luteopustulata* (Mulsant) (from Telangana), *Nephus tagiapatus* (Kamiya) (from Gujarat), *Micraspis univittata* (Hope) (from Telangana) and *Phrynocaria circumusta* (Mulsant) (from Odisha).

Taxonomical changes were also o*b*served in two species belonging to tribe Epilachnini; *Epilachna langpingensis* Zeng & Yang, 1996 and *E. sureilica* (Kapur, 1961) are transferred to the genus *Afissa* Dieke, 1947 followed *by* generic changes consulting phylogentic review of world genera of Epilachnini *b*y Tomaszewska and Szawaryn (2016). Subsequently, two new combinations are formed *Afissa langpingensis (*Zeng & Yang, 1996), **comb. n.** and *Afissa sureilica* Kapur, 1961 **comb. n.**

Figure I. Haitus of **A.** *Nephus tagiapatus* (Kamiya, 1965); **B.** *Illeis bistigmosa* (Mulsant, 1850); **C.** *Illeis indica* Timberlake, 1943; **D.** *Micraspis univittata* (Hope, 1831); **E.** *Phrynocaria circumusta* (Mulsant, 1850); **F.** *Propylea dissecta* (Mulsant, 1850); **G.** *Propylea luteopustulata* (Mulsant, 1850); **H.** *Afissa sureilica* Kapur, 1961 **comb. n.**

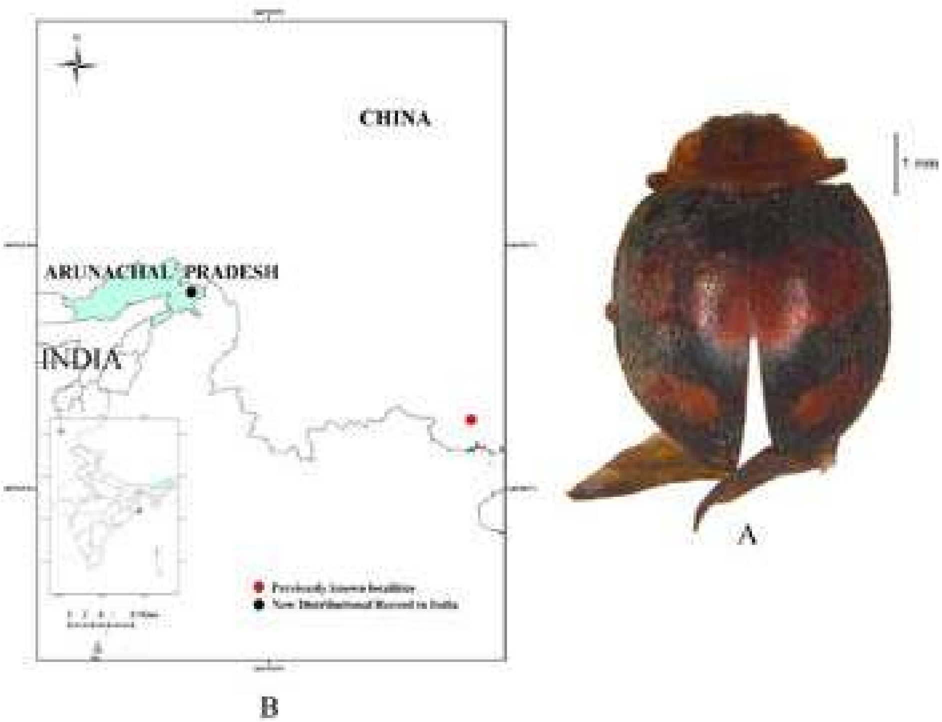

Figure II. A. Haitus of *Afissa langpingensis (*Zeng et Yang, 1996) **comb. n.**; **B.** *map showing new distribution record.*

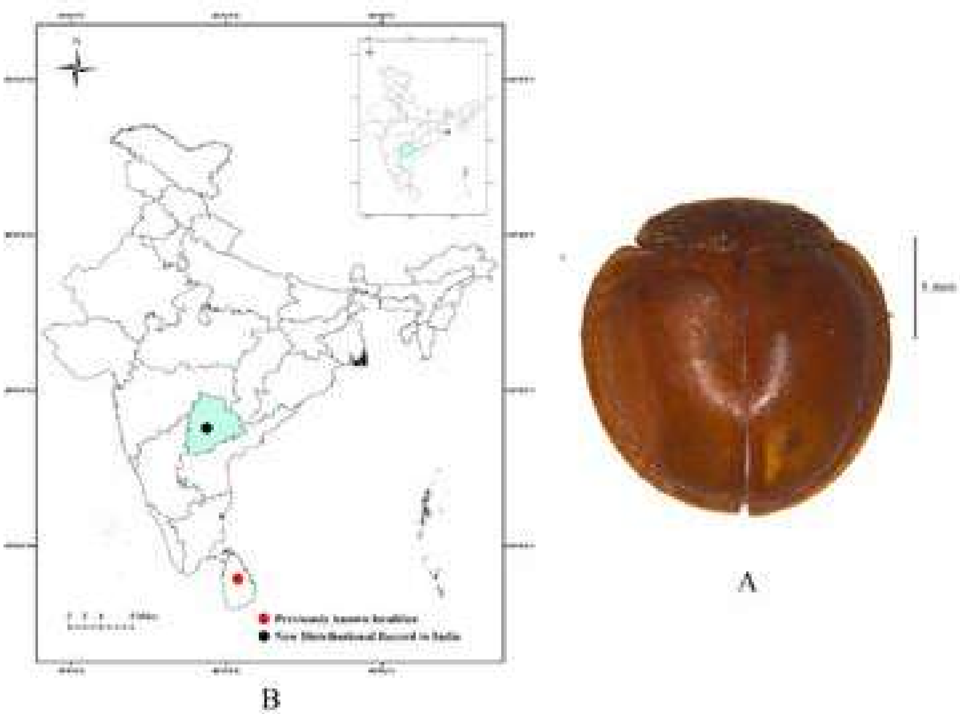

Figure III. A. Haitus of *Jauravia albidula* Motschulsky, 1866; **B.** *map showing new distribution record.*

Acknowledgements

The authors are highly grateful to Dr. Dhriti Banerjee, Director Zoological Survey of India for providing necessary facilities.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

New record of sponge from Narara Reef, Gulf of Kutch

G. Sivaleela[1]*, S. Devakumar[1], and Michelle Kelly[2]

[1]Zoological Survey of India, Marine Biology Regional Centre, 130, Santhome High Road, Chennai- 600 028, Tamil Nadu, India

[2]Oceans Centre, National Institute of Water & Atmospheric Research (NIWA) Ltd, Private Bag 99940, Auckland 1149, New Zealand

E-mail: [1]kbabyrani1995@gmail.com, [2]irengbamlinthoi78@gmail.com,[3]rajmanikh@rediffmail.com

Abstract

We report one species of sponge i.e. *Haliclona* (*Reniera*) *debilis* Pulitzer-Finali, 1993 collected from Narara Reef areas of Gulf of Kutch, Gujarat, as a new record to India. The details of the morphometric analysis along with previous distributional details are depicted here. This study also confirms the report of *Haliclona (?Reniera) cf. cinerea (Grant, 1826) sensu* Dendy (1916) from the aforementioned study area.

Keywords: Porifera, Haplosclerida, Chalinidae, Gujarat Coast

Introduction

Porifera (sponges) are among the most common benthic epifaunal invertebrates in shallow coastal inshore environments of temperate and tropical zones. The history of sponge research in the Gulf of Kutch and Gujarat is very limited. Dendy (1916) described ten Haplosclerida from the collections of James Hornell (1905–1906) from the Okhamandal Coast (seven of which are accepted species of *Haliclona* in the *World Porifera Database* (https://www.marinespecies.org/porifera/) (WPD); and much later, Thomas (1996) described 25 species from Port Okha to the west of Narara, two of which were Haplosclerida but none of which were species of *Haliclona*. Dendy (1916)'s species of *Haliclona* include five valid species and two questionable species. The five valid species include: *Gellius fibulatus* var. *microsigma* Dendy, 1916, now accepted as *H.* (*G.*) *cymaeformis* (Esper, 1806) in WPD; *Gellius ridleyi* Hentschel, 1912, now accepted as *H.* (*G.*) *ridleyi* (Hentschel, 1912) in WPD; *Reniera hornelli* Dendy (1916), now accepted as *H. hornelli* (Dendy, 1916) in WPD; *Reniera semifibrosa* Dendy, 1916, now accepted as *H. semifibrosa* (Dendy, 1916) in WPD; and *Siphonochalina minor* Dendy, 1916, now accepted as *H. pacifica* Hooper in Hooper & Wiedenmayer, 1994, in WPD. Two records are considered to be inaccurate in WPD because they represent species first described elsewhere: *Reniera topsenti* (Thiele, 1905), now accepted as *H.* (*R.*) *topsenti* (Thiele, 1905), was considered inaccurate by Burton (1929) as this species was first described from Patagonia; and *Reniera permollis* (Bowerbank, 1866), now accepted as *H.* (*R.*) *cinerea* (Grant, 1826) in WPD, is a northeastern Atlantic species. Dendy (1916)'s record of *R. permollis* in Western India is thus questionable, but his specimens are valid species of *Haliclona* because of the skeleton architecture. Species of *Haliclona* are difficult to identify without the diagnostic morphology and live colouration, which are frequently lost after collection and preservation, and almost never present in older descriptions (Kelly and Rowden, 2019). The purpose of this study is to record these living characters in fresh specimens that resemble Dendy's *Reniera permollis* and update that record.

*Author for correspondence : sivaleelambrc9@gmail.com

Article Received on: 02.04.2023
Accepted on: 24.04.2023

Material and Methods

Sponge specimens were collected from the Narara Reef of Gulf of Kutch, Gujarat by snorkeling and hand collection. Specimens were photographed *in situ* using a Nikon Z6II Underwater still camera, and in the lab using a Nikon Eclipse 50i Clinical microscope. Location maps were created using ArcGIS® Pro software, ver. 3.0.3. Upon collection, specimens were preserved in 95% ethanol and stored in 70% ethanol. Spicule preparations were made following the methods of Boury-Esnault & Rützler (1997). For light microscopy, spicules were cleaned in nitric acid at 80°C, rinsed several times in water and spread on a glass microscope slide, air-dried, and mounted with a permanent mountant medium. Spicules were examined using a Nikon Eclipse 50i Clinical microscope at 40–400× fitted with a PixeLINK digital camera that was connected to NIS elements imaging software. Digital images were taken for spicule measurements, a minimum of twenty spicules were measured for each specimen examined. Spicules were measured for maximum length and maximum width and are presented as mean length (range) × mean width (range). Spicule measurements in the species descriptions are the mean of all tabulated measurements for the examined specimens. The skeletons were examined via a series of impermanent thin sections. Specimens were deposited in the National Zoological Collection at the Marine Biology Regional Centre of the Zoological Survey of India, Chennai (accession prefix MBRC/ZSI/S.553 & S.584).

Results

A species of *Haliclona* (*Reniera*) *debilis* Pulitzer-Finali, 1993 is reported from Narara Reef areas of Gulf of Kutch, Gujarat as new to Indian waters. This study also approves the report of *Haliclona (?Reniera) cf. cinerea (Grant, 1826) sensu* Dendy (1916) from the study area. The details are cited below. We also describe living Narara sponges that resemble *H.* (*R.*) *debilis* and compare them to *H.* (*R.*) *debilis* and other species in the Western Indo-Pacific Province (Table 1).

Systematics

Class Demospongiae Sollas, 1885

Order Haplosclerida Topsent, 1928

Family Chalinidae Gray, 1867)

Genus *Haliclona* Grant, 1867

Subgenus *Haliclona* (*Reniera*) Schmidt, 1862

Diagnosis. Delicate sponges with a cushion-shaped or an encrusting morphology, or clusters of tubes. Consistency varying from soft and compressible but fragile to moderately firm. Colours are commonly bright, varying from purple, violet to orange and yellow. Surface is smooth and even. If present, ectosomal skeleton has a regular, tangential, unispicular, isotropic, reticulation. Choanosomal skeleton also a delicate, regular, unispicular, isotropic reticulation. Oxeas are frequently blunt pointed or strongylote. Microscleres, if present, toxas and sigmas (modified from de Weerdt 2002).

Type species. *Reniera aquaeductus* Schmidt, 1862

***Haliclona* (*Reniera*) *debilis* Pulitzer-Finali, 1993**

Fig. 1, 3; Table 1

Haliclona debilis Pulitzer-Finali, 1993: 325, fig. 63.

Haliclona (*Reniera*) *debilis,* Kelly 1997: 124 + fig.

Material Examined. MBRC/ZSI/S.584: Location-Narara, Gujarat (Lat. 22.37–22.46° N & Long. 69.56–69.66° E); Date- 19.xii.2022; Habitat-Intertidal; Collector- G. Sivaleela (Fig. 1).

Type & locality. R.N.KEN.158, Ras Iwetine Mombasa, Kenya.

Description. Sponge forms clusters of short, thick, conjoined tubes arising from a thick base, lobes topped with large oscules leading to deep cylindrical tubes, attached basally to coral rubble (Fig. 3A–C); 116 mm high, 57 wide mm, whole sponge 54 mm diameter; surface macroscopically smooth, microscopically punctate with subsurface canals; texture soft, compressible, elastic, easily torn in life; colour in life bright fuchsia to purple (Fig. 3A, B), grey in preservative (Fig. 3C), yellowish brown in the dried state.

Skeleton and spicules. Choanosomal skeleton consists of a delicate, unispicular, isotropic reticulation, formed by single spicules lightly attached end to end. Ectosomal skeleton a delicate reticulation in places (Fig. 3D). Oxeas, stout, slightly curved, 86 (73–97) × 5 (3–6) µm (Fig. 3E).

Substrate, depth range, and ecology. Often nestled amongst seagrass or *Halimeda* plants on muddy sand flats adjacent to mangroves, 0–1 m (Kelly 1997); in Narara (Fig. 1), found in the intertidal on dead coral rubble amongst dense cyanobacteria in the intertidal (Fig. 3A, B).

Distribution. Kenya, Tanzania (Zanzibar Island) (Pulitzer-Finali 1993; Kelly 1997); Narara, Gujarat Coast.

Remarks. New record to India. Fifty-three species of *Haliclona* (*Reniera*) are currently known from predominantly cold temperate waters of Chile and China in the Pacific, and the Western Caribbean and Western Mediterranean in the Atlantic Ocean (de Voogd *et al.* 2023). Only five species are known from the Western Indo-Pacific Province in addition to *Haliclona* (*Reniera*) *debilis* (Table 1): *Haliclona* (*R.*) *atra* Pulizer-Finali, 1993, also from Kenya; *H.* (*R.*) *cribricutis* (Dendy, 1922) and *H.* (*R.*) *tufoides* (Dendy, 1922) from the Seychelles; *H.* (*R.*) *ligniformis* (Dendy, 1922) from Chagos, and *H.* (*R.*) *tabernacula* (Row, 1911) from the Red Sea. All species differ considerably from *H.* (*R.*) *debilis* in terms of their spicule dimensions, which in all species are well over double the length of those in *H.* (*R.*) *debilis*. Kenyan *Haliclona* (*R.*) *atra* Pulitzer-Finali, 1997 is the closest species in terms of skeletal architecture, but the sponge is branching and black, and the spicules are double the length. *Haliclona* (*Reniera*) *debilis* has the smallest of all oxeas in the Chalinide described thus far for Western India.

2. ***Haliclona* (?*Reniera*) cf. *cinerea* (Grant, 1826) *sensu* Dendy (1916)**

Fig. 1, 2; Table 1

Reniera permollis (Bowerbank, 1866), Dendy 1916: 109.

Material Examined. MBRC/ZSI/S.553 (5 specimens); Location- Narara, Gulf of Kutch, Gujarat (Lat. 22.37–22.46° N & Long. 69.56–69.66° E); Date- 19. xii, 2022; Habitat- Intertidal; Collector- G. Sivaleela (Fig. 1).

Description. Irregular globular to basally encrusting sponge with small spherical oscules, 2–3 mm diameter, always on the apex of lobes (Fig. 2A). Surface microhispid with projecting spicules, texture soft; colour in life bright peach pink, in preservative pale pinkish tan (Fig. 2B).

Skeleton & spicules. Isodictyal reticulation of single spicules, end-to-end, with some minor development of primary tracts, 1 spicule wide (Fig. 2C). Oxeas, slightly curved, 119 (110–130) × 5 (4–6) µm (Fig. 2D).

Substrate, depth range, and ecology. Attached to dead coral rubble, intertidal.

Distribution. Adatra; north of Poshetra; off Beyt (Beyt Dwarka) (Previous doubtful record) and Narara (Present confirm record), Gulf of Kutch, Gujarat.

Remarks. Dendy (1916) described a number of specimens as encrusting on parchment-like worm-tubes, growing to a considerable size, but so irregular as to be impossible to measure. The texture was very soft and friable, and the surface was minutely hispid, with small, scattered oscules. The skeleton was described as "an irregular isodictyal reticulation of mostly single spicules, but with a strong tendency to form primary fibres, several spicules thick, separated from each other by one spicule's length. The oxea are gradually curved and sharply pointed, 120 × 6 µm wide. Dendy (1916) considered the identification of *Reniera permollis* to be "good", especially with the "nut-brown colour", but noted the similarity of *R. permollis* to *R. cinerea* (the former is now recognised as a junior synonym of the latter).

Of all the five species of *Haliclona* described by Dendy (1916), our specimens most closely resemble those described by Dendy (1916: 109) as *Reniera permollis*, especially in terms of the overall morphology (irregular and lobate encrusting), and spicule morphology (slender, curved) and dimensions (119 µm *versus* 120 µm (Dendy 1916)); no other Western Indo-Pacific species has spicules around 120 µm long (see Table 1). The only major difference between Dendy's specimens and the Narara specimens is the tendency to development of primary lines in Dendy's specimens, compared with ours which show only minor development of unispicular lines (Fig. 2C). Dendy's Western Indian specimens differ from the northeastern Atlantic species, *Haliclona* (*Reniera*) *cinerea*, based on location (Gray first described it from the western coastline of Scotland, but now common in the northeastern Atlantic), colouration (originally described as blackish grey), skeleton (possessing a very regular, tangential, unispicular, isotropic ectosomal and choanosomal reticulation of oxeas), and spicule dimensions, being 100 (77–113) × 7 (5–10) µm (de Weerdt, 2002), and considerably smaller than Dendy's specimens' spicules.

The presence of occasional primary fibres in Dendy's specimens, and minor development of these in the Narara specimens, raises some doubt as to the present identification as these features are more common in *Haliclona* (*Haliclona*). We consider the following representation to be acceptable: *Haliclona* (?*Reniera*) cf. *cinerea* (Grant, 1826) *sensu* Dendy (1916: 109).

Discussion

Here we update the record for *Reniera permollis* (Bowerbank, 1866) in Dendy (1916: 109) from the Gulf of Kutch and add a new record for India. Dendy (1916)'s original descriptions do not include the key diagnostic characters that we are able to add (morphology images and colouration and range in spicule dimensions) and which are necessary for future recognition in the field. The colour in life and morphology of the Western Indian specimens of *H.* (*R.*) *debilis* (squat fuschia tubes) is remarkably similar to those described from Mombasa by Pulitzer-Finali (1993) and described and illustrated from Zanzibar by Kelly (1997). These species are both easily distinguished from all other species of the subgenus in the Western Indo-Pacific Province, and we are comfortable with reporting a correction to the Porifera record, and adding a new record for the region, as the Western India and East Africa Coral Coast marine ecoregions are linked biogeographically through the Western Indo-Pacific Province.

Table 1. Comparison of *Haliclona* (?*Reniera*) cf. *cinerea* (Grant, 1826) *sensu* Dendy (1916) and *Haliclona* (*Reniera*) *debilis* Pulitzer-Finali, 1993 (holotype) with species described from Kenya and other locations in the Western Indo-Pacific Province.

Taxa	Synonyms	Locality & depth	Spicules & dimensions	Description	Remarks
Gelliodes fibroreticulata (Dendy, 1916)	*Reniera fibroreticulata* Dendy, 1916	Gulf of Kutch, Gujarat	Oxeas, 100 × 6 µm, in a close irregular network of single spicules and numerous, multispicular fibres, 400 µm thick.	Short anastomosing branches, sponge 31 mm long, 20 mm high, 5 mm thick; surface smooth; texture firm	
Haliclona (?*Reniera*) cf. *cinerea* (Grant, 1826) *sens*u Dendy (1916)	*Reniera permollis* (Bowerbank, 1866) *sensu* Dendy (1916)	Adatra, north of Poshetra. Off Beyt Dwarka, Gulf of Kutch, Gujarat, 5–7 m	Oxeas, 120 × 6 µm, irregular isodictyal reticulation of single spicules, some multispicular fibres, separated by a spicule	Encrusting sponge growing over parchment-like worm tubes; colour dark brown; texture soft, fragile; surface hispid due to projecting spicules and fibres; oscules small and scattered.	*Reniera permollis* (Bowerbank, 1866) is now accepted as *Haliclona* (*R.*) *cinerea* (Grant, 1826). Dendy (1916)'s record from Western India is questionable as *H.* (*R.*) *cinerea* is from the northeastern Atlantic.

Taxa	Synonyms	Locality & depth	Spicules & dimensions	Description	Remarks
Haliclona (*Gellius*) *cymaeformis* (Esper, 1806)	*Gellius fibulatus* var. *microsigma* Dendy, 1916	Off Beyt Dwarka, Gulf of Kutch, Gujarat, 27–31 m	Oxeas, 250 × 10 µm, sigmas 16.4 µm (Dendy 1916); oxeas, 155 (128–177) × 5–8 µm, sigmas 18 (17–20) µm (Kelly-Borges & Bergquist, 1977)	An erect bushy or ramose sponge with bifurcating branch tips. Completely invests the red algae *Ceratodictyon spongiosum*. Deep green in life	
Haliclona (*Gellius*) *ridleyi* (Hentschel, 1912)	*Gellius ridleyi* Hentschel, 1912	Aru Islands, 10 m	Oxeas, 136–192 µm, sigmas 15–25 µm	Composed of thick, horizontal or vertical, 1 cm thick lamellae, bearing small oscules in rows on the margins, length up to 14 cm; surface smooth, colour pale grey to reddish brown.	
Haliclona (*Reniera*) *atra* Pulizer-Finali, 1993	*Adocia atra* Pulizer-Finali, 1993	Kenya, 2–4 m	Oxeas, 160–180 × 9 µm, unispicular reticulation	Irregularly cylindrical, branching from the base, 20 cm long, 1 cm thick, colour in life and preservative, black; soft, limp	
Haliclona (*Reniera*) *cribricutis* (Dendy, 1922)	*Reniera cribricutis* Dendy, 1922	Seychelles, 38–55 m	Oxeas, 170 × 6 µm, confused subisodictyal reticulation of plurispicular fibres	Subcylindrical, unbranched, 68 mm by 15 mm, 5 mm oscules, numerous surface subdermal cavities; texture soft	
Haliclona (*Reniera*) *debilis* Pulizer-Finali, 1993	*Haliclona debilis* Pulizer-Finali, 1993	Kenya, 0–1 m	Oxeas, 70–85 × 3–4.5 µm, unispicular reticulation	Cluster of coalescent tubes, 3 cm high, 7-15 mm wide, thin walls; extremely soft, fragile	

Taxa	Synonyms	Locality & depth	Spicules & dimensions	Description	Remarks
Haliclona (*Reniera*) *ligniformis* (Dendy, 1922)	*Reniera ligniformis* Dendy, 1922	Chagos Archipelago, lagoon	Oxeas, 140 × 6 µm, dense, confused subisodictyal reticulation	Erect, tree-like, angular, flattened branches; surface smooth, hispid, narrowly grooved; texture resembling driftwood	
Haliclona (*Reniera*) *tabernacula* (Row, 1911)	*Reniera tabernacula* Row, 1911	Red Sea Agig Harbour	Oxeas, 110–140 × 35 µm, dense plurispicular fibres	Triangular sponge, 55 mm long by 22 mm wide, flattened, almost lamellar, tough but easily compressible	
Haliclona (*Reniera*) *tufoides* (Dendy, 1922)	*Reniera tufoides* Dendy, 1922	Seychelles, 512 m	Stout oxeas, 270 × 12 µm, loose sub-isodictyal uni- to plurispicular reticulation	Flattened, cake like, thick dermal membrane, elongate subsurface canals; texture hard, incompressible	
Haliclona hornelli (Dendy, 1916)	*Reniera hornelli* Dendy (1916)	SW of Beyt Dwarka Island, Gulf of Kutch, Gujarat	Oxeas, 140 × 8 µm, in thin, multispicular fibres running towards the surface, united by one spicule length	Irregularly subglobose body, numerous large oscules with deep cylindrical oscular tube. Surface 'wooly'due to deep, close-set inhalant canals; texture soft	

Taxa	Synonyms	Locality & depth	Spicules & dimensions	Description	Remarks
Haliclona pacifica Hooper in Hooper & Wiedenmayer, 1994	*Siphonochalina minor* Dendy, 1916	Adatra Reef, Dheb Mora, 2 m	Oxeas, 130 × 6 µm, in a rectangular mesh of stout multispicular fibres	Flattened, branching and anastomosing stolons from which arise anastomosing tubes, terminating in a wide vent	
Haliclona semifibrosa (Dendy, 1916)	*Reniera semifibrosa* Dendy, 1916	Dhed Mora, between Beyt Dwarka and Arama, west of Beyt Dwarka Island, Gulf of Kutch, Gujarat, 5–9 m	Stout oxeas, 160 × 10 µm, in a unispicular, isodictyal reticulation and ectosomal reticulation, and subdermal reticulation of fibres, representing growth lines	Massive convex crust, closely adherent to the substrate, interior hollow, 85 mm high, 15 mm thick; surface smooth; texture firm	
Reniera topsenti (Thiele, 1905) *sensu* Dendy (1916)	*Reniera topsenti* (Thiele, 1905)	Adatra, Gulf of Kutch, Gujarat	Oxeas, 200 × 9 µm in an irregular reticulation of mostly single spicules with a tendency to form slender, multispicular fibres running to the surface	Depressed ramose-lobose form, numerous large oscules; texture soft, fragile	*Reniera topsenti* (Thiele, 1905) is now accepted as *Haliclona* (*Reniera*) *topsenti* (Thiele, 1905). Dendy (1916)'s record in Western India is inaccurate (Burton, 1929) because the skeletal architecture of Dendy's specimen is more akin to *Haliclona* (*Haliclona*).

FIGURES

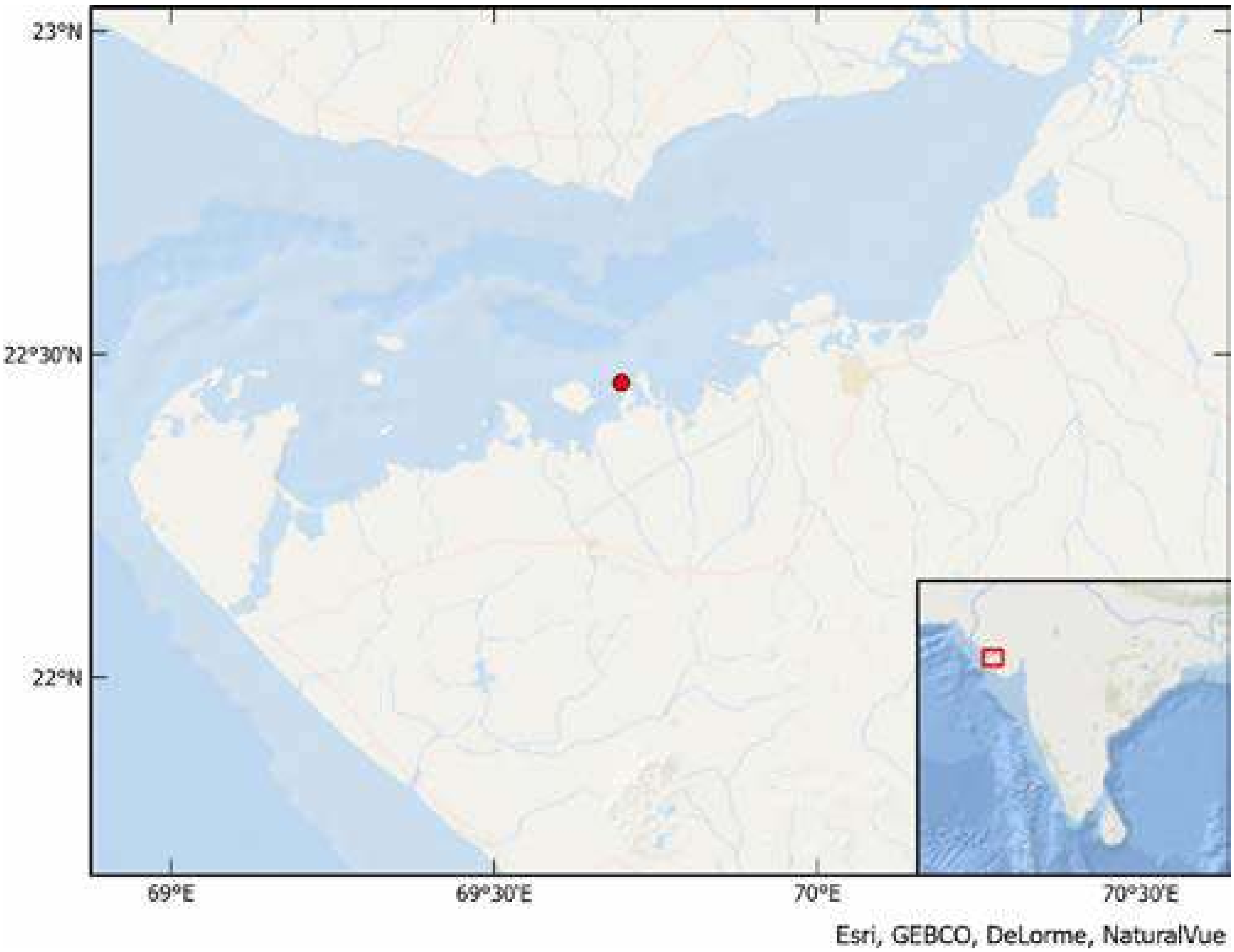

Figure 1. Study site, showing Narara on the Gujarat Coast, Gulf of Kutch, Western India.

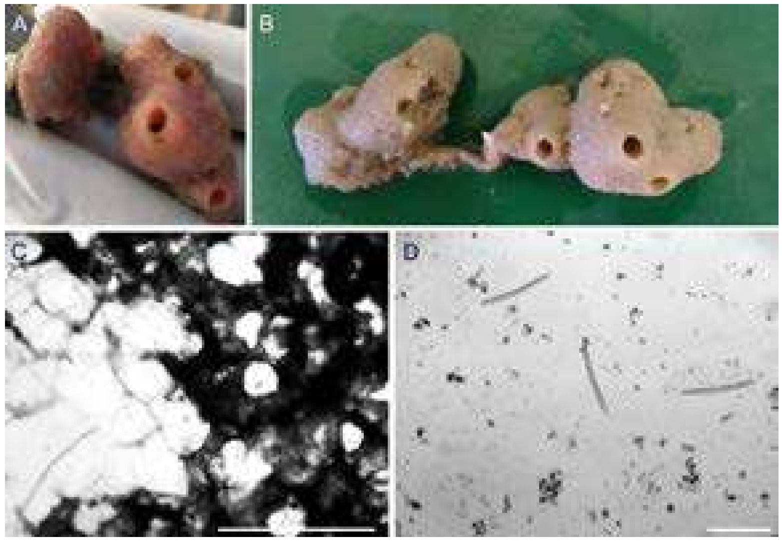

Figure 2. *Haliclona* (*Reniera*) cf. *cinerea* (Grant, 1826) *sensu* Dendy (1916), specimen MBRC/ZSI/S.553, from Narara, Gulf of Kutch, Gujarat, Western India: **A.** Fresh specimen showing peach pink colour in life; **B.** Preserved specimen showing faint pink to tan colouration; **C.** Choanosomal skeleton showing delicate unispicular tracts and isodictyal reticulation, scale = 500 **µ**m; **D.** Oxeas, scale = 100 **µ**m.

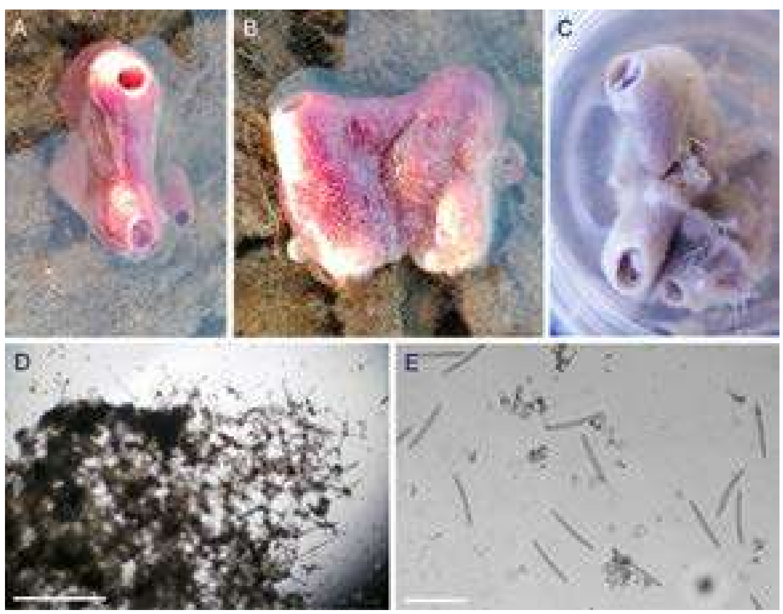

Figure 3. *Haliclona* (*Reniera*) *debilis* Pulitzer-Finali, 1993, specimen MBRC/ZSI/S.584 from Narara, Gulf of Kutch, Gujarat, Western India: **A, B.** Freshly collected specimen, showing the bright fuschia colour in life and faintly conulose surface covered by a translucent membrane; **C.** Preserved specimen showing the subdermal canals visible through the surface membrane, and loss of colour upon preservation; **E.** Ectosomal skeleton squash showing delicate single-spicule isodictyal reticulation, scale = 500 **µ**m.; **F.** Oxeas, scale = 100 **µ**m.

Recent surveys at Narara Reef of Gulf of Kutch, on the Gulf of Kutch, Gujarat, revealed numerous sponges in the intertidal, two of which are species of *Haliclona* Grant, 1835, one strongly resembling *Reniera permollis* (Bowerbank, 1866) *sensu* Dendy (1916), and the other closely comparable to *H.* (*R.*) *debilis* Pulitzer-Finali, 1997, first documented from shallow coastal waters off Mombasa, Kenya (Pulitzer-Finali 1997) and Zanzibar (Kelly, 1997).

Acknowledgements

The authors are thankful to the Director of the Zoological Survey of India, Kolkata, and Dr. Rajkumar Rajan, Officer-in-Charge, Zoological Survey of India, Chennai, for the support and assistance. We are grateful to Dr. Satyanaraya (Retired Scientist-D) & IOCL Consultant, Gujarat for and survey team members, Dr. Ramkumar, Dr. Thanappan (IOCL project Gujarat). We thank Devakumar (JRF IOCL project) and D, Viswanathan, Junior Zoological Assistant at MBRC/ZSI, Chennai, for assistance. We thank Carina Sim-Smith for creating Figures 1–3 and Toufiek Samaai for his advice on marine ecoregions and biogeographic affinities.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

New distributional record of Anthidiine bee (Apoidea: Megachilidae) from Ladakh, India and a checklist of the family Megachilidae Latreille, 1802 (Hymenoptera: Insecta) of India

P M Osman Javid[1], Rifat H. Raina[2], P.C Pathania[3] and Sajad H. Paray[1*]

[1] Department of Zoology, School of Biosciences and Biotechnology*
BGSB University, Rajouri, J&K, India
[2]Desert Regional Centre, Zoological Survey of India, Jodhpur, Rajasthan, India
[3]The High Altitude Regional Centre, Zoological Survey of India, Saproon, Solan, India

Abstract

The checklist of the Bee family Megachilidae, from India, is presented. Megachilidae is one of the hyper-diverse bee family that includes leafcutter, resin and mason bees. In India, it is the largest bee family with a total of **179 species** under **23 genera** & **36 subgenera under 2 subfamilies in 3 tribes**. This checklist is compiled based on the previously published literature and new survey cum collection data carried out from 2020 to 2022. Here, one species has been recorded as new to Ladakh namely *Anthidium florentinum* (Fabricius, 1775) from Zanskar, Ladakh.

Keywords: Checklist, Megachilidae, India, Distribution, Bees

Introduction

Bees belonging to the family Megachilidae are commonly called leaf cutter, wood borers, mason bees and cuckoo bees. They can be found in widely diverse habitats on all the continents except Antarctica ranging from lowland tropical rainforests to deserts to alpine environments (Litman et al, 2011). Solitary bees are of much economic value because of their role in the pollination of natural, urban and agricultural vegetation. (Berenbaum et al, 2006, Gonzalez et al, 2012). At present, about 4000 species under 70 subgenera are described worldwide (Michener, 2007: Ascher & Pickering, 2020) whereas, more than 150 species of the genus *Megachile* belonging to a dozen subgenera are recognized as valid from Southeast Asia (Ascher & Pickering, 2020). In India it is the largest family with a total of 179 species belonging to 23 genera & 36 subgenera in 3 tribes under 2 subfamilies namely: Lithurginae & Megachilinae. Family Megachilidae constitutes about 40% alone of the bee fauna of India (Gupta, 1993). These bees being important pollinators of many wild plant species, also play an important role in the maintenance of the ecosystems. There has been a unique pollen-collecting adaptation in which the scopa of the pollen-collecting hairs of a female is located on the ventral surface of the metasoma in the family Megachilidae rather than mostly or exclusively on the hind legs as in other bee families.

Bees of the tribe Anthidiini (Hymenoptera: Megachilidae) can be distinguished from other megachilids in Asia by the short stigma and usually the presence of conspicuous yellow or red integumental markings (Michener 2007; Kumar *et al.* 2017). Anthidiine bees occur almost, worldwide, except in Antarctica and Australia (except for one introduced species), in many different habitats. Anthidiini bees are commonly known as 'resin and carder bees', reflecting the materials from which they built their nests Soil particles or plant resins (Michener, 2007). The tribe Anthidiini currently consists of 894 known species belonging to 40 genera worldwide (Ascher and Pickering 2021). The known Indian fauna includes 46 species (Kasparek, 2017; Kumar et al, 2017; Ascher and Pickering, 2021).

*Author for correspondence : sajadzoo@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Materials and Methods

This work is based on the data collected from the published literature and some additional new distributional data is given based on the collection data obtained from 2020-2022 from Jammu and Kashmir and Ladakh. These collections were done in the plains like in Orchid gardens, agricultural fields and at the higher reaches of the Himalayas. Bee specimens have been collected with a sweep insect net, and killed in a glass killing bottle, by using ethyl acetate, with an air-tight cap. The freshly killed specimens have been pinned and stretched as per the standard procedure for bees. Pinned specimens belonging to the family Megachilidae had been separated, labelled and stored in an insect cabinet for their taxonomic studies.

Identification

For morphological identification, specimens have been identified under stereo zoom trinocular microscope up to Species-level by using dichotomous keys designed by Bingham, 1897: Michener, 2000, 2007: Gupta, 1992 & from the relevant literature.

Results

Family Megachilidae Latreille, 1802

Subfamily Megachilinae

Tribe Anthidini

Anthidium (Anthidium) florentinum Fabricius, 1775

(Fig. 1)

Apis florentina Fabricius, 1775: 384,

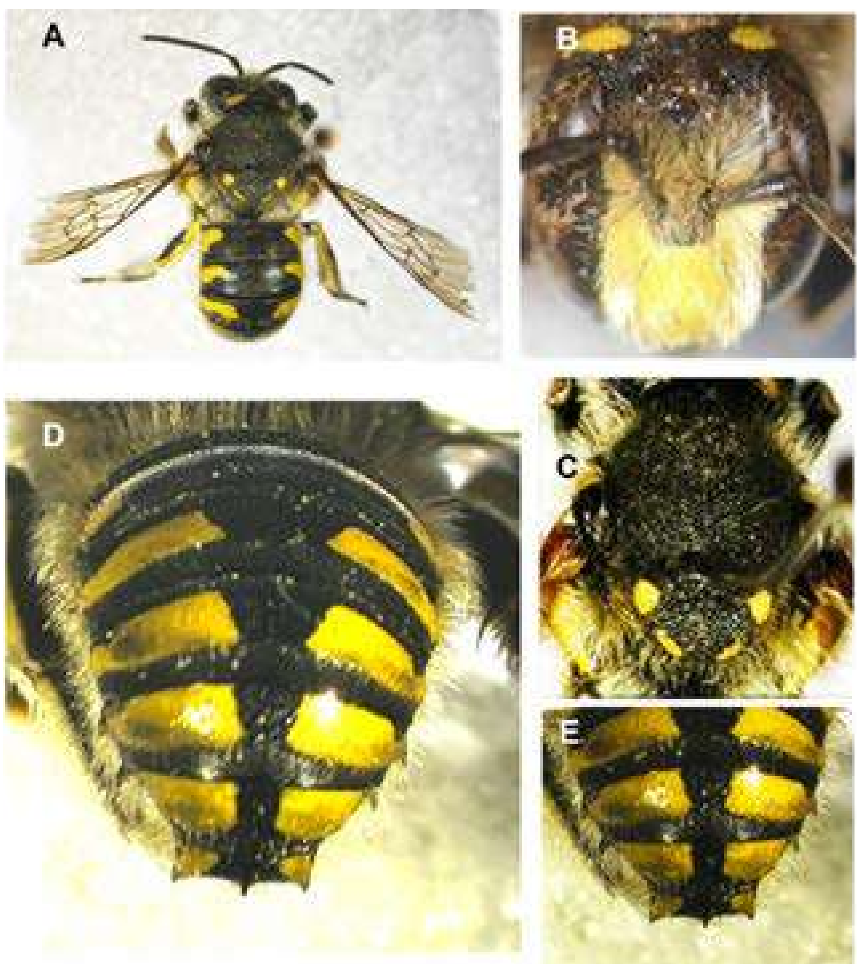

Fig. 1. *Anthidium florentinum* : A, habitus, dorsal view; B, head, frontal view; C, mesosoma, dorsal view; D, metasoma, dorsal view; and E, tergites showing lateral spines.

Diagnosis : Male.(Fig. 1A). Mandible tri-dentate, yellow, with dark brown teeth; clypeus yellow; yellow maculation on paraocular region almost reaching middle of the eye (Fig. 1B); vertex with lateral yellow maculation. Tegula with yellow spot anteriorly;boomerang-shaped maculation on scutum anterolaterally (Fig. 1C); wings subhyaline; arolia absent. Hind femur with ventral tooth near the base. Maculation on all terga interrupted medially, with the interruptions gradually decreasing towards T6; lateral margins on T2–T4 slightly protuberant, with sparse tufts of white pubescence (Fig. 1D); lateral spine of T5 yellow and T6 brown; T7 spiniform with three acute apical spines (Fig. 1E); S6 with median apical margin truncately produced.

Material examined : 2 , India, Ladakh, Zanskar, 33.2759° N, 76.5355° E, 18 .VIII .2022, sweep net, coll. P M Osman.

Distribution: India, Nainital (Uttarakhand)

Additional material examined: Zanskar, Padam (Ladakh), (New record)

A checklist of the species belonging to the family Megachilidae occurring in India is provided here.

Family Megachilidae Latreille, 1802

Subfamily *Lithurginae* Michener, 1983

Genus *Lithurge* Latreille, 1825

Subgenus *Lithurge* Latreille, 1825

1 *Lithurge* (*Lithurge*) *atratus* (Smith, 1853)

Distribution: Mussoorie, Dehradun (Uttarakhand)

2 *Lithurge* (*Lithurge*) *dentipes* (Smith, 1853)

Distribution: Gongtok (Sikkim), Kaziranga (Assam)

3 *Lithurge* (*Lithurge*) *taprobanae* (Cameron, 1902)

Distribution: Solan (Himachal Pradesh), Dehradun (Uttarakhand), Ludhian (Punjab)

4 *Lithurge* (*Lithurge*) *rufipes* (Smith, 1853)

Distribution: Lonavala (Maharashtra)

5 *Lithurge* (*Lithurge*) *tiwarii* (Gupta & Tiwari, 1987)

Distribution: Pondicherry

6 *Lithurge* (*Lithurge*) *rubricatus* (Smith, 1853)

Distribution: Tiruchirapalli, Madurai (Tamil Nadu)

7 *Lithurge* (*Lithurge*) *albofacialis* (Gupta, 1993)

Distribution: Haryana (Himachal Pradesh)

8 *Lithurge* (*Lithurge*) *nigroabdominalis* (Gupta, 1993)

Distribution: Haryana (Himachal Pradesh)

9 *Lithurge* (*Lithurge*) *ovoabdominalis* (Gupta, 1993)

Distribution: Haryana (Himachal Pradesh)

10 *Lithurge* (*Lithurge*) *apiformis* (Gupta, 1993)

Distribution: Haryana (Himachal Pradesh)

11 *Lithurge* (*Lithurge*) *indicus* (Gupta, 1993)

Distribution: Haryana (Himachal Pradesh)

12 *Lithurge* (*Lithurge*) *veeravaliensis* (Gupta, 1993)

Distribution: Haryana (Himachal Pradesh)

2 **Subfamily Megachilinae**

Tribe Anthidiini

Genus *Eoanthidium* Popov, 1950

Subgenus *Eoanthidium* Popov, 1950

1. *Eoanthidium* (*Eoanthidium*) *adentatum* (Gupta& simlot 1993)

Distribution: Alwar, Kota, Deeg (Rajashtan)

2 *Eoanthidium* (*Hemidiellum*) *punjabensis* (Gupta& Sharma 1993)

Distribution: Pathankot (Punjab)

Genus *Dianthidium* Cockerell, 1900

Subgenus *Icteranthidium*, Michener, 1984

1. *Dianthidium* (*Icteranthidium*) *sinapinum* (Cockerell, 1911)

Distribution: Nagaur (Rajasthan)

2. *Dianthidium* (*Icteranthidium*) *saltatore* (Nurse, 1901)

Distribution: Deesa (Gujarat), Nagaur (Rajasthan)

3. *Dianthidium* (*Icteranthidium*) *tshangiricum orientale (*Mavromoustakis, 1951)

Distribution: Nagaur (Rajasthan)

4. *Dianthidium favoclypeatum* (Gupta, 1993)

Distribution: Pathankot (Punjab), Dehradun (Uttarakhand)

Genus *Bathanthidium*, Mavromoustakis, 1953

1. *Bathanthidium (Manthidium) binghami* (Friese, 1901)

Distribution: Buxa Tiger Reserve (West Bengal)

Genus *Trachusa* Panzer, 1804

Subgenus *Trichanthidium* Pasteels, 1969

1. *Trachusa* (*Trichanthidium*) *himalayensis* (Gupta, 1993)

   Distribution: Dehradun (Uttarakhand)

   Subgenus *Orientotrachusa* Gupta, 1993

2. *Trachusa* (*Orientotrachusa*) *orientale* (Bingham, 1897)

   Distribution: Pune (Maharashtra), Solan (Himachal Pradesh), Alwar (Rajasthan)

3. *Trachusa* (*Orientotrachusa*) *flavomaculatum* (Cameron, 1897)

   Distribution: Kota (Rajasthan), Bingham 1897, records from Poona (Maharashtra)

4. *Trachusa* (*Orientotrachusa*) *serratocaudata* (Gupta, Sharma & Simlote 1993)

   Distribution: Deesa (Gujarat), Nagaur (Rajasthan)

Genus *Anthidium* Fabricius, 1805

Subgenus Anthidium Fabricius, 1805

Genus Anthidum Fabricius, 1805

1. *Anthidium* (*Anthidium*) *florentinum* (Fabricius, 1775)

   Distribution: Nainital (Uttarakhand), Zanskar, Padam (Ladakh), (New record)

   Subgenus *Proanthidium* Friese, 1898

2. *Anthidium* (*Proanthidium*) *qingtaoi* (Niu and Zhu, 2020)

   Distribution: Chumathang (Ladakh), China (Xizang) (Niu et al 2020)

3. *Anthidium* (*Proanthidium*) *conciliatum* (Nurse, 1903)

   Distribution: Gulmarg, Baramulla (Kashmir), Manali (Himachal Pradesh)

4. *Anthidium* (*proanthidium*) *kashmirensis* (Mavromoustakis, 1937)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir)

5. *Anthidium* (*Proanthidium*) *sikkimense* (Mavromoustakis, 1937)

   Distribution: Gangtok (Sikkim)

6. *Anthidium* (*Proanthidium*) *nursei* (Cockerell, 1992)

   Distribution: Dehradun (Uttarakhand), Gulmarg (Kashmir) Kullu (Himachal Pradesh)

7. *Anthidium* (*Proanthidium*) *himalayense* (Gupta & Simlote, 1995)

   Distribution: Mussoorie (Uttarakhand), Gulmarg (Kashmir), Kargil, Leh (Ladakh)

8. *Anthidium alticola* (Tkalcu, 1967)

   Distribution: Kolkata (West Bengal)

9. *Anthidium ordinatum* (Smith, 1879)

   Distribution: Sikkim, Pathankote (Punjab), Rajasthan West Bengal

10. *Anthidium saltator* (Nurse, 1902)

    Distribution: Gulmarg, Baramulla (Kashmir), Mussoorie (Uttarakhand)

11. *Anthidium longstaffi* (Mavromoustakis, 1948)

    Distribution: Gulmarg, Baramulla (Kashmir), Dehradun, Mussoorie (Uttarakhand)

Genus *Anthidiellum* Cockerell, 1904

Subgenus *Pycnanthidium*

1. *Anthidiellum* (*Pycnanthidium*) *carinatum* (Wu, 1962)

   Distribution: Dharmanagar (Tripura), Hainan, Yunnan (China), (Wu 1962)

Genus *Parevaspis* Ritsema, 1874

Subgenus *Parevaspis* Ritesma, 1874

1. *Parevaspis* (*Parevaspis) carbonaria* (Smith, 1854)

   Distribution: Alwar, Sikar (Rajasthan), Pathankot (Punjab)

Tribe Osmiini

Genus *Heriades* Spinola, 1908

Subgenus *Michenerella* Krombein, 1950

1. *Heriades* (*Michenerella*) *longifaciatus* (Gupta & Tewari, 1987)

   Distribution: Kullu (Himachal Pradesh), Dehradun, Mussoorie (Uttarakhand)

2. *Heriades* (*Michenerella*) *tenuis* (Nurse, 1904)

   Distribution: Deesa (Gujarat), Kullu (Himachal Pradesh)

3. *Heriades* (*Michenerella*) *binghami* (Cameron, 1897)

   Distribution: Deesa (Gujarat)

4. *Heriades* (*Michenerella*) *rufoflagellatus* (Gupta & Simlote, 1993)

   Distribution: Manali, Kangra (Himachal Pradesh)

Genus *orientoheriades* Gupta, 1987

1. *Orientoheriades indicus* (Gupta, Sharma & Simlote, 1993)

   Distribution: Kullu (Himachal Pradesh)
2. *Orientoheriades nursei* (Gupta & Sharma, 1993)

   Distribution: Nagwani, Kullu (Himachal Pradesh)
3. *Orientoheriades patella* (Nurse, 1902)

   Distribution: Kulla, Manali, Mandi (Himachal Pradesh), Nurse 1901, collected from Shimla (Himachal Pradesh)
4. *Orientoheriades nigrous* (Gupta & Sharma , 1993)

   Distribution Kullu (Himachal Pradesh)
5. *Orientoheriades solanensis* (Gupta, Simlote & Sharma , 1993)

   Distribution: Solan (Himachal Pradesh)
6. *Orientoheriades micheneri* (Gupta, 1993)

   Distribution: Kansas (Uttarakhand)
7. *Orientoheriades orientalis* (Gupta, 1987)

   Distribution: Kullu, Manali, Kangra (Himachal Pradesh)
8. *Orientoheriades erectus* (Gupta, 1987)

   Distribution: Kullu, Manali (Himachal Pradesh)
9. *Orientoheriades himalayensis* (Gupta, 1993)

   Distribution: Kullu (Himachal Pradesh)
10. *Orientoheriades haryanensis* (Gupta, Sharma & simlote, 1993)

    Distribution: Sonipat (Haryana)
11. *Orientoheriades auroscopatus* (Gupta, sharma & simlote 1993)

    Distribution: Kullu, Manali, (Himachal Pradesh)
12. *Orientoheriades fasciatus* (Gupta, Sharma & simlote 1993

    Distribution: Manali, Kullu (Himachal Pradesh)
13. *Orientoheriades hexadenticulatus* (Gupta, Sharma & simlote, 1993)

    Distribution: Kullu, Manali (Himachal Pradesh)
14. *Orientoheriades rufomarginatus* (Gupta, Sharma & simlote, 1993)

    Distribution: Kullu, Manali (Himachal Pradesh)
15. *Orientoheriades lobatus* (Gupta, & sharma, 1993)

    Distribution: Manali (Himachal Pradesh)
16. *Orientoheriades pulchripes* (Cameron, 1987)

    Distribution: Mussoorie (Uttarakhand)
17. *Orientoheriades bidentatus* (Gupta & Simlote, 1993)

    Distribution: Kullu (Himachal Pradesh)

Genus *Pseudoheriades* Peters, 1970

1. *Pseudoheriades rajasthaniensis* (Gupta, Sharma & Simlote, 1993)

   Distribution: Udaipur (Rajasthan)
2. *Pseudoheriades himalayensis* (Gupta, Sharma & simlote, 1993)

   Distribution: Kullu (Himachal Pradesh)

Genus *Noteriades* Cockerell, 1931

1. *Noteriades infasciatus* (Simlote & Gupta, 1993)

   Distribution: Sundernagar (Himachal Pradesh) collected by Simlote 1992
2. *Noteriades himalayensis* (Simlote & Gupta, 1993)

   Distribution Kullu, Manali (Himachal Pradesh)
3. *Noteriades tergofasciatus* (Simlote & Gupta, 1993)

   Distribution: Kullu (Himachal Pradesh)
4. *Noteriades striolatus* (Cameron, 1906)

   Distribution: Sundernagar (Himachal Pradesh)

Genus *Spinasternella* Gupta & Sharma, 1993

1. *Spinasternella mevatus* (Gupta & Sharma , 1993)

   Distribution: Mevat (Haryana) Alwar (Rajasthan)
2. *Spinasternella pentatuberculata* (Gupta & Sharma , 1993)

   Distribution: Alwar (Rajasthan) Mandi (Himachal Pradesh)
3. *Spinasternella rufomandibulata* (Gupta & Sharma , 1993)

   Distribution: Tolawas, Alwar (Rajasthan)

Genus *Hoplitis* Klug, 1807

Subgenus *Liosmia* Thomson, 1872

1. *Hoplitis(Liosmia) freygessneri* (Fries, 1899)

   Distribution: Pathankot , Batala (Punjab)

   Subgenus *Tridentosmia* Schmied, 1886
2. *Hoplitis (Tridentosmia) karakalensis* (Popov, 1936)

   Distribution: Pathankot (Punjab)

3. *Hoplitis (Tridentosmia) moricei* (Friese, 1899)

   Distribution: Manali (Himachal Pradesh)

Genus *Anthocopa* Lepeletier & Serville, 1825

Subgenus: *Anthocopa* Lepeletier & Serville, 1825

1. *Anthocopa* (*Anthocopa*) *rubricrus* (Friese, 1899)

   Distribution: Deesa (Gujarat), Ludhiana (Punjab)

2. *Anthocopa* (*Anthocopa*) *saundersi* (Vachal, 1891)

   Distribution: Pathankot (Punjab)

3. *Anthocopa cathena* (Cameron, 1908)

   Distribution: Deesa (Gujarat)

4. *Anthocopa indostana* (Cameron, 1908)

   Distribution: Deesa (Gujarat)

Genus *Osmia* Panzer, 1806

Subgenus *Chalcosmia* Schmied, 1886

1. *Osmia* (*Chalcosmia*) *adae* (Bingham, 1897)

   Distribution: Kullu, Manali (Himachal Pradesh), Srinagar, Gulmarg (Kashmir)

2. *Osmia* (*Chalcosmia*) *caerulescens caerulescens* (Linneaus, 1758)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir), Manali (Himachal Pradesh), Pusa (Bihar)

3. *Osmia cyanea* (Giraud, 1866)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir), Manali (Himachal Pradesh), Pusa (Bihar)

4. *Osmia purpurea* (Cresson, 1864)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir), Manali (Himachal Pradesh), Pusa (Bihar)

5. *Osmia rustica* (Cresson, 1864)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir), Manali (Himachal Pradesh), Pusa (Bihar)

6. *Osmia caerulescens* (Dalla torre, 1897)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir), Manali (Himachal Pradesh), Pusa (Bihar)

7. *Osmia kashmirenesis* (Nurse, 1903)

   Distribution: Gulmarg, Baramulla (Kashmir), Manali (Himachal Pradesh) Pusa (Bihar)

8. *Osmia dutti* (Cockerell, 1922)

   Distribution: Gulmarg, Baramulla, Kupwara (Kashmir), Manali (Himachal Pradesh), Pusa (Bihar)

9. *Osmia* (*Chalcosmia) sita* (Nurse, 1904)

   Distribution: Manali (Himachal Pradesh)

   Subgenus Caerulosmia Zanden, 1988

10. *Osmia* (*Caerulosmia*) *sponsa* (Nurse, 1904)

    Distribution: Manali (Himachal Pradesh) Pusa (Bihar)

11. *Osmia gulmargenesis* (Nurse, 1903)

    Distribution: Gulmarg, Srinagar (Kashmir)

12. O*smia balucha* (Nurse, 1 904)

    Distribution: Pathankot (Punjab) Manali, Mandi (Himachal Pradesh)

13. *Osmia nursei* (Friese, 1911)

    Distribution: Alwar, Nagaur (Rajasthan)

14. *Osmia lignaria* (Say, 1837)

    Distribution: Anantnag (Kashmir)

Genus *Robertsonella* Titus, 1904

1. *Robertsonella Himachali* (Gupta, 1991)

   Distribution: Kullu (Himachal Pradesh), Pathankot (Punjab)

Tribe Megachilini

Genus *Creightonella* Cockerell, 1908

1. *Creightonella albifrons* (Smith, 1853)

   Distribution: Alwar (Rajasthan), Bingham 1897, reported from Northwest province & Bombay

Genus *Eumegachile* Friese, 1899

Subgenus *Sayapis* Titus, 1905

1. *Eumegachile* (*Sayapsis*) *subfuscus* (Cameron, 1908)

   Distribution: Alwar, Deeg, Kota (Rajasthan), Mandi (Himachal Pradesh), Cameron, 1908 reported from Deesa (Gujarat)

2. *Eumegachile* (*Sayapsis*) *inepta* (Cameron, 1906)

   Distribution: Mandi, Dharamshala (Himachal Pradesh)

3. *Eumegachile* (*Sayapsis*) *tetradenta* (Gupta, 1988)

   Distribution: Pathankot (Punjab)

4. *Eumegachile* (*Sayapsis*) *rajasthaniensis* (Gupta, 1988)

   Distribution: Deeg, Alwar (Rajasthan)

   Subgenus *Eumegachile* Friese, 1899

5. *Eumegachie* (*Eumegachie*) *tricincta* (Bingham, 1897)

   Distribution: Kullu, Mandi, Solan (Himachal Pradesh)

Genus *Chalicodoma* Lepeletier, 1841

Subgenus *Callomegachile* Michener, 1962

1. *Chalicodoma* (*Callomegachile*) *disjuncta* (Fabricius, 1781)

   Distribution: Udaipur (Himachal Pradesh), Sikar (Rajasthan) Pathankot (Punjab)

2. *Chalicodoma* (*Callomegachile*) *cephalotes* (Smith, 1853)

   Distribution: Alwar, Deeg, Kota (Rajasthan) Ludhiana, Pathankot (Punjab), Kullu, Mandi (Himachal Pradesh), Bingham 1897, reported from Dehradun (Uttarakhand)

3. *Chalicodoma* (*Callomegachile*) *stirostoma* (Cameron, 1913)

   Distribution: Alwar, Kota (Rajasthan), Kullu (Himachal Pradesh), Cameron 1913, reported from Dehradun (Uttarakhand)

4. *Chalicodoma* (*Callomegachile*) *umbripennis* (Smith, 1853)

   Distribution: Alwar, Deeg, Kota (Rajasthan), Ludhiana, Pathankot (Punjab) Kullu, Mandi (Himachal Pradesh), Bingham 1897, reported from Nepal, Sikkim & Tenasserim (Malaysia)

5. *Chalicodoma* (*Callomegachile*) *quartine* (Gribodo, 1884)

   Distribution: Alwar, Deeg, Kota (Rajasthan), Ludhiana, Pathankot Kullu (Punjab), Mandi (Himachal Pradesh), Bingham 1897, reported from upper Burma & Tenasserim

Subgenus *Chelostomoda* Michener, 1962

6. *Chalicodoma* (*Chelostomoda*) *phaola* (Cameron, 1907)

   Distribution: Sikar, Kota (Rajasthan), Cameron 1907, reported from Deesa (Gujarat)

7. *Chalicodoma* (*Chelostomoda*) *nana* (Bingham, 1897)

   Distribution: Kullu, Solan (Himachal Pradesh), Bingham 1897, reported from Tenasserim (Malaysia)

8. *Chalicodoma* (*Chelostomoda*) *saphira* (Cameron, 1907)

   Distribution: Manali (Himachal Pradesh)

Subgenus *Pseudomegachilie* Friese, 1899

9. *Chalicodoma* (*Pseudomegachilie*) *lanata* (Fabricius, 1775)

   Distribution: Alwar, Deega, Sikar (Rajasthan) Chandigarh, Bingham 1897, reported throughout India

10. *Chalicodoma (Pseudomegachilie) creusa* (Bingham, 1898)

    Distribution: Sonipat (Haryana), Mandi (Himachal Pradesh), Deesa, (Gujarat), Alwar, Sikar (Rajasthan)

11. *Chalicodoma* (*Pseudomegachilie*) *velutina* (Smith, 1853)

    Distribution: Northern India Smith Bingham 1897 reported from Tenasserium

12. *Chalicodoma* (*Pseudomegachilie*) *Vigilans* (Smith, 1879)

    Distribution: Kupwara (Kashmir)

13. *Chalicodoma* (*Pseudomegachilie*) *flavipes* (Spinola, 1838)

    Distribution: Manali, Kangra (Himachal Pradesh), Gulmarg (Kashmir)

14. *Chalicodoma elfrona* (Cameron, 1908)

    Distribution: Dessa (Gujarat)

Genus *Cressoniella* Mitchell, 1980

Subgenus *Neomegachilie* Mitchell, 1934

1. *Cressoniella* (*Neomegachilie*) *conjuncta* (Smith, 1879)

   Distribution: Mandi (Himachal Pradesh), Gharo (West Bengal)

2. *Cressoniella* (*Neomegachilie*) *lerma* (Cameron, 1908)

   Distribution: Alwar (Rajasthan), Deesa (Gujarat), Pathankot (Punjab) Kullu, Kangra (Himachal Pradesh) Cameron, 1908 Reported from Deesa (Gujarat)

Subgenus *Orientocressoniella* Gupta, 1993

3. *Cressoniella* (*Orientocressoniella*) *relata* (Smith, 1879)

   Distribution: Alwar, Kota (Rajasthan) Kullu, Kangra, Manali (Himachal Pradesh), Bingham 1897, reported from Burma & China

4. *Cressoniella* (*Orientocressoniella*) *anthracina* (Smith, 1853)

   Distribution: Alwar, Kota (Rajasthan) Kullu, Kangra, Manali (Himachal Pradesh) Bingham 1897 reported from throughout the North West provinces and Bengal

5. *Cressoniella (Orientocressoniella) simlaensis* (Cameron, 1906)

   Distribution: Kullu (Himachal Pradesh), Cameron1906, reported from Shimla (Himachal Pradesh)

Subgenus *Neocressoniella* Gupta, 1993

6. *Cressoniella* (*Neocressoniella*) *carbonaria* (Smith, 1853)

   Distribution: Alwar (Rajasthan) Kangra, Palampur (Himachal Pradesh) Deesa (Gujarat)

7. *Cressoniella* (*Neocressoniella*) *rufothoracica* (Gupta & Sharma, 1993)

   Distribution: Alwar , Umrain (Rajasthan), Rajgarh (Madhya Pradesh), Narainpura (Ahmedabad)

8. *Cressoniella* (*Neocressoniella*) *elizabethae* (Bingham, 1897)

   Distribution: Shimla (Himachal Pradesh), Batra (Chattisgarh), Mussoorie (Uttarakhand) Bingham 1897 reported from Tenasserium (Malaysia)

9. *Cressoniella* (*Neocressoniella*) *amputate* (Smith, 1857)

   Distribution: Sikkim, Bingham 1897, reported from Tenasserium (Malaysia)

Genus *Megachile* Latreille, 1802

Subgenus *Aethomegachile* Engel & Baker, 2006

1. *Megachile* (*Aethomegachile*) *laticeps* (Smith, 1853)

   Distribution: Maharashtra, Alwar (Rajasthan)

2. *Megachile* (*Aethomegachile*) *conjuncta* (Smith, 1853)

   Distribution: Gangtok (Sikkim), Gupta 1999 reported it around North West India in the states of Rajasthan and Gujarat, Jammu & Kashmir (Ascher & Pickering, 2020)

Subgenus *Eurymella* Pasteels, 1965

3. *Megachile* (*Eurymella*) *rugicauda* (Cameron, 1908)

   Distribution: Sikar, Nagaur (Rajasthan), Deesa (Gujarat)

4. *Megachile* (*Eurymella*) *rufibasalis* (Gupta, simlote & Sharma, 1993)

   Distribution: Pathankot (Punjab)

5. *Megachile* (*Eurymella*) *haryanensis* (Gupta, Sharma & Simlote, 1993)

   Distribution: Hissar (Haryana)

6. *Megachile* (*Eurymella*) *peniculatum* (Gupta, 1993)

   Distribution : Alwar (Rajasthan), Mussoorie (Uttarakhand), Pathankot (Punjab)

Subgenus *Callochile* Michener, 1962

8. *Megachile* (*Callochile*) *bicolor* Fabricius, 1781

   Distribution: Alwar, Sikar (Rajasthan), Deega, (Uttar Pradesh), Mandi, Kangra (Himachal Pradesh).

Subgenus *(Eutricharaea)* Thomson, 1872

9. *Megachile* (*Eutricharaea*) *femorata* (Smith, 1853)

   Distribution: Alwar, Sikar (Rajasthan), Kullu, Manali, Kangra (Himachal Pradesh)

10. *Megachile* (*Eutricharaea*) *vera* (Nurse, 1901)

    Distribution: Alwar, Sikar, Udaipur (Rajasthan), Kullu, Manali, Kangra, (Himachal Pradesh)

11. *Megachile* (*Eutricharaea*) *hera* (Bingham, 1897)

    Distribution: Alwar, Sikar Udaipur, (Rajasthan), Kullu, Manali, Kangra, (Himachal Pradesh) Baramula, Anantnag (Kashmir)

12. *Megachile* (*Eutricharaea*) *chlorigaster* (Cameron, 1897)

    Distribution:Alwar, Sikar (Rajasthan), Kullu, Manali, Kangra (Himachal Pradesh)

13. *Megachile* (*Eutricharaea*) *coelioxysides* (Bingham, 1899)

    Distribution: Alwar, (Rajasthan) Kullu, Manali , Kangra (Himachal Pradesh), Leh, Kargil (Ladakh)

14. *Megachile* (*Eutricharaea*) *gathela* (Cameron, 1908)

    Distribution: Alwar, Sikar (Rajasthan) Kullu, Manali, Kangra, Shimla, (Himachal Pradesh), Sonipat (Haryana)

15. *Megachile* (*Eutricharaea*) *studiosa* (Bingham, 1899)

    Distribution: Sikar, (Rajasthan) Naghar (Uttarakhand)

16. *Megachile* (*Eutricharaea*) *suavida* (Cameron, 1908)

    Distribution: Deesa (Gujarat), Nagaur (Uttarakhand)

17. *Megachilie binghami* (Meade-waldo, 1912)

    Distribution: Arunachal Pradesh, Dehradun (Uttarakhand), West Bengal

18. *Megachilie stulta* (Bingham, 1897)

    Distribution: Sikkim, Banglore (Karnataka)

19. *Megachilie umbripennis* (Smith, 1853)

    Distribution: Sikkim, Pathankot (Punjab)

20. *Megachilie faceta* (Bingham, 1897)

    Distribution: Shillong (Meghalaya)

21. *Megachilie rotundata* (Fabricius, 1787)

    Distribution: Kullu, (Himachal Pradesh), Leh, Kargil (Ladakh)

22. *Megachilie centuncularis* (Linneaus, 1758)

    Distribution: Kullu, (Himachal Pradesh), Gulmarg, Kupwara (Kashmir)

23. *Megachilie albifornis* (Smith, 1853)

    Distribution: Lonavala (Maharasthra), Banglore (Karnataka)

24. *Megachilie anthracina* (Smith, 1853)

    Distribution: Ludhiana (Punjab), Dehradun, Mussoorie (Uttarakhand)

25. *Megachilie badia* (Bingham, 1809)

    Distribution: Pathankot (Punjab), Dehradun (Uttarakhand)

26. *Megachilie bellula* (Bingham, 1897)

    Distribution: Mussoorie (Uttarakhand), Kullu (Himachal Pradesh)

27. *Megachilie behavanae* (Bingham, 1897)

    Distribution: Sikkim, Ludhiana (Punjab)

28. *Megachilie cephalotes* (Smith, 1853)

    Distribution: Sikkim

29. *Megachilie faceta* (Bingham, 1987)

    Distribution: Shillong (Meghalaya)

30. *Megachilie vigilans* (Smith 1878)

    Distribution: Gangtok (Sikkim)

31. *Megachilie imitatrix* (Smith, 1853)

    Distribution: Dehradun (Uttarakhand)

32. *Megachilie implicator* (Cameron, 1897)

    Distribution: Mussoorie (Uttarakhand), Ludhiana (Punjab)

33. *Megachilie ladakhensis* (Tkaleu, 1988)

    Distribution : Leh, Kargil (Ladakh)

34. *Megachilie nana* (Bingham, 1897)

    Distribution: Mussoorie (Uttarakhand), Gangtok (Sikkim)

35. *Megachilie obtusata* (Cameron, 1909)

    Distribution: Pathankot (Punjab), Sonipat (Haryana)

36. *Megachilie velutina* (Smith, 1853)

    Distribution: Gangtok (Sikkim), Ludhiana (Punjab), Dehradun (Uttarakhand)

Genus *Hemicoeloxys* Pastells, 1968

1. *Hemicoeloxys* (*rufiventris*) *nursei* (Cockerell, 1922)

   Distribution: Deesa (Gujarat)

Genus *Coelioxys* Latreille, 1809

Subgenus *Orientocoelioxys* Gupta, 1992

1. *Coelioxys* (*Orientocoelioxys*) *angulatus* (Smith, 1870)

   Distribution: Imphal (Manipur)

2. *Coelioxys* (*Orientocoelioxys*) *quadrifasciatus* (Gupta, 1992)

   Distribution:Alwar (Rajasthan), Mandi, Kullu, Kangri (Himachal Pradesh)

Subgenus *Boreocoelioxys* Mitchell, 1973

3. *Coelioxys* (*Boreocoelioxys*) *gudhaensis* (Gupta & Sharma, 1993)

   Distribution: Sikar (Rajasthan), Gudha (Haryana)

Subgenus *Xerocoelioxys* Mitchell, 1973

4. *Coelioxys* (*Xerocoelioxys*) *Taurus* (Nurse, 1901)

   Distribution: Dantiwada, Deesa (Gujarat)

5. *Coelioxys* (*Xerocoelioxys*) *nigrodentatusm* (Gupta & Sharma, 1993)

   Distribution: Sikar, Alwar, Deeg (Rajasthan)

Subgenus *Tropicocoelioxys* Gupta, 1991

6. *Coelioxys* (*Tropicocoelioxys*) *perseus* (Nurse, 1904)

   Distribution: Kota (Rajasthan) Nurse 1904 reported from Mount Abu (Rajasthan)

7. *Coelioxys* (*Tropicocoelioxys*) *veeravaliensis* (Gupta, & Sharma, 1993)

   Distribution: Veraval (Gujarat)

8. *Coelioxys* (*Tropicocoelioxys*) *genoconcavitus* (Gupta, 1991)

   Distribution: Bangalore (Karnataka)

9. *Coelioxys* (*Tropicocoelioxys*) *tenuliniata* (Cameron, 1913)

   Distribution: Mandi, Kullu (Himachal Pradesh) Dehradun (Uttarakhand)

Subgenus *Schizocoelioxys* Mitchell, 1973

10. *Coelioxys* (*Schizocoelioxys*) *decipiens* (Spinola, 1838)

    Distribution: Pathankot (Punjab)

11. *Coelioxys* (*Schizocoelioxys*) *apicata* (Smith, 1854)

    Distribution: Deesa, Palanpur, Sikar (Rajasthan)

12. *Coelioxys* (*Schizocoelioxys*) *rajasthaniensis* (Gupta, 1992)

    Distribution: Alwar (Rajasthan)

13. *Coelioxys* (*Schizocoelioxys*) *fuscopterous* (Gupta & Sharma, 1993)

    Distribution: Narainpur (Odisha)

Subgenus *Glyptocoelioxys* Mitchell, 1973

14. *Coelioxys* (*Glyptocoelioxys*) *sulcispina* (Cameron, 1913)

    Distribution: Kangra (Himachal Pradesh)

15. *Coelioxys* (*Glyptocoelioxys*) *cuneatus* (Smith, 1875)

    Distribution: Palampur (Himachal Pradesh)

    Subgenus *Nigrocoelioxys* Gupta, 1993

16. *Coelioxys* (*Nigrocoelioxys*) *pasteeli* (Gupta, 1992)

    Distribution: Alwar, Deeg, Sikar (Rajasthan)

17. *Coelioxys* (*Nigrocoelioxys*) *ruficaudis* (Cameron, 1913)

    Distribution: Mandi, Cameron 1913 reported from Shimla

18. *Coelioxys* (*Nigrocoelioxys*) *confuses* (Smith, 1875)

    Distribution: Manikaran (Himachal Pradesh)

19. *Coelioxys* (*Nigrocoelioxys*) *latus* (Cameron, 1908)

    Distribution: Mandi, Shimla (Himachal Pradesh)

20. *Coelioxys* (*Nigrocoelioxys*) *hissarensis* (Gupta & Sharma, 1993)

    Distribution: Hissar (Haryana)

21. *Coelioxys* (*Nigrocoelioxys*) *fuscipennis* (Smith, 1854)

    Distribution: Kota (Rajasthan), Mandi, Kullu (Himachal pradesh)

22. *Coelioxys* (*Nigrocoelioxys*) *sexmaculatus* (Cameron, 1897)

    Distribution: Udaipur (Rajasthan) , Deesa (Gujarat)

23. *Coelioxys* (*Nigrocoelioxys*) *capitatus* (Smith, 1845)

    Distribution: Alwar, Deeg, Kota (Rajasthan)

    Subgenus *Coelioxys* Latreille, 1809

24. *Coelioxys* (*Coelioxys*) *farinose* (Smith, 1854)

    Distribution: Pathankot, Ludhiana, Jalandhar (Punjab)

25. *Coelioxys* (*Coelioxys*) *torrida* (Smith, 1854)

    Distribution: Kangra, Mandi (Himachal Pradesh)

26. *Coelioxys* (*Coelioxys*) *indicus* (Gupta, 1990)

    Distribution: Alwar (Himachal Pradesh), Pathankot (Punjab), Deeg, Sikar (Rajasthan)

27. *Coelioxys* (*Coelioxys*) *ducalis* (Smith, 1854)

    Distribution: Dharamshala (Himachal Pradesh)

28. *Colelioxys guptai* (Sachwarz, 1999)

    Distribution: Kullu (Himachal Pradesh), Dehradun (Uttarakhand), Jalandhar (Punjab)

Discussion

The present study reveals one new distributional record as new to Ladakh namely, *Anthidium florentinum* Fabricius, 1775 from Zanskar, Ladakh, India.

Based on the literature and collection surveys, a total of **179 species** of the family Megachilidae belonging to **23 genera** and **36 subgenera** under 2 subfamilies & 3 Tribes have been enlisted in this paper.

Based on the biogeographic distribution in India, 102 species are found in the Himalayan region. Genus *Megachilie*, *Osmia*, *Coelioxyus* & *Anthidium* shows widespread distribution both in the Himalayas and south India.

In "Jammu & Kashmir" the family Megachilidae is reported by **19 species** and in Ladakh **5 species** have been reported. This data have been compiled from the previously published literature and new survey cum collection from 2020 to 2022.

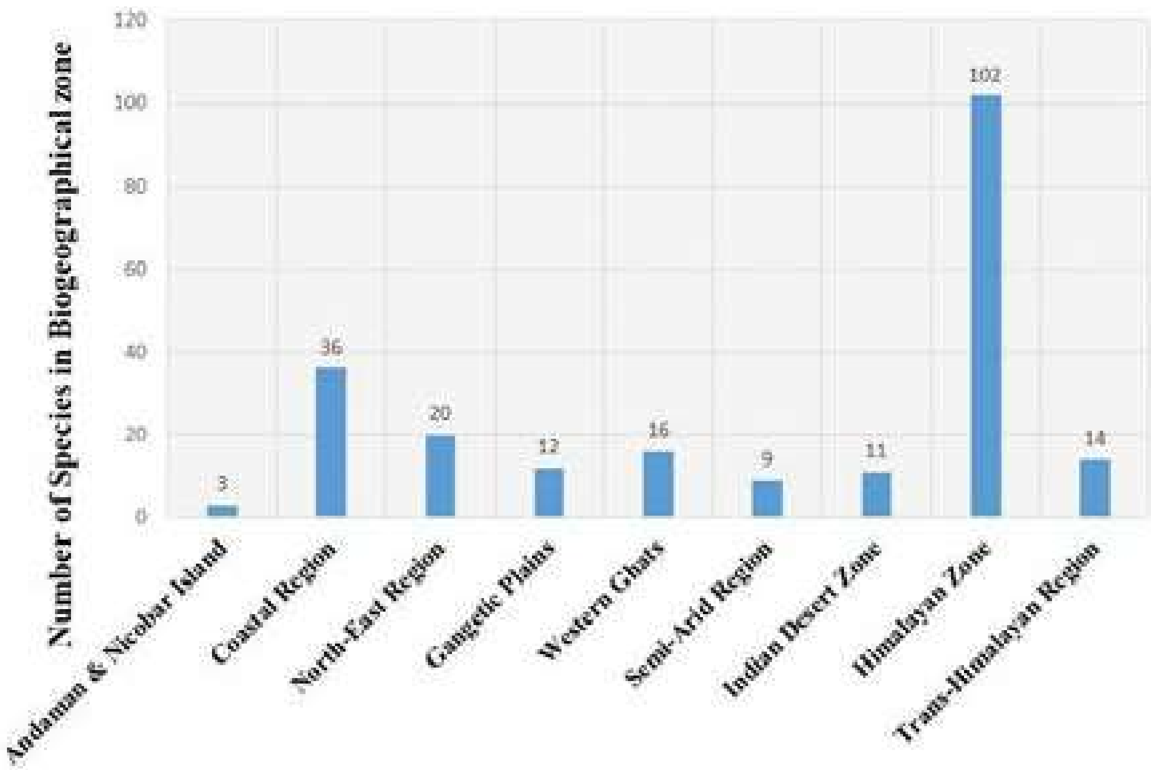

Figure 1: Biogeographical Distribution of Megachilidae Bees in India

Acknowledgements

The first author is highly thankful to Malik Masrat and Malik Amir for their help and encouragement during the survey cum collection tour in the Kashmir division. We are highly thankful to Aquib Majeed, Zahid Hussain and Tabarak Ali for their support in the laboratory work. Sajad H. Parey is thankful to different funding agencies like NMHS, Almora and SERB for providing research grants, under which lab infrastructure was built and used for the present investigation.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

First record of a whitefly, *Asialeyrodes euphoriae* Takahashi, 1942 (Hemiptera: Aleyrodidae) from India

Anil Kumar Dubey and Lakshmi Kousalya
Zoological Survey of India, M- Block, New Alipore, Kolkata, India.
email: anil.2kd@gmail.com

Abstract

Asialeyrodes euphoriae Takahashi, found infesting an unidentified shrub in the South Andaman, is the first record to the Indian fauna of whitefly. Puparia of the *A. euphoriae* are broadly oval in shape, have complete submarginal furrow, and found on the both surface of the leaves.

Keywords: Aleyrodidae, *Asialeyrodes*, new species, Nicobar Island, *tuberculata*, India

Introduction

Whiteflies are phloem sap-sucking insects belonging to the insect order Hemiptera. A few of them are pest and vectors of viruses causing diseases to plants. There are 1707 species in 197 genera known from the world and 497 species from India. Of these, the whitefly genus *Asialeyrodes* Corbett, 1935 is represented from the Oriental and Australian regions. It was first reported from the Andaman Islands through description of *Asialeyrodes nicobarica* Dubey, 2019. Recently, *Asialeyrodes euphoriae* Takahashi, 1942 is discovered on an unidentified shrub in the South Andaman, Andaman and Nicobar Islands. The species was described by Takahashi from Thailand in 1942 and unknown from elsewhere till now. After resurrection of the genus *Icfrealeyrodes* Dubey and Sundararaj, 2006 and transfer of a few *Asialeyrodes* species to *Icfrealeyrodes*, only seven species (including the *A. euphoriae*) are now known under *Asialeyrodes* from India. A brief description with diagnostics of *A. euphoriae* is given here with microscopic photographs.

Materials and Methods

A survey was conducted in the Chidiyatapu, South Andaman, Andaman and Nicobar Islands for collection of whiteflies. An unidentified plant infested with puparia of *Asialeyrodes euphoriae* Takahashi was collected A4 size paper envelops. The collection locality is marked on the map using Google Map (Fig. 1). Puparia were detached from leaves and preserved in 95% ethyl alcohol for nearly one month, and then slide mounted following method of Dubey and David (2012). Puparial morphological terminology is as in Bink-Moenen (1983), Martin (1985) and Gill (1990). Measurements were taken for 10 puparia. Auto-montage images of habitus was taken using a Leica made microscope M205 A. A compound microscope Olympus BX 43 was used for measurements and imaging from the Hemiptera Section, Zoological Survey of India, New Alipore, Kolkata. The determined slides are deposited in the National Zoological Collection, Zoological Survey of India, Kolkata.

*Author for correspondence : pkmspider@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Taxonomy

Systematic classification

Phylum: Arthropoda von Siebold, 1848

Class: Insecta Linnaeus, 1758

Order: Hemiptera Linnaeus, 1758

Suborder: Sternorrhyncha Amyot & Serville, 1843

Infraorder: Aleyrodomorpha Chou, 1963

Family: Aleyrodidae Westwood, 1840

Subfamily: Aleyrodinae Westwood, 1840

***Asialeyrodes euphoriae* Takahashi, 1942**

(Figs 2–5)

Puparium. Creamy white to brown, median area dark brown; with secretion of little wax on dorsal surface; oval (Figs 2, 3); broadest from metathorax to abdominal segment III; not constricted at thoracic tracheal pore opening areas, tracheal pores not indicated at the margin; male and female puparia differ in size; female 1967–2193 µm long, 1686–1844 µm wide; male 1444–1521 µm long, 1130–1260 µm wide; found singly on both surface of leaves, more in number on the lower surface, 1–9 puparia per leaf.

Margin: Crenulate (Fig 4), 6–7 crenulations in 0.1 mm; not invaginated at caudal and thoracic tracheal openings and not forming deep pore.

Dorsum: Tuberculate. Submargin broad, nearly equal to the half width of the dorsal disc; narrow submarginal area with irregular dorsal plates. Dorsal disc differentiated from the submargin by a prominent submarginal furrow intersecting the caudal furrow area. The median length of abdominal segment VII shorter than the segment VIII. Longitudinal and transverse moulting sutures reaching submarginal furrow. Intersegmental sutures reaching submedian area. Submedian pockets and depressions present. A longitudinal row of tubercles present on submedian area near termination of abdominal segment sutures. The distance between vasiform orifice and the caudal pore opening five times the length of the vasiform orifice. Thoracic tracheal furrows absent; caudal tracheal furrow present. Pore/porettes pairs present, two rows on submedian area and many scattered on subdorsum and submargin. Pockets discontinuous.

Vasiform orifice: Triangular (Fig. 5), posterior and lateral margins with transverse plates; female 87–97 µm long, 74-76 µm wide; male 71–80 µm long, 65-67 µm wide; operculum subcordate, covering half the length of the orifice, female 36–40 µm long, 56–57 µm wide; male 32–33 µm long, 45-46 µm wide; lingula exposed, triangular, female 17–20 µm long, male 13–14 µm long; a pair of setae placed subapically.

Venter: Thoracic and caudal tracheal folds present, filled with stipples. Paired ventral eighth abdominal setae present, 12–14 µm long, 64-78 µm apart. Antennae reaching base of mesothoracic legs in female, 411–141 µm long, reaching parallel to apex of metathoracic legs in the male. Adhesive pads and spiracles visible.

Chaetotaxy: Anterior marginal setae 22 µm long. Posterior marginal setae broken. Cephalic setae 11–14 µm long; eighth abdominal setae cephalolaterad to the vasiform orifice, 11–14 µm long; caudal setae present; the first abdominal and submarginal setae absent.

Material examined. India: Andaman and Nicobar Islands, South Andaman, Chidiyatapu, 27 puparia on 15 slides, 25-iii-2022, A. K. Dubey and L. Kousalya (Registration No. In ZSI, Kolkata 15361/H15 to 15366/H15; deposited in ZSI, Kolkata); 8 puparia on 5 slides, on an unidentified tree seedling, 7-10-2022, A. K. Dubey and L. Kousalya (deposited in ZSI, Kolkata).

Host plants: Unidentified tree seedling.

Distribution. INDIA: Thailand (Takahashi, 1942); Andaman and Nicobar Islands (new record).

Remarks: Puparia of this species doesn't fit well in the genus *Asialeyrodes* in lacking the first abdominal setae, thoracic tracheal pore openings and in the shape of vasiform orifice. Further study is required to evaluate placement of this species in *Asialeyrodes*. The male puparia are smaller than female and have longer antennae, reaching apex of metathoracic legs.

Figure 1. Map showing type locality of *A. euphoriae*

Figure 2. *A. euphoriae*, habitus on leaf.

Figure 3. *A. euphoriae*, puparium.

Figure 4. *A. euphoriae*, margin.

Figure 5. *A. euphoriae*, vasiform orifice.

Acknowledgements

We thank the Director, ZSI, Kolkata for the facilities. We are thankful to the Science and Engineering Research Board, New Delhi for financial support (SERB/CRG/2020/000318).

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

First report of *Trimorus* Förster (Hymenoptera: Scelionidae) from West Bengal, India with description of a new species

Rupam Debnath[1a], Sunita Patra[1b, 2], Abitha[1c, 2] and K. Rajmohana[1*]

[1]Zoological Survey of India, Prani Vigyan Bhawan, M-block New Alipore, Kolkata- 700053, West Bengal, India

[2]Department of Zoology, University of Calcutta, Kolkata

Abstract

Genus *Trimorus* Förster is one of the five genera recorded from India under the subfamily Teleasinae (Hymenoptera: Scelionidae). They are egg parasitoids of carabid beetles and are generally encountered in both cultivated and natural landscapes. With 317 species known globally, *Trimorus* is moderately species-rich. The genus is represented with 32 species from India to date. We came across a couple of unusually robust and large females of *Teleasinae,* during our recent surveys in West Bengal, having a striking body coloration of yellowish-orange and black. Based on some key morphological characters, the species was identified as an undescribed species of *Trimorus.* The lack of lateral mesoscutellar spines distinguished it easily from *Gryonoides* Dodd. The present work documents Genus *Trimorus* for the first time from West Bengal with description of a new species.

Keywords: *Trimorus*, Teleasinae, Scelionidae, New species, India

Introduction

The parasitoid wasps of the superfamily Platygastroidea (Hymenoptera: Insecta) are extremely diverse in distribution with about 6048 described species under 264 genera globally. This is one of the major groups of parasitic Hymenoptera (Rajmohana and Patra 2019) and is the third largest superfamily after Ichneumonoidea and Chalcidoidea (Austin *et al*., 2005). Scelionidae is one of the families of this superfamily and includes three subfamilies: Telenominae, Teleasinae and Scelioninae (Johnson 1992). Comprising 13 genera, Teleasinae has nearly 500 species worldwide (Veenakumari *et al*., 2022). In India the subfamily is represented by 44 species under 5 genera- *Dvivarnus* Rajmohana and Veenakumari, *Odontoscelio* Kieffer, *Trimorus* Förster, *Trisacantha* Ashmead and *Xenomerus* Walker (Johnson 1992; Mani 1975; Mukerjee 1981, 1993, 1994; Rajmohana 2014; Veenakumari *et al*., 2014, 2022). Among all genera of Teleasinae, *Trimorus* is species-rich genus, with 317 species (Veenakumari *et al.* 2022), globally, while only 32 species are reported from India (Mani 1975; Mukerjee 1981, 1993, 1994; Rajmohana 2014; Veenakumari *et al*., 2014, 2022).

The species of Teleasinae are egg parasitoids of Carabidae (Coleoptera: Insecta), the ground beetles (Miko *et al*., 2010). They are usually encountered in both agricultural and natural landscapes. However, because of their small size, they often go unnoticed, due to which, they remain taxonomically little known and their actual diversity can be several times the observed value (Austin *et al*., 2005). Subfamily Teleasinae was never explored in detail in India. Hence, as a part of our ongoing taxonomic studies on the family Scelionidae of West Bengal, *Trimorus abhirupus* Debnath, Rajmohana and Sunita sp. nov. is being described as new to science, and genus *Trimorus* is being documented for the first time from West Bengal.

*Author for correspondence : mohana.skumar@gmail.com, a. rupam.zoology@gmail.com; b. sunita479@gmail.com; c. abithap39@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Material and Methods

Specimens were collected using yellow pan traps set in a patch of wild grasses at Bethuadahari Wildlife Sanctuary, West Bengal (Figure 1). The collected specimens were then preserved in 100% ethanol and later card mounted. All studies were carried out under Leica M205A stereo zoom microscope, with a 1X objective. Images were taken using the integrated camera Leica DSC-500 and later processed using Leica Application Suite (LAS) software. Morphological terminology follows Masner (1976, 1980) and Mikó *et al.* (2007, 2010). For measurements of body parts of the specimens, Mikó *et al.* (2010) followed. The description of surface sculpture follows Eady (1968) and Harris (1979). The new species name has been prospectively registered with Zoobank and type materials are deposited in the National Zoological Collections (NZC) at the Zoological Survey of India (ZSI), Kolkata.

Abbreviations

A1–A12 = antennomeres 1-12 (A1 = scape, A2 = pedicel, r- radicle, cl- clava)

FCI = frontal cephalic index (ratio of HW/HH)

HH = head height

HL = head length

HW= head width

IOS = interorbital space

LCI = lateral cephalic index (ratio of HH/HL)

LOL = lateral ocellar line

ML = maximum length of mesoscutum

OD = ocellar diameter

OOL = ocular ocellar line

POL = posterior ocellar line

T1–T6 = metasomal tergites 1-6

TSL= length of transscutal line

Results

Systematic accounts

Class Insecta Linnaeus, 1758

Order Hymenoptera Linnaeus, 1758

Superfamily Platygastroidea Naumann, 1991

Family Scelionidae Haliday, 1839

Subfamily Teleasinae Ashmead, 1902

Genus ***Trimorus*** Förster, 1856

Trimorus abhirupus **Debnath, Rajmohana and Sunita sp. nov.**

(Figure 2A-I)

Zoobank ID: http://zoobank.org/26A91DD8-43F8-4D89-80D5-BEAE364D7465

Description:

Female: Body length = 2.62 mm.

Colour. Body predominantly yellowish-orange except the following: head, mesoscutellum, metascutellum, metanotal spine black; T1, T2, posterior 1/4th of medial T3, medial 3/4th of T4-T6 brownish black; mandibles yellow, tips reddish-brown. Setae white. Radicle pale yellow; A1, A5-A12 black, A2-A4 white. Wings uniformly infuscated light brown.

Head. FCI = 1.86; LCI = 1.63; HW/IOS = 1.86; head about 1.34x as wide as mesosoma (HW/TSL = 1.34). Frons clothed with regularly arranged dense pubescence, oriented laterally to both sides except transverse bare band extending medially between inner margin of eyes; lower frons punctate with setae, central keel distinct, extends up to anterior ocellus; interantennal process rounded. POL > OOL > LOL in the ratio of 16.3:9:5; OOL 2.25x of OD; hyperoccipital carina absent; eyes large, almost bare. Vertex and occiput highly coriaceous with dense setae; occipital carina present, foveolate (Figure 2G). Malar region costate and densely hairy; facial striae not exceeding the middle level of the eye; orbital carina extending to top of eye margin; gena costate with dense setae. Torular triangle short, sparsely setose, less than height of clypeus. Radicle elongate (r/A1 = 0.30); A1 elongate, longer than clava (A1/cl = 1.17); A2 length shorter than A3 and A4 length; A5 and A6 subequal in length. The proportions of length to width of A1 to A5 medially being 58:10, 12:6, 29:8, 31:9, 18:11. Clava 6.36x as long as wide with six clavomeres. Mandibles tridentate, ventral tooth > dorsal tooth > medial tooth; mandible width 1.06x of clypeus width.

Mesosoma. Mesoscutum much wider than long (TSL/ML = 1.74), rugose punctate with setae; mesoscutal suprahumeral sulcus and humeral sulcus absent; notaulus absent. Mesoscutellum about 1.69x as wide as long; rugose punctate with setae; scutoscutellar sulcus foveolate laterally, smooth medially; posterior mesoscutellar sulcus complete, foveolate. Metanotal trough foveolate; metanotal spine long, robust and stout, longitudinally striated, tip of the spine curved ventrally, 1.19x mesoscutellum length. Propleural epicoxal sulcus sulcate (Figure 2C). Pronotal suprahumeral sulcus present; epomial carina not distinct; posterior pronotal sulcus complete; netrion present, smooth. Mesopleural carina present; anterior rows of foveae of mesopleural carina present, areolate; posterior rows of foveae of mesopleural carina absent; mesepimeral sulcus complete; speculum transversely costate; femoral depression smooth in upper half, transversely costate in the lower half. Metapleural sulcus sulcate, paracoxal sulcus present. Lateral propodeal carina present, inverted Y-shaped; plica present; plical area with dense setae; posterior propodeal projection is present as a tooth, 2.67x as long as wide (Figure 2I). Legs elongate. Fore wing 3.5x as long as wide; marginal vein 5.0x as long as stigmal vein; hind wing about 4.2x as long as wide.

Metasoma. T1 pedunculate, width less than 0.5× T1+T2 length (T1W/T1+T2L = 0.41), longitudinally costate throughout. T2 longitudinally costate up to its 3/4th, setose sublaterally, posterior 1/4th smooth. T3 smooth, shiny, 1.25x as wide as long, about 1.3x as wide as mesoscutum (T3W/TSL = 1.27), laterally and sublaterally setose. T4-T6 smooth; densely setose. The proportions of width to length of T1 to T4 medially being 23:28; 45:27; 78:62; 62:9.

Male: Unknown.

Etymology: The species epithet is derived from the Sanskrit word 'abhirup' = 'beautiful' due to its strikingly beautiful appearance.

Materials Examined: Holotype : Female : **INDIA**, West Bengal, Nadia, Bethuadahari Wildlife Sanctuary (23.598614 N, 88.391431 E), Altitude 40m ASL, 08.xii.2021, coll: Rajmohana and party (Reg. no. 29773/H3). Paratype: 1 Female, last two segments of right antenna and A3-A12 of left antenna missing, with collection data same as that of the holotype (Reg. no. 29774/H3).

Diagnosis: *Trimorus abhirupus* sp. nov. is unique from all other oriental *Trimorus* species due to its its striking body coloration. In the key to species of *Trimorus* by Rajmohana (2014), *T. abhirupus* comes closest to *T. dubarensis* Mukerjee, 1981 but differs in general body colour (yellowish-orange with black head, mesoscutellum, metanotal spine and some brownish-black portions of tergites vs black), metanotal spine (long vs short), body length (2.62 mm vs 1.04 mm), pubescent eyes (almost bare vs finely and densely pubescent), T2 striation (0.75 of T2 longitudinally striated vs entirely longitudinally striated), smaller T3 (2.3x T2 length or less vs 2.7x T2 length). Though a similar kind of metanotal spine has been reported from the male species of *T. mukerjeei* Özdikmen, 2011, this new species differs from the former in the following combination of characters: in *T. longispina* general colour of the body is reddish-brown to black, notauli complete but faint; whereas in *T. abhirupus* general body colour is as aforementioned, and notauli absent. Based on body coloration, this species is similar to some members of the neotropical genus *Gryonoides* Dodd, but the lack of lateral mesoscutellar spines distinguishes it from *Gryonoides* at once.

Discussion

With the description of *Trimorus abhirupus* Debnath, Rajmohana and Sunita sp. nov. the genus *Trimorus* is reported for the first time from West Bengal. As the exploration of Indian Platygastroidea is far from complete, nothing definitive can be said about their distribution patterns. Their study was mainly been confined to South India, with most species being reported from the Western Ghats and the Deccan Plateau (Rajmohana and Patra 2019). In India, *Trimorus* has been reported from the Andamans, Odisha, Karnataka, Kerala, Maharashtra, Uttarakhand, Uttar Pradesh and Tamil Nadu. But due to a dearth of exploratory studies on this genus from the highly biodiverse regions of Eastern India, it has never been reported from West Bengal.

Under the family Scelionidae, members of Teleasinae are reported as egg parasitoids for carabid beetles and therefore play a vital role in shaping carabid populations in natural and agricultural ecosystems (Austin *et al.* 2005, Mikó *et al.* 2021). Host data are present only for three species of *Trimorus* to date (Mikó *et al.* 2021). Other than Carabidae, *T. fulvimanus* Kieffer is known to attack the eggs of *Acylophorus wagenshieberi* Kiesenwetter (Staphylinidae: Coleoptera) (Staniec 2005). Sharkey (1981) hypothesized that *T. mandibularis* (Ashmead) shares some characteristics with *Teleas* Latrelle. These characteristics include the presence of mesotibial spines and enlarged mandibles which help females to dig into the soil for laying eggs. *T. abhirupus* lacks mesotibial spines and enlarged mandibles. Mikó *et al.* (2021) also reported that most of the teleasines don't have enlarged mandibles, mesotibial spines, or rugulose sculptures on mesosoma. However, a more detailed study of their diversity and natural history is warranted to know their biology.

Figures

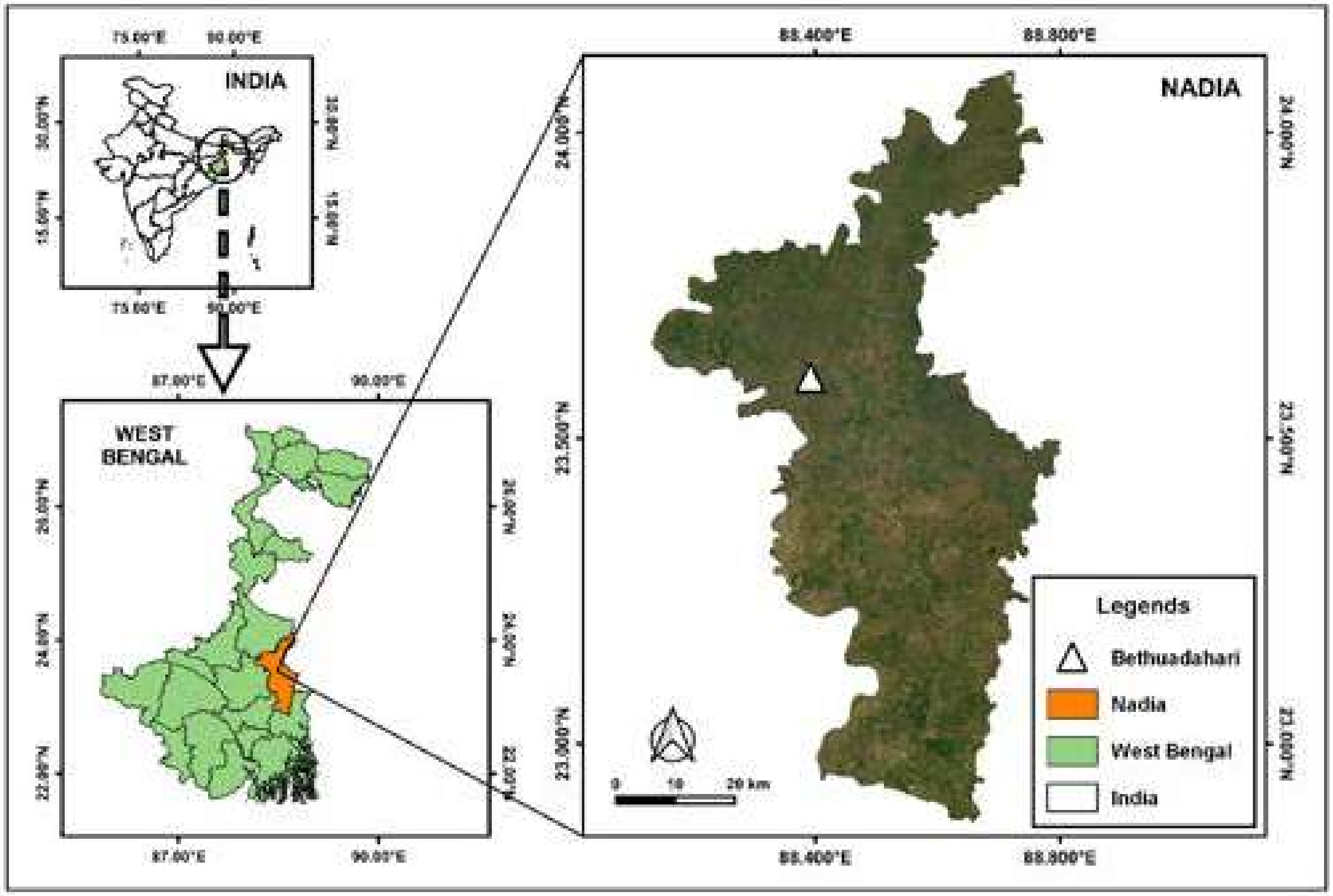

Figure 1. Collection locality map

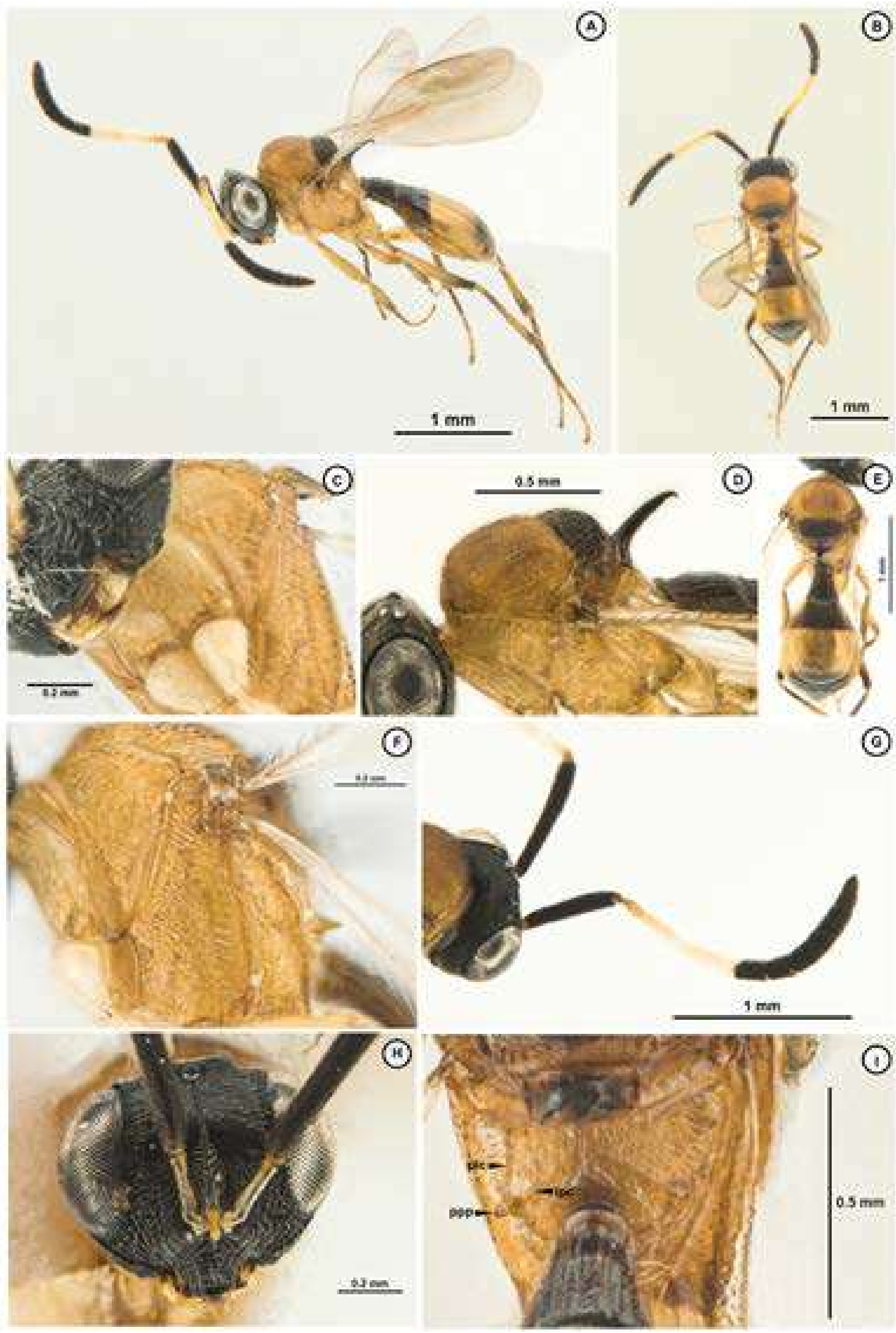

Figure 2. *Trimorus abhirupus* Debnath, Rajmohana and Sunita sp. nov. Female. A. Lateral habitus, B. Dorsal habitus, C. Fronto-lateral view, D. Dorso-lateral view of mesosoma, E. Dorsal view of mesosoma and metasoma, F. Lateral view of mesosoma, G. Antenna H. Frontal view of head, I. Propodeal area (plc- plica, lpc- lateral propodeal carina, ppp- posterior propodeal projection)

Acknowledgements

The authors are thankful to the Director, Zoological Survey of India for providing the necessary facilities to carry out this study. K. Rajmohana and Rupam Debnath are grateful to the Department of Science and Technology and Science and Engineering Research Board (DST-SERB) (Project: CRG/2021/005047) for the funding support. Sunita Patra is thankful to the Ministry of Environment, Forest and Climate Change for providing the Senior Research Fellowship. Abitha is thankful to the Council of Scientific & Industrial Research for providing the Junior Research Fellowship. Rupam Debnath, Sunita Patra and Abitha are grateful to their lab mates for their wholehearted support and encouragement.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Redescription of a labeonid fish *Garra nasuta* (McClelland, 1838) from its type locality in Meghalaya India

Ibansiewdor Marngar and Yumnam Lokeshwor*

Department of Zoology, Assam Don Bosco University, Tapesia Gardens, Kamarkuchi, Assam – 782402

Abstract

Garra nasuta (McClelland, 1838) is redescribed based on the specimens collected from two river basins in the Khasi Hills, Meghalaya. It was described as *Platycara nasuta* by McClelland in 1828 from Kasya mountains, Assam (now Khasi Hills, Meghalaya). The type specimens of *G. nasuta* do not exist, and its identity is not yet clear. The study has been based on morphological, anatomical, and osteological characteristics. A neotype has been designated to solve the taxonomic ambiguities of *Garra nasuta.* It is distinguished from other congeners in having a trilobed proboscis, a pit-like crease between nares, 33–34 lateral line scales, 9–10 pre-dorsal scales, and 16 circumpeduncular scales.

Keywords: *Platycara nasuta*, *Garra*, Khasi Hills, redescription, neotype

Introduction

The labeonine genus *Garra* Hamilton is a highly diversified bottom-dwelling rheophilic cyprinid with modified body features, viz. slender and sub-cylindrical body, a mental adhesive disc and horizontally extended paired fins. They are dispersed from Borneo and Southern China to Sub-Saharan Africa and the Southwest, Southeast and East Asia Arabian Peninsula (Zhang & Chen, 2002). There are 261 species of the genus *Garra* all around the world, 85 species from India and 61 species from eastern Himalaya, including neighbouring countries like Bhutan, Nepal, Tibet, and Myanmar (Fricke *et al.,* 2023). The development of the proboscis, the distribution pattern of the tubercles and the transverse lobe on the snout are of taxonomic significance in unique species of the genus (Nebeshwar & Vishwanath, 2013). The species of *Garra* found in southern and south-eastern Asia is divided into five groups based on snout morphology: smooth, transverse lobe, proboscis, rostral flap, and the rostral lobe (Nebeshwar & Vishwanath, 2017). The freshwater bodies of Northeastern India harboured 18 species of *Garra* with proboscis; *G. nasuta* is one of them, a unique species that inhabit only in the hill streams.

The type species of *Garra nasuta* (McClelland, 1838). described from "Kasya mountains", Assam (now Khasi Hills, Meghalaya), does not exist. Significant diagnostic information of the species is available in neither McClelland's (1838) text nor the accompanying illustration, except mentioning only the presence of a pit between the nares. Menon (1964) attempted to redescribe this stenotopic species based on the specimens from Assam, India; Sittang drainage in southern Shan State Myanmar and from parts of China and had mentioned the presence of a prominent trilobed proboscis which is not mentioned in McClelland (1838). Thus, the identity of *Garra nasuta* is not yet clear. Given this taxonomic ambiguity, *Garra nasuta* is redescribed and revalidated here with freshly collected specimens from Khasi Hills (original collection site of McClelland, 1838) and Jaintia Hills Meghalaya.

*Author for correspondence : lokeshwor.singh@dbuniversity.ac.in
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Materials and Methods

The specimens were fixed in 10% buffer formalin and then transferred to 70% ethanol. Measurements were made point to point with a dial calliper (Mitutoyo) to the nearest 0.1 mm on the left side of the specimens whenever possible. Count, measurements and terminology follow Nebeshwar & Vishwanath (2013). Head length and body part measurements are given as proportions of standard length (SL). Subunits of the head are presented as proportions of both dorsal (DHL) and lateral head length (LHL). Fin rays were counted under stereozoom microscope and were confirmed through a cleared and stained specimens following Taylor & Van Dike (1985). Numbers in parentheses following a meristic value indicates the number of species with that particular count. Vertebral count and the identification of bones were done from cleared and stained specimens following Sawada (1982). The neotype is deposited in the Zoological Survey of India, Kolkata. Other specimens were deposited in the Assam Don Bosco University Museum of Fish (ADBU-MF). Gill rakers were counted from the first left side of gill arch.

***Garra nasuta* (McClelland, 1838)**
Fig. 1 (A-D)
Platycara nasuta McClelland, 1838: 947, pl. 55, fig. 2 (type locality: Khasi Hills, Meghalaya, India).

Local name: Doh trun (in khasi dialect)

Type materials:

Neotype: Male, 115.6 mm SL; India: Meghalaya, Ri-bhoi district, Ñiangdai River near Ñiangdai village (Brahmaputra drainage system), 25°40′13"N 91°49′27"E, altitude 856 m ASL, 20.iv.2022, coll. Batngenlang Mawlong and N. Mylliem Umlong (Reg. No. ZSI FF 9809).

Material examined: Syntypes: 11 exs., 65.0–119.1 mm SL; data as for neotype (Reg. No. ADBU-FM/5088/2–12). Syntypes: 6 exs., 51.0–119.3 mm SL; India, Meghalaya, West Jaintia hills, Amtyrngui River at Amdoh (Barak-Surma-Meghna drainage system), 25°11′30.49"N 92°03′45.79"E, Altitude 216 m ALS, 6.vi.2020, coll. Mardikordor Pohchen (Reg. No. ADBU-FM/5088/13–18).

Two specimens viz. Syntype: Male, 106.7 mm SL (Reg. No. ADBU-FM/5088/5) and Syntype: Female, 91.5 mm SL (Reg. No. ADBU-FM/5088/9) were cleared and stained for osteology.

Diagnosis. *Garra nasuta* (McClelland, 1839) is distinguished from its congeners in the Brahmaputra River basin in having trilobed proboscis with anteriorly truncated margin in the median lobe and a transverse lobe, a head deeply depressed at the snout; lateral line with 33–34 pore scales, 10 predorsal scales and 16 circumpeduncular scales row; dorsal fin higher than body depth at dorsal-origin; mouth inferior, semicircular; a fainted blackish spot at the upper angle of gill opening.

Description. General body shape as in Fig. 1. Morphometric data in Table 1. Body elongated, dorsal profile rising abruptly from base of medial proboscis forming a convex internares then evenly to supraoccipital process. Dorsal profile of body gently convex to dorsal-fin origin, slightly compressed laterally, more compressed in caudal peduncle region. Ventral profile flat to pelvic-fin origin and straight till anal-fin base. Dorsal head profile rising abruptly just before anterior nostril and forming somewhat convex at internares. Head moderately large and depressed, mouth inferior, semi-circular, lower lip forms a suctorial disc on chin consist of semi-cartilaginous pad, abstemiously convex interorbital distance; height less than length; width greater than height. Snout slightly protruding with transverse lobe of 13-19 small- to large-sized uni- to tetracuspid acanthoid tubercles; 3-9 small tubercles on lateral margin of proboscis, lobe isolated posteriorly by a profound or narrow transverse groove; a pit or groove at on proboscis between nares, just anterior to anterior nostril on each side (Fig. 2 A-E). Proboscis well developed protruding forward with 3-9 uni- to tetracuspid tubercles, 7-12 uni- to tetracuspid tubercles on anteroventral margin; an unicuspid tubercles between eye and posterior nares at ventral fringe of later.

Barbels two pairs; rostral barbel anteroventrally located, shorter than eye diameter; maxillary barbel at corner of mouth, shorter than rostral barbel. Rostral cap well developed, moderately fimbriate, about one sixth of length of its distal margin on each lateral extremity smooth; papillate ventral surface moderately wide (Fig. 2 C). Anteromedian fold transverse and slightly arched, densely covered by numerous small and round papillae, arched groove between anteromedian fold and central callous pad sparingly papillated. Mental disc well developed, wider than length; central callous pad elliptical width, wider than length, extending beyond posterior margin of eye, but not reaching level of pectoral-fin origin. Anterolateral lobe well developed, slightly elliptical, densely papillated, and about one-third part covered by rostral fold. Gill opening moderate, origin posterior to eye, almost straight to superior margin of eye, and extending just below pectoral-fin origin not reaching posterior fringe of mental disc; ventral preopercle groove, more inclined, and reaching callous pad base below mental disc. Nostril closer to anterior margin of eye than to tip of snout, anterior nares parted by a large rounded membrane flap from posterior, posterior nares slightly larger than anterior.

Dorsal fin with ii (18) simple and 8½ (18) branched rays, last simple ray longer than both dorsal and lateral head length, first branched ray longest, last branched ray not extending vertical to anal-fin origin; distal margin convex; origin closer to snout tip than to caudal-fin base, inserted in anterior to vertical from pelvic-fin origin. Pectoral fin with i (18) simple and 15 (18) branched rays, reaching two third distance to pelvic-fin origin; length shorter than head length; fifth branched ray longest, not reaching pelvic-fin base; distal margin sub acuminate. Pelvic fin with i (18) simple and 8 (18) branched rays; second branched ray longest, reaching beyond midway to anal-fin origin, surpassing anus when adpressed; origin closer to anal-fin origin than to pectoral-fin origin; distal margin sub acuminate. Anal fin with ii (18) simple and 5½ (18) branched rays; first branched ray longest, reaching caudal-fin base when adpressed; distal margin slightly concave; origin closer to caudal-fin base than to pelvic-fin origin. Vent closer to anal-fin origin than to pelvic-fin origin. Caudal fin forked with 10+9 (18) principal caudal rays and 7 (18) procurrent rays in both upper and lower lobe; lower lobe longer than upper lob and caudal-fin forked.

Lateral line complete, nearly straight, with 30+3 (15), 31+3 (3) pored cycloid scales, scale size decreasing towards caudal-fin base except last 2 larger scales. Transverse scale rows above lateral line 4½ (18); between lateral line and pelvic-fin origin 3½ (18) and between lateral line and anal-fin origin 4½ (18). Predorsal scales 9 (2) & 10 (16); regularly arranged same size as verge scales. Circumpeduncular scales 16 (18). Scales from anus to anal-fin origin 3 (15) – 4 (3). Doral-fin base scales 6 (18), last scale connected to base of dorsal fin. Anal-fin base scales 5, last scale connected to base of anal fin. Chest and belly scaled and embedded in skin. One long axillary scale at pelvic-fin base, its tip reaching to posterior end of pelvic-fin base.

Osteological features. Total vertebrae 32 (2); abdominal 17 (2); caudal 15 (2); predorsal 9 (2) vertebrae; dorsal-fin insertion between 9th and 10th vertebrae; anal fin insertion between 21st and 22nd vertebrae; pelvic fin insertion vertical to 10th vertebrae. 5th ceratobranchial with 13 (2) teeth in three rows. First branchial arch with 22 (2) gill rakers viz. 18 (2) in hypobranchial and 4 (2) in epi-branchial.

Sexual dimorphism. Males with more large tubercles on transverse lobe, proboscis and anterolateral snout. Females are distinguished from males in having a longer snout (15.0–16.5% SL vs. 12.9–15.4), wider central callous pad (9.2–11.3% SL vs. 7.8–9.8), longer pre pectoral length (24.0–27.0% SL vs. 21.6–24.4), and shorter pelvic-fin length (16.0–21.9% SL vs. 21.4–25.5).

Colour. In 10% buffer formalin, the body is dark brown or grey on the head, dorsum, and flank. Mouth, chest, and abdomen yellowish. Distal margin of the anal, pelvic, and pectoral fins greyish white. Dorsal fin is greyish brown; pectoral and pelvic-fins origin yellowish and greyish cream till the edge of the rays. Caudal fin greyish hyaline with a dusky to brown streak on a distal region of each lobe and median rays. Eye pupil greyish with a black circle. A faint blackish spot immediately anterior to the upper angle of the gill opening. Tubercles on the transverse lobe and proboscis are light brown.

Distribution and habitat. *Garra nasuta* is presently found in Ñiangdai River near Ñiangdai village (Brahmaputra drainage system) Khasi Hills and Amtyrngui River at Amdoh (Barak-Surma-Meghna drainage system), West Jaintia hills, Meghalaya (Fig. 3).

Discussion

Garra nasuta is characteristic in having a snout with a trilobed proboscis protruding downward above the transverse groove and tuberculated transverse lobe, and the presence of pit between nares. It belongs to the snout with proboscis and transverse lobe species group (Nebeshwar & Vishwanath, 2017). There are 21 valid species of *Garra* having proboscis and transverse lobe in the snout. Of these 15 species occur in the Brahmaputra and the Barak-Surma-Meghna drainage systems, viz. *Garra arunachalensis* Nebeshwar & Vishwanath 2013, *G. biloboristris* Roni & Vishwanath 2017, *G. bimaculacauda* Thoni *et al.* 2016, *G. birostris* Nebeshwar & Vishwanath 2013, *G. chathensis* Ezung *et al.* 2020, *G. clavirostris* Roni *et al.* 2017, *G. gotyla* (Gray 1830), *G. jaldhakaensis* Kosygin *et al.* 2021, *G. parastenorhynchus* Thoni *et al.* 2016, *G. paratrilobata* Roni *et al.* 2019, *G. quadritirostris* Nebeshwar & Vishwanath 2013, *G. ranganenis*

Tamang *et al.* 2019, *G. subtrictorostris* Roni & Vishwanath 2018, and *G. tamangi* Gurumayum & Kosygin 2016; 5 species from the Chindwin-Irrawaddy drainage system viz. *G. chindwinensis* Premananda *et al.* 2017, *G. cornigera* Shangningam & Vishwanath 2015, *G. litanensis* Vishwanath 1993, *G. moyonkhulleni* Moyon & Arunkumar 2018, and *G. trilobata* Shangningam & Vishwanath 2015; and a single species viz. *G. koladynensis* Nebeshwar & Vishwanath 2017 from the Kaladan drainage system.

Garra nasuta is distinguished from all the congeners (having snout with proboscis and transverse lobe) viz. *G. arunachalensis, G. birostris, G. biloboristris, G. bimaculacauda, G. chathensis, G. clavirostris, G. gotyla, G. jaldhakaensis, G. ranganenis, G. tamangi, G. quadritirostris, G. paratrilobata, G. parastenorhynchus* and *G. subtrictorostris* by presence (vs. absence) of a pit between nares. It further distinguished from the *G. arunachalensis* in its number of lateral line scales (33–34 vs. 35), circumpeduncular scales (16 vs. 12), anal-fin base scales (5 vs. 3–4), simple dorsal- and anal-fin ray (ii vs. iii), number of vertebrae (32 vs. 33–34), mental-disc length (38.5–49.5% HL vs. 59.0–66.0), callous-pad length (25.1–38.5% HL vs. 14.3–16.3), callous-pad width (33.2–38.9% HL vs. 39.0–48.0), and dorsal-fin length (24.2–31.6% SL vs. 16.4–20.1); from *G. birostris* in its number of circumpeduncular scales (16 vs. 12), anal-fin base scales (5 vs. 3–4), simple dorsal-fin rays (ii vs. iii), simple anal-fin ray (ii vs. iii), and caudal peduncle length (11.4–14.0% SL vs. 14.5–17.5); from *G. biloboristris* in the absence (vs. presence) of two separate arch-shaped lobes in the proboscis, number of dorsal-fin base scales (6 vs. 7), dorsal- and anal-fin simple rays (ii vs. iii), pectoral-fin rays (i,14 vs. i,12–13), pelvic-fin rays (i,8 vs. ii,7), and number of vertebrae (32 vs. 31); from *G. bimaculacauda* in its number of circumpeduncular scales (16 vs. 12), pre dorsal length (10 vs. 8), simple anal-fin rays (ii vs. i), and caudal peduncle length (11.4–14.0% SL vs. 14.6–15.7); from *G. chathensis* in its caudal peduncle length (11.4–14.0% SL vs. 16.9–18.2), snout length (52.5–62.1% HL vs. 35.9–49.7), mental-disc width (49.7–66.9% HL vs. 44.4–50.3), number of transverse scales row (4½/3½/4½ vs. 3½/3/3½), and dorsal- and anal-fin simple rays (ii vs. iii); from *G. clavirostris* in its trilobed (vs. unilobed) proboscis, and mental-disc length (38.5–49.5% HL vs. 50.9–65.7); from *G. gotyla* in its number of lateral line scales (33–34 vs. 42), caudal-peduncle length (11.4–14.0% SL vs. 14.7–17.7), callous-pad length (25.1–38.5% HL vs. 20.0–24.0), and number of anal-fin base scales (5 vs. 3–4); from *G. jaldhakaensis* in its caudal-peduncle length (11.4–14.0% SL vs. 15.2–17.0), mental-disc length (38.5–49.5% HL vs. 34.6–37.2), callous-pad length (25.1–38.5% HL vs. 20.0–21.3), callous-pad width (33.2–38.9% HL vs. 27.1–30.4), number of transverse scales rows between lateral line and anal-fin origin (4½ vs. 3), dorsal-fin base scales (6 vs. 7), and anal-fin rays (ii,5½ vs ii,4); from *G. ranganenis* in its caudal-peduncle length (11.4–14.0% SL vs. 14.0–17.1), eye diameter (18.1–27.1% HL vs. 15.0–18.0), number of circumpeduncular scales row (16 vs. 12), predorsal scales (10 vs. 11), transverse scales above and below lateral line (4½/3½/4½ vs. 3½ /2½–3/3½), and pectoral-fin rays (i,14 vs. i,13); from *G. tamangi* in its caudal-peduncle length (11.4–14.0% SL vs. 14.7–16.5), and number of transverse scale row between lateral line and pelvic-fin origin (3½ vs. 2½); from *G. quadritirostris* in its caudal-peduncle length (11.4–14.0% SL vs. 14.2–17.7), number of lateral line scales (33–34 vs. 37), circumpeduncular scales (16 vs. 12), transverse scales above and below lateral line (4½/3½/4½ vs. 3½–4/2½/3½), and the number of anal-fin base scales (6 vs. 2–5); from *G. paratrilobata* in its number of branched pectoral-fin rays (8 vs. 9), abdominal + caudal vertebrae (17+15 vs. 21+11), and head depth at eyes (11.6–14.3% SL vs. 14.4–16.3); from *G. parastenorhynchus* in its number of lateral line scales (33–34 vs. 31–32), anal-fin rays (ii,5½ vs. i,5), length of caudal peduncle (11.4–13.9% SL vs. 14.8–16.6), snout length (52.5–62.1% HL vs. 44.6–51.2), interorbital distance (40.7–47.2% HL vs. 34.7–39.5), mental disc length (41.7–50.7% HL vs. 32.6–37.2), callous pad length (25.1–38.5% HL vs. 15.7–21.1), and callous pad width (33.2–38.9% HL vs. 24.4–27.4); and from *G. subtrictorostris* in its trilobed proboscis (vs. narrow antrorse unilobed), eye diameter (18.1–27.1% HL vs. 13–16), number of branched pectoral-fin rays (14 vs. 15), and number of transverse scale rows between dorsal-fin origin to lateral line (4½ vs. 5½).

Garra nasuta is further distinguished from all the congeners from the Chindwin-Irrawaddy drainage system, viz. *G. chindwinensis, G. cornigera, G. litanensis, G. moyonkhulleni,* and *G. trilobata,* in its number of circumpeduncular scales row (16 vs. 12 in *G. chindwinensis,* 14 in *G. cornigera, G. moyonkhulleni* and *G. trilobata*), and both dorsal-and anal-fin simple rays (ii vs. iii) except *G. moyonkhulleni*. It further distinguished from *G. chindwinensis* in its dorsal-fin length (24.2–31.6% SL vs. 20.0–22.6), eye diameter (18.1–27.1% HL vs. 14.0–15.0), and the number of transverse scales between lateral line; from *G. cornigera* in its number of transverse scales above and below lateral line (4½/3½/4½ vs. 3½ /4/3½), pectoral-fin rays (i,14 vs. i,13), vertebrae number (32 vs. 34), and anal-fin base scales (5 vs. 3–4); from *G.litanensis* in its number of lateral-line scale rows (33–34 vs. 32); from *G. moyonkhulleni* in its caudal peduncle length (11.4–14.0% SL vs. 14.4–17.7), pelvic-anal distance (24.0–29.0% SL vs. 21.9–23.5), snout length (52.5–62.1% HL vs. 44.0–49.1), and the number of predorsal scales (10 vs. 8); and from *G. trilobata* in its mental disc length (38.5–49.5% HL vs. 20.0–34.0), and the number of lateral line scales (33–34 vs. 31–32) .

Garra nasuta is further distinguished from its only congener from the Kaladan drainage system *G. koladynensis* in its number of both dorsal- and anal-fin simple rays (ii vs. iii), the presence of a black spot posterior (vs. anterior) to gill opening, and the presence (vs. absent) of the upper lip.

While redescribing *Garra nasuta*, Menon (1964) used specimens from Assam, Sittang drainage in southern Shan State, Myanmar and from parts of China (without mentioning catalogue or types) which is out of the range of Brahmaputra River basin of the type species mentioned by McClelland. It might be another species whose validity is still needed to ascertain. Thus, Menon's description of *Garra nasuta* is not worthy of validating its status. Vishwanath (2021) observed that a stenotopic *Garra* species is not supposed to be widely distributed in different drainages of the northeastern India, Myanmar, and China. The present study was conducted on fishes collected from the streams and rivers in and around Khasi Hills and Jaintia Hills of Meghalaya to validate the identity of *G. nasuta*. We have collected two populations, one at the upper reach of Umiam reservoir (Brahmaputra drainage system) and the other in Amtyrngui River, West Jaintia hills (Barak-Surma-Meghana drainage system) Meghalaya. Both populations conform to important characters given by McClelland. It is validated here as *Garra nasuta*.

Comparative materials and data

Garra arunachalensis: Holotype: 121.0 mm SL; India, Arunachal Pradesh, Lower Devang valley district, Deopani River at Roing (Brahmaputra River basin), 29°09′35"N 95°54′08"E (Reg. No. MUMF 4304),

Garra birostris: Holotype: 102.0 mm SL; India, Arunachal Pradesh, Papum Pare district, Dikrong River at Doimukh (Brahmaputra River basin), 27°08′19"N 93°44′51"E (Reg. No. MUMF 4302),

Garra biloboristris: Holotype: 92.3 mm SL; India, Assam, Chirang district, Kanamakra River (Brahmaputra River basin), 26°45′0.59"N 90°39′17.36"E, Altitude 191 m ASL (Reg. No. MUMF 22017),

Garra clavirostris: Holotype: 117.5 mm SL; India, Assam, Dima Hasao district, Dilaima River at Boro Chenam (Brahmaputra River basin), 25°18′03"N 92°52′05"E, Altitude 401 m ASL (Reg. No. MUMF 22004).

Garra cornigera: Holotype: 76.0 mm SL; India, Manipur, Ukhrul district, Sanalok River (Chindwin River basin), 24°52′N 94°39′E (Reg. No. MUMF 12061).

Garra gotyla: Neotype: 104.3 mm SL: India, Sikkim, Tista River at Rangpo (Ganga River basin), 27°10′43"N 88°32′10"E (Reg. No. MUMF 4300).

Garra koladynensis: Holotype: 130.6 mm SL; India, Mizoram, Lawntlai district, Koladyne River at Kawlchaw (Kaladan River basin), 22°23'N 92°57'E (Reg. No. MUMF 4313).

Garra litanensis: Holotype: 92.5 mm SL; India, Manipur, Ukhrul district, Litan stream at Litan (Chidwin River basin) (Reg. No. MUMF 68/1).

Garra paratrilobata: Holotype: 137.0 mm SL; India, Manipur, Noney district, Leimatak River at Awangkhul village (Barak-Surma-Meghna River basin), 24°49'07.20"N 92°57'00.60"E (Reg. No. MUMF 22050). Syntype: 86.9–100.0 mm SL; India, Meghalaya, South Garo Hills, Simsang River (Barak-Surma-Meghna River basin) (Reg. No. ADBU-MF/5088/19-20).

Garra substrictorostris: Holotype: 173.0 mm SL; India, Manipur, Churachandpur district, Leimatak River at Leimatak village (Barak-Surma-Meghna River basin), 24°34'33"N 93°40'01"E (Reg. No. MUMF 22034).

Garra quadratorostris: Holotype: 108.0 mm SL; India, Sikkim, Tista River at Rangpo (Ganga River basin), 27°10'43"N 88°32'10"E (Reg. No. MUMF 4306).

Published information used for comparison: Ezung *et al.* (2020) for *Garra chathensis*; Gurumayum & Kosygin (2016) for *G. tamangi*; Kosygin *et al.* (2021) for *G. jaldhakaensis*; Moyon & Arunkumar (2018) *G. moyonkhulleni*; Shangningam & Vishwanath (2015) for *Garra trilobata*; Premananda *et al.* (2017) for *G. chindwinensis*; Thoni *et al.* (2016) for *G. bimacuculacauda* and *G. parastenorhynchus*; ang Tamang *et al.* (2019) for *G. ranganensis*.

FIGURES

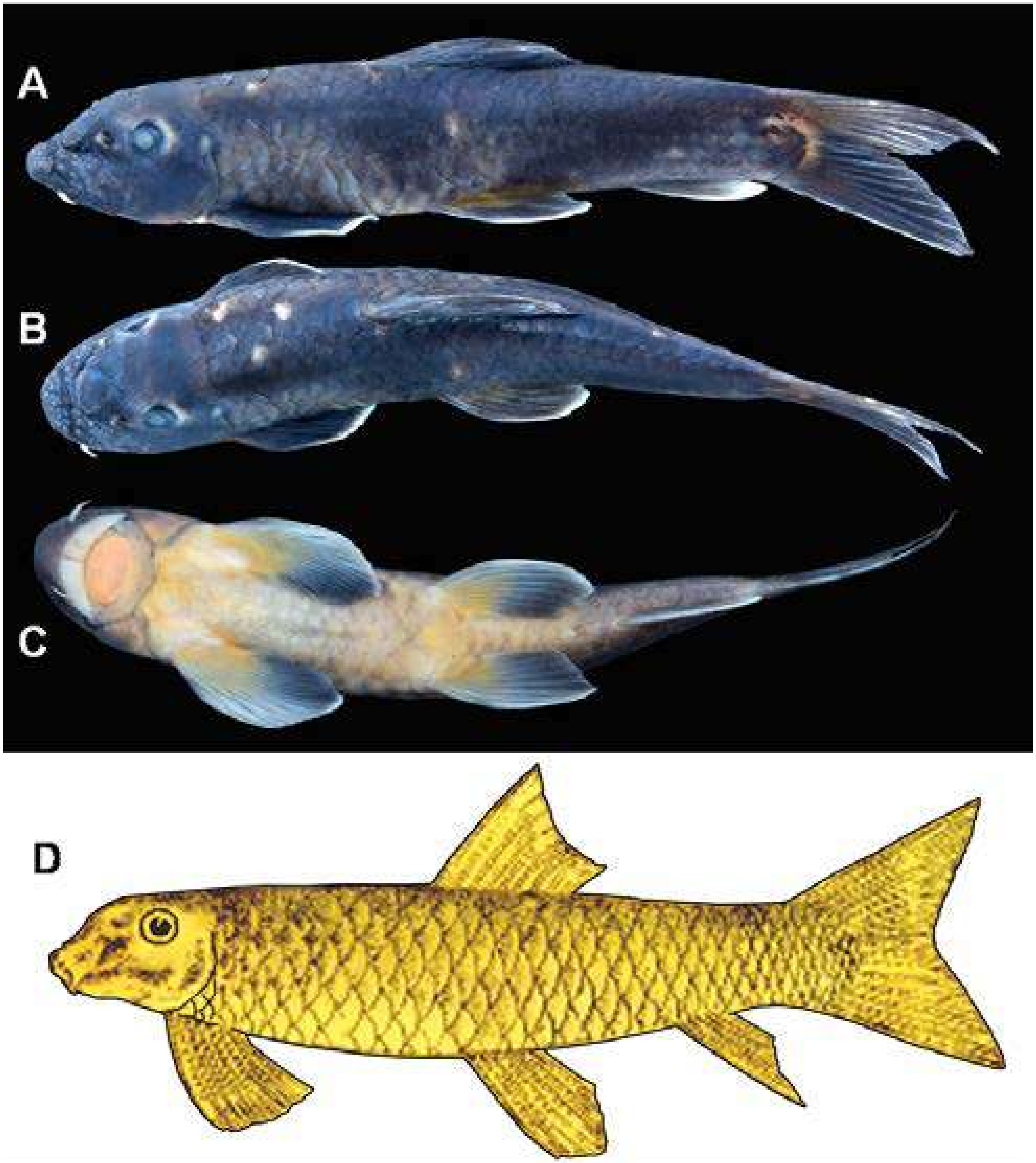

Figure 1. *Gara nasuta*, ADBU-FM/5088/1, neotype, 115.6 mm SL, male **(A)** lateral, **(B)** dorsal, **(C)** ventral, **(D)** Illustrated image (redrawn) from Plate 55 (fig. 2) of McClelland (1838).

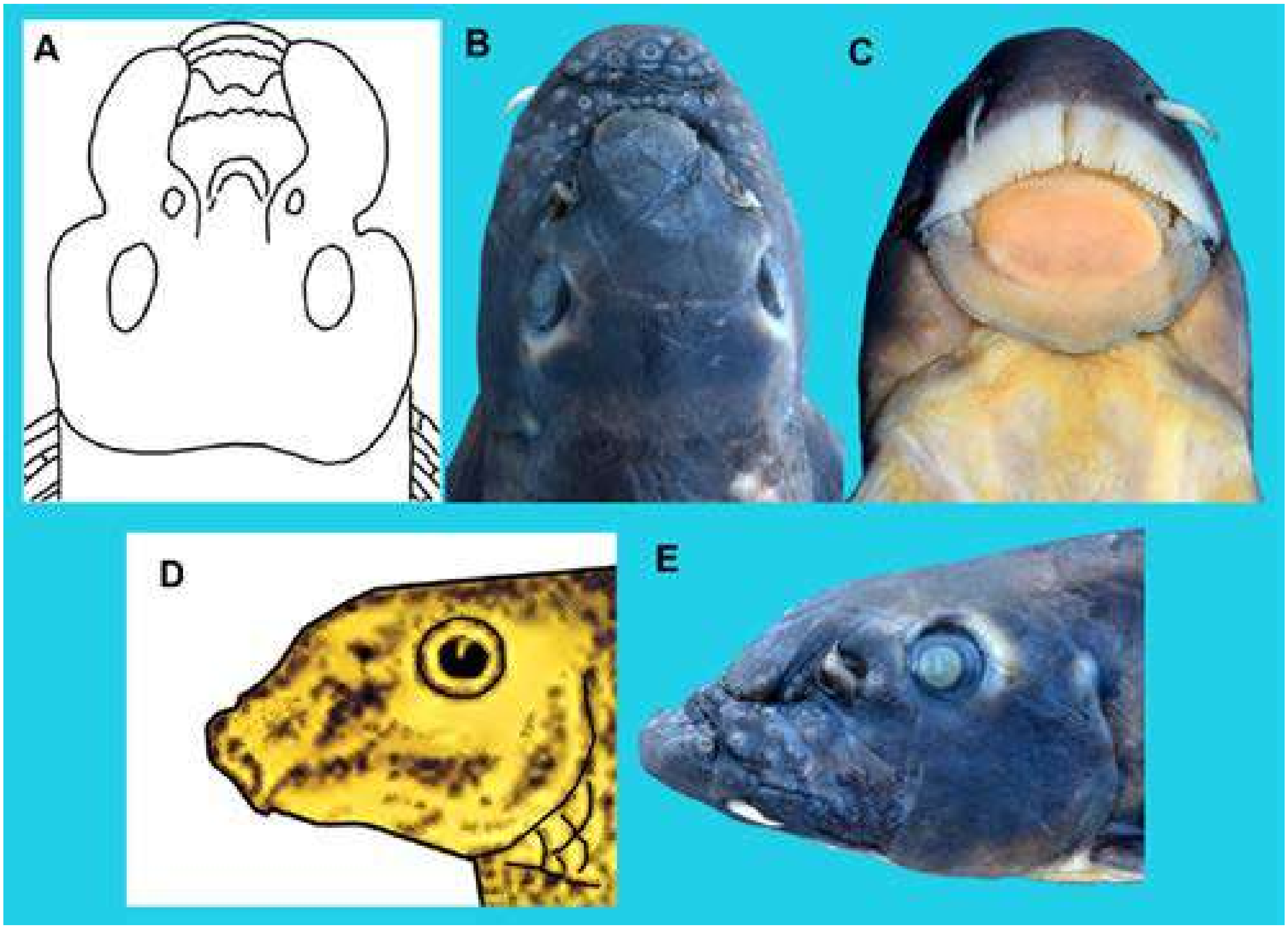

Figure 2. *Garra nasuta* **A**. Illustrated image of dorsal head (redrawn) from Plate 55 (fig. 2a) of McClelland (1838); **B.** Dorsal head of neotype (ADBU-FM/5088/1, 115.6 mm SL, male); **C.** Ventral head of neotype (ADBU-FM/5088/1, 115.6 mm SL, male) showing oromandibular structure; **D.** Illustrated image of lateral head (redrawn) from Plate 55 (fig. 2b) of McClelland (1838); E. Lateral head of neotype (ADBU-FM/5088/1, 115.6 mm SL, male) showing oromandibular structure.

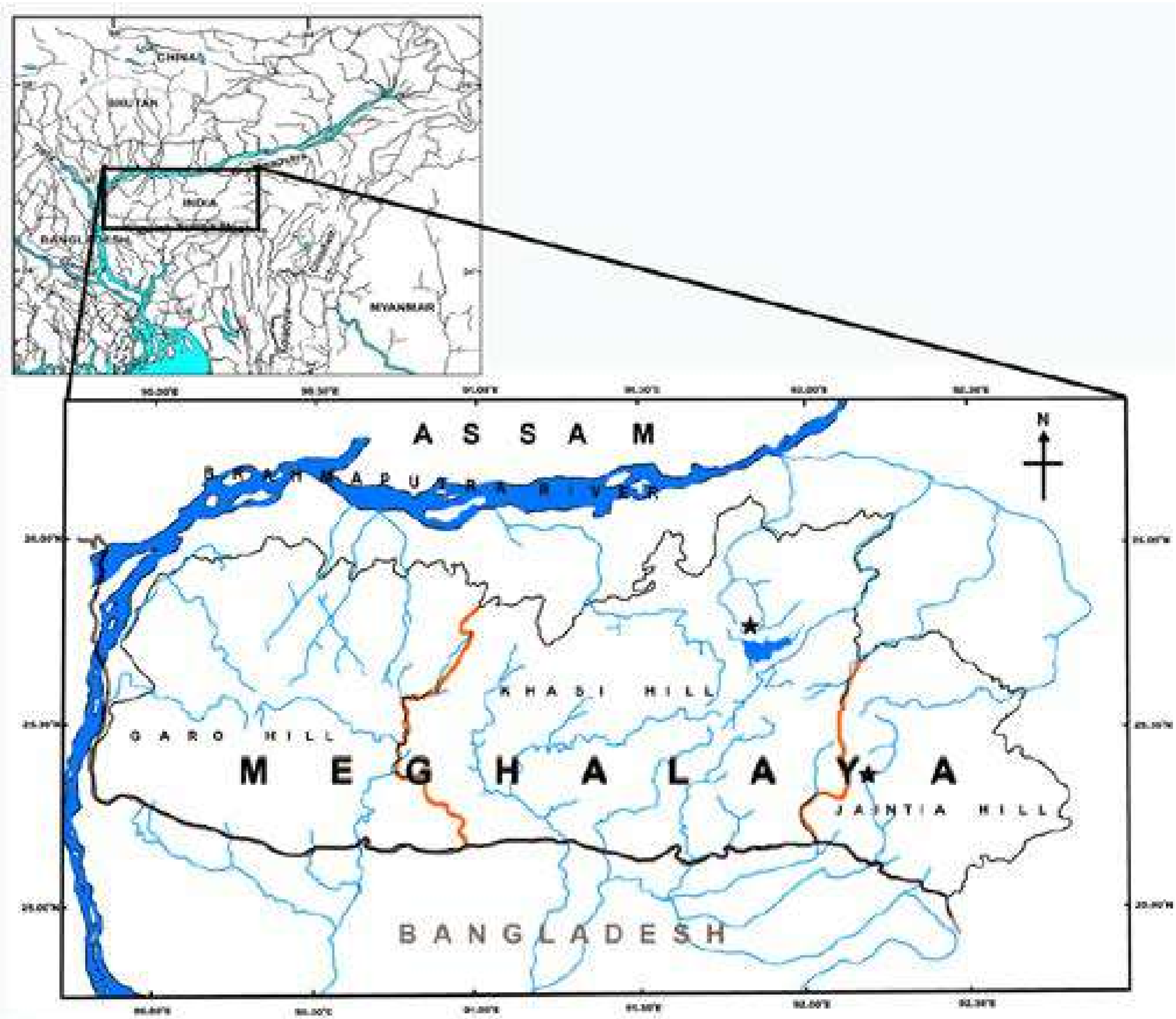

Figure 3. A map of Northeastern India and magnified drainage map of Meghalaya showing collection site of *Garra nasuta* (solid black stars) in Meghalaya.

TABLES

Table 1. Biometric data of *Garra nasuta* (McClelland, 1838*)* (n = 18); range and mean ± SD includes Neotype.

	Neotype ZSI FF 9809	Syntypes (ADBU-FM/5088/2-18)		
		Range	Mean	S.D.
Standard length (mm)	115.6	51.1–119.1		
% in Standard length				
Body depth	20.6	17.7–23.2	20.8	1.5
Head length (dorsal)	25.8	23.2–28.9	26.3	1.5
Head length (lateral)	25.6	23.7–28.2	26.6	1.5
Head depth at nape	16.9	15.2–18.9	17.4	1.1
Head depth at eye	13.5	11.6–15.2	13.5	1.1
Caudal peduncle length	12.7	11.4–14.0	12.7	0.8
Caudal peduncle depth	14.0	11.2–14.2	13.1	0.7
Predorsal length	46.7	45.3- 51.1	48.5	1.8
Prepectoral length	24.4	14.1–27.0	23.7	2.8
Prepelvic length	53.6	50.5–56.6	53.2	1.7
Preanus length	72.4	68.2–75.7	71.3	1.9
Preanal length	79.9	75.2–82.4	78.8	1.9
Dorsal-fin length	26.0	24.2–31.6	27.2	1.6
Dorsal-fin base length	18.3	14.7–19.2	17.0	1.5
Pectoral-fin length	25.0	19.2–25.9	23.9	1.7
Pelvic-fin length	21.7	19.2–25.9	23.9	1.7
Anal-fin length	20.4	18.3–21.6	20.4	1.1
Anal-fin base length	8.1	6.8–9.1	8.0	0.7
Snout length	14.9	12.9–16.9	15.3	1.2
Eyes diameter	4.8	4.5–7.5	5.6	0.8
Interorbital distance	11.0	10.1–12.7	11.6	0.7
Callous-pad width	9.8	8.5–10.5	9.5	0.8
Callous-pad length	7.6	6.2–10.5	7.8	1.2
Mental-disc width	15.1	12.5–18.2	14.5	1.3
Mental-disc length	11.4	9.8–13.8	11.6	1.0
Mouth-gap width	16.2	13.6–19.2	16.6	1.4
Body width (anal origin)	10.0	6.9–13.7	9.4	1.6
Body width (dorsal origin)	16.7	15.1–19.0	17.1	1.5
Distance from anus to anal distance	6.4	5.1–8.6	6.8	1.4

	Neotype ZSI FF 9809	Syntypes (ADBU-FM/5088/2-18)		
		Range	Mean	S.D.
Pelvic-anal distance	25.8	24.0–29.0	26.4	1.6
Max. head width at cheek	17.7	15.6–21.4	18.6	1.6
Head width (at anterior nares)	15.2	13.8–19.2	16.6	1.6
% in Head length (dorsal)				
Snout length	57.7	52.5–62.1	58.3	2.7
Eye diameter	18.5	18.1–27.1	21.7	2.6
Interorbital distance	42.6	40.7–47.2	44.1	2.1
Mental-disc length	44.3	38.5–49.5	43.5	2.6
Mental-disc width	58.7	49.7–66.9	55.1	4.2
Callous-pad length	29.5	25.1–38.5	29.7	3.5
Callous-pad width	37.9	33.2–38.9	35.8	1.8
% in Head length (lateral)				
Snout length	58.1	51.9–60.5	57.6	2.7
Eye diameter	28.2	25.5–36.2	32.5	3.0
Interorbital distance	81.4	80.0–96.2	85.9	6.0
Mental disc length	15.8	13.8–19.1	16.2	1.3
Mental disc width	74.1	60.4–87.2	70.9	6.8
Callous pad length	30.7	24.0–43.5	33.1	6.1
Callous pad width	58.6	33.2–49.2	41.5	4.2
Scales counts				
Lateral line scales	30+3=33	30+3–31+3		
Transverse scales	4½/3½/4½	4½/3½/4½		
Circumpeduncle scales row	16	16		
Predorsal scales	10	10		
Anus to anal fin scales	4	3-4		
Anal-fin base scales	5	5		
Dorsal-fin base scales	6	6		
Meristic counts				
Dorsal-fin rays	ii,8½	ii,8½		
Pectoral-fins rays	i,14	i,14		
Pelvic-fin rays	i,8	i,8		
Anal-fin rays	ii,5½	ii,5½		
Caudal-fin rays	9+8	9+8		

Acknowledgements

We are very grateful to Fr Stephen Mavely, Vice Chancellor, Assam Don Bosco University for his encouragement in conducting research and providing laboratory facility and to Dr. L. Kosygin of ZSI, Kolkata for registration of neotype. We are very thankful to Dr. Bikramjit Singha and an anonymous reviewer for their valuable comments and suggestions to improve the manuscript. We also extend our gratitude to the organizers of Animal Taxonomy Summit (ATS, 2023), Zoological Survey of India, Kolkata, for acceptance of the abstract of this research paper for oral presentation and to Batngenlang Mawlong, Mardikordor Pohchen, Junitha C Marak and Evashisha Wanniang for sharing information and specimens.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Redescription of *Carbula aliena* Distant, 1918 (Hemiptera: Heteroptera: Pentatomidae) from West Bengal, India with reference to male genitalia and a key to the Indian species

Amartya Pal[1], Swetapadma Dash[1], M. E. Hassan[2] and Devanshu Gupta[1]

[1]*Zoological Survey of India, M-Block, New Alipore, Kolkata, West Bengal, India-700053*

[2]*Zoological Survey of India, Gangetic Plain Regional Centre, Sector -8, Vijay Nagar Bahadurpur Housing Colony, Patna- 800026.*

Email: *amartyapal08@gmail.com, oasisnainital@gmail.com, ehtashamulhassan@gmail.com and devanshuguptagb4102@gmail.com*

Abstract

Carbula aliena Distant, 1918 (Hemiptera: Heteroptera: Pentatomidae) is re-described and illustrated based on the material collected from the Alipurduar district, West Bengal, India. New characters are included, along with illustrations of male morphometric measurements to facilitate easy species detection. A key to the Indian species of *Carbula* Stål, 1865 is also prepared.

Keywords: Taxonomy, Stink bugs, identification key, morphometric measurements**,** key**.**

Introduction

The genus *Carbula* Stål, 1865 (Hemiptera: Pentatomidae) is represented by 76 species from the world (Kaur, 2013) with 10 species from India. Genus *Carbula* is characterized by broadly ovate body; head rounded or somewhat truncated at apex with lobes of equal length; first segment of antennae not reaching the apex of the head and having pronotum with anterolateral margin generally obtuse, terminated by a rarely crenulated levigate margins. The genus *Carbula* could be differentiated from its allied genus *Eysarcoris* Hahn, 1834 in having scutellum apically narrowed and distinctly shorter than corium (scutellum apically broad and equal to corium in *Eysarcoris*).

Distant (1918) described the species *Carbula aliena* based on external colouration and a few morphological features, which are insufficient to identify the species correctly. This species was reported only from Karnataka: Chikkaballapura (Distant, 1918), Mysuru, Fraserpet (Chatterjee, 1934). While working on a collection of Himalayan and sub- himalayan Pentatomidae, we found one specimen of *C. aliena* from Alipurduar district, West Bengal, India. This paper aims to re-describe and illustrate this species, along with illustrations of male genital and to provide new distributional record from sub-himalayan region of West Bengal. We also prepared an identification key to the Indian species of *Carbula* Stål, 1865 from India.

Material and Methods

The material for the present study includes dry-pinned specimens housed at the Hemiptera Section of the Zoological Survey of India, Kolkata, West Bengal. Photographs were taken using Leica M205A stereomicroscope with a coupled Leica DMC 4500 camera, and processed in LAS V4.12 software to perform morphometric measurements. Photographs were edited using Adobe Photoshop CS (Version 8.0). Male genitalia were dissected following Ahmad (1986). Identities of species were confirmed through morphology of the male genitalia. Morphological terms used

*Author for correspondence : pmsuresh43@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

for male genitalia follow Salini (2019). There is no female specimen in the collection. All measurements are given in millimetres.

Results and Discussions

Taxonomy

Carbula aliena Distant, 1918 (Figs 1–8)
Carbula aliena: Distant, 1918: 133.

Type locality.INDIA: Karnataka: Chikkaballapura

***Material examined*:** 1♂, INDIA: West Bengal, Alipurduar district, South Rydak Range, 04.xi.2018, M.E. Hassan and party (Lat.: 26.572154 N, Long.: 89.768288 E).

Body: Macropterous, yellowish brown mottled with black spots, shiny, densely and coarsely punctate black.

Dorsal coloration: General colour yellowish brown mottled with black spots (Fig. 1); The marginal lines on both the lateral lobe of head are black; eyes reddish-brown; anterior lateral margins of pronotum and basal 1/3rd of hemelytra pale yellow; humeri black; first three segment of antennae pale yellow, segment IV and V yellowish brown but apical two-third portion of segment V somewhat dark brown than rest of the portion; basal part of corium reddish brown, but the apical portion darkly punctated.

Ventral Coloration: Abdomen yellowish brown with a broad central reddish brown band on 2nd and 3rd abdominal segment, rostrum yellowish brown with the apex black; legs yellowish brown with blackly punctuations; genital capsule, dark brown.

Head: Slightly wider than longer including eyes (Width : Length 1 : 0.92), mandibular plates usually reach the apex of clypeus; antennae five-segmented, segment IV longest, segment V longer than II, III, segment I smallest; rostrum long, four-segmented, reaches up to the metacoxae or slightly passing it, segment I is the longest (Fig. 4).

Thorax: Pronotum subtriangular, wider than longer, its width is about 2.5 times than its length and about 3 times wider than head, anterolateral margins smooth, humeral angles of pronotum produced laterally into comparatively blunt and short spinous projection (Fig. 3); scutellum slightly broader than longer (1.00 : 0.96) with a Y-shaped pale yellowish mark at middle portion and punctuate except each basal angle and the apex; hemelytral membrane passing tip of abdomen (Fig. 2); legs with fine hairs on tibia and tarsus and blackly punctate; prominent black spots on the base of each coxae.

Abdomen: Abdomen broader than longer (1.00: 0.73) and with a broad central reddish brown band on 2nd and 3rd abdominal segment (Fig. 2).

Male genitalia: *Pygophore*. Slightly broader than longer(1.00 : 0.82), quadrangular, dorsal rim moderately concave between caudal lobes with small, narrow median notch; ventral rim concave with broad V-notch medially (Fig. 5). *Phallus*. Phallotheca elongate, slightly narrowed proximally and sclerotized, one pair of slightly sclerotized processes of aedeagus, encircled by transparent, membranous conjunctival processes which longer than processes of aedeagus; aedeagus short, tubular and much shorter than processes of aedeagus (Fig. 6). *Paramere*. Moderately sclerotized, crown bilobed (Fig. 7, 8), Upper lobe of parameres slightly angulate apically with another apically rounded short process which is smaller than main lobe, lower lobe more or less slender, slightly curved upwards facing towards upper lobe, inner margin of lower lobe brownish; stem short.

Measurements: (in mm)

Male (n = 1). Body length 6.495 head: length 1.269, width (across eyes) 1.368, interocular width 0.673; ocular length 0.383; ocular width 0.288; antennal segments: I 0.378, II 0.606, III 0.530, IV 0.985, V 0.897; rostral segments: I 0.875, II 1.068, III 0.559, IV 0.414; pronotum length 1.711, width: 4.269; scutellum length 2.281, width (at basal angles) 2.361; Corium length 3.228, width 1.150.

Distribution: India: Karnataka (Chikkaballapura, Mysuru, Fraserpet) and West Bengal (Alipurduar) (Fig. 9).

Key to species of *Carbula* Stål, 1865 from India

1 Antero-lateral margins of pronotum smooth, luteous levigate and not crenulated 2
- Antero-lateral margins of pronotum crenulated 9

2 Humeral angles obtusely angulate .... ***socia* (Walker, 1867)**
- Humeral angles usually spinously produced 3

3 More upwardly and forwardly directed humeral angles, scutellum densely punctate .... ***aliena* Distant, 1918**
- Less upwardly and forwardly directed humeral angles, scutellum sparingly and coarsely punctate 4

4 Scutellum with a Y-shaped luteous mark at middle portion and punctuate except each basal angle and the apex .... ***scutellata* Distant, 1887**
- Scutellum uniformly brownish-ochraceous without any Y-shaped luteous mark 5

5 Central continuous spot on each of the abdominal segments; rostrum passing metacoxae reaching up to II abdominal segment but sometimes up to anterior margin of III abdominal segment, humeral angle less produced with apices broadly subacute .... ***indica* (Westwood, 1837)**
- Central spot on each of the two terminal abdominal segments; humeral angle broadly produced with apices obtuse and slightly paler and levigate 6

6 Rostrum just passing the posterior coxae .... ***crassiventris* (Dallas, 1849)**
- Rostrum reaching posterior coxae 7

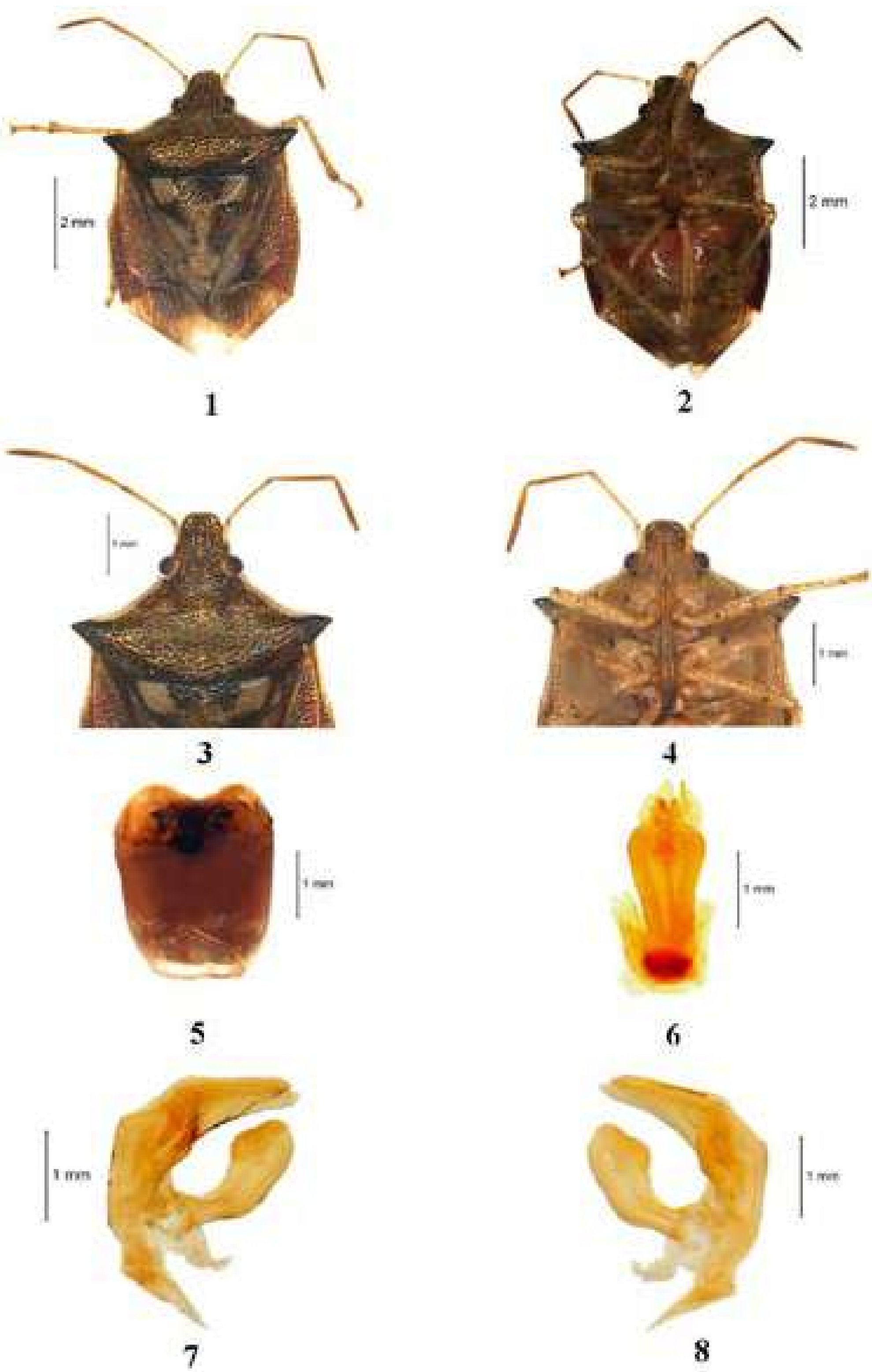
7 Pronotum with lateral angles broadly produced and obtusely prominent; scutellum without any small spot near each basal angle .... ***rugulosa* Distant, 1902**
- Pronotum with lateral angles strongly produced, black and robust; scutellum with a small spot near each basal angle. . 8

8 Antenna pale castaneous, second and third joints subequal, fourth with the apical area black, fifth black with the base ochraceous; legs testaceous .... ***aspavia* Distant, 1908**
- Antenna with the first, second, and third joints ochraceous, fourth and fifthblackwith their basesochraceous; legs finely black-spotted .... ***producta* Distant, 1901**

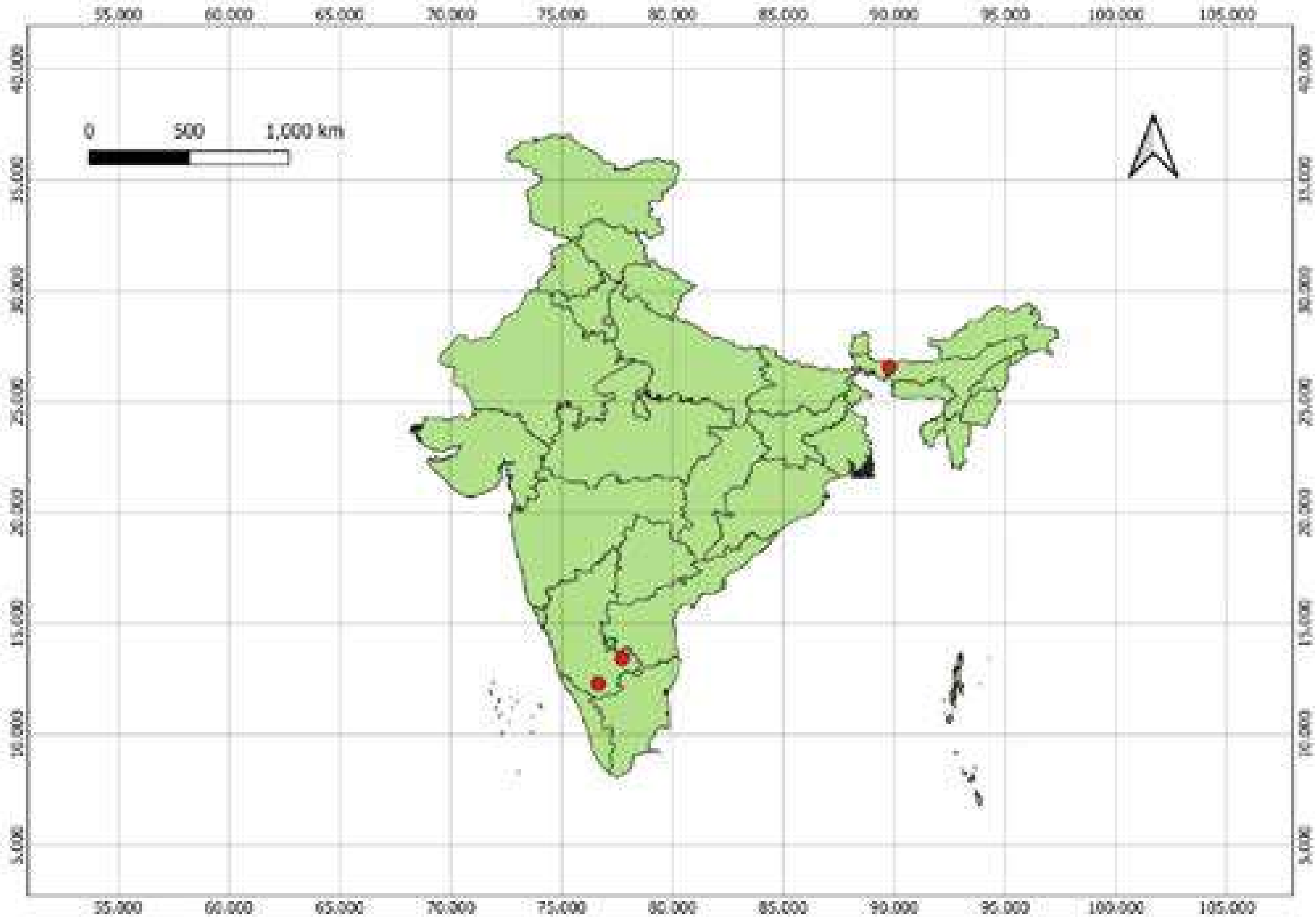
9 Humeral angles with subacute spines, very slightly directed backward ....***biguttata* (Fabricius, 1794)**
- Humeral angles rounded without any spines .... ***insocia* (Walker, 1868)**

Discussion:

Carbula aliena Distant, 1918 is much allied with *C. scutellata* Distant, 1887 during re-examination of the respective specimens we found some minute morphological differences between these two species. Re-examination revealed that humeral angle of pronotum shorter and more forwardly directed in *C. aliena*; in comparison with *C. scutellata* the scutellum of *C. aliena* is more densely and darkly punctuated; *C. aliena* is smaller than *C. scutellata* in body size. Along with these morphological differences we need the proper description of male genitalia of *C. aliena* to distinguish this species from allied ones. Thus we need to re-describe *C. aliena* to solve the above mentioned taxonomic puzzles.



Figures 1–8. Carbula aliena Distant, 1918. 1. Habitus (dorsal view), 2. Habitus (ventral view), 3. Head and Pronotum, 4. Ventral (Thorax), 5. Pygophore (dorsal), 6, Phallus, 7 -8. Paramere,



Figures 9. Distribution Map of *Carbula aliena* Distant, 1918

Acknowledgements

The authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India for encouragements and laboratory facilities. We are greatly thankful to Dr. C. Raghunathan, Divisional-in-charge, Entomology Division, Zoological Survey of India for his valuable suggestions and support. Authors are also thankful to all the officers and staffs of Hemiptera section for their helpful co-operation.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

First record of *Acrida acuminata* Stål, 1873 (Orthoptera: Acrididae: Acridinae) from India with description of its female genitalia

Hirdesh Kumar[1], Mohd. Kamil Usmani[2] & D. Suresh Chand[3]

[1,3]Zoological Survey of India, Prani Vigyan Bhawan, Block M, New Alipore, Kolkata, West Bengal 700053, India
[2]Department of Zoology, Aligarh Muslim University, Aligarh, Uttar Pradesh, India
Email: entomologist1985@gmail.com[1]; usmanikamil94@gmail.com[2]; dschand_manish@rediffmail.com[3]

Abstract

The genus *Acrida* includes 41 species worldwide of which 7 species are reported from India. The female specimen of *Acrida acuminata* Stål, 1873 was collected from Himachal Pradesh, which is recorded for the first time from India. An opportunity is taken to redescribe and illustrate the female including its genitalia.

Keywords: grasshoppers, short-horned, slant-faced, Western Himalaya

Introduction

The genus *Acrida* Linnaeus, 1758 belongs to the family Acrididae and includes 41 species worldwide (Cigliano *et al.*, 2023). Gupta & Chandra (2019) catalogued 7 species of *Acrida* from different biogeographic regions of India. Based on male and female specimens, *Acrida acuminata* was described by Stål (1873) from South Africa. Although Bolivar (1893) synonymised it as *Tryxalis* (*Tryxalis*) *acuminata,* Kirby (1902) validated it again. Sjostedt (1931) described a new species, *Acrida acuminata* variety *histrionica* from Africa. In 1953, Dirsh & Uvarov synonymised it as *Acrida acuminata*. In his revision of the genus *Acrida*, Dirsh (1954) redescribed *Acrida acuminata*. Steinmann (1963) also included *Acrida acuminata* in key to species but till now its female genitalia is not studied. Therefore opportunity is taken to redescribe and illustrate the female including its genitalia.

Materials and methods

The specimen used in the present study was collected from Himachal Pradesh, India, part of the Western Himalayan Biogeographic zone, during a survey conducted in connection with a major research project entitled "Studies on biosystematics and biodiversity of Acridoidea (Orthoptera) in northern states of India" in 2010. For the study of morphology and genitalia, the collected specimen was processed following the method of Kumar *et al.* (2018). Identification of species was done with the help of key and diagnosis provided by Dirsh (1954) and Steinmann (1963). Photographs of specimens were taken with Nikon digital camera (D-7000) and other figures were taken with a digital camera attached to a Leica stereo-zoom microscope (Leica M205A). The specimen was deposited in the National Zoological Collection of the Zoological Survey of India, Kolkata, India (NZSI).

*Author for correspondence :
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Results

Family Acrididae Macleay, 1821

Subfamily Acridinae Macleay, 1821

Tribe Acridini Macleay, 1821

Genus *Acrida* Linnaeus, 1758

***Acrida acuminata* Stål, 1873**

(Figs 1–2)

Acrida acuminata Stål, 1873: 97 (Syntype – Male and female; Southern Africa; deposited in NHRS Stockholm); Kirby, 1902: 95; Dirsh & Uvarov, 1953: 231; Dirsh, 1954: 126; Johnston, 1956: 654; Steinmann, 1963: 403; Dirsh, 1965: 401; Johnston, 1968: 286; Picker *et al.* 2005: 96.

Material examined. India, Himachal Pradesh, Solan, 03.XI.2010, 1♀, on grasses, Coll. H. Kumar.

Redescription

Female (Fig. 1A). Antennae (Fig. 1H) 18 segmented, shorter than head and pronotum together; head (Fig. 1B) strongly elongated, from above and in profile moderately widened, as long as or slightly shorter than pronotum; frons (Fig. 1F) oblique, in profile weakly incurved. Fastigium of vertex (Fig. 1B) long, lateral sides parallel, longer than wide, apex rounded; shorter than eye length in top view. Width of vertex between the anterior margins of eyes more than 5.9 times wider than the frontal ridge between the antennal sockets. Eyes elongated oval, maximum diameter of an eye more than 2.0 times longer than the vertex between the anterior margins of eyes. Frontal ridge (Fig. 1D) very narrow and deeply sulcated with high lateral carina reaching up to the clypeus. Lateral carinae of pronotum (Fig. 1C) almost straight, parallel, transverse sulcus beyond the middle of pronotal disc, posterior margin of pronotum acute angular and pointed, sides incurved; lower ventral margin of pronotum straight (Fig. 1G). Mesosternal lobes (Fig. 1E) rounded interspace longer than wide; metasternal pits separated. Elytra strongly surpassing the apex of hind knee, strongly narrow, apex pointed. Wing shorter than elytra, very narrow. Lateral lobe of hind knee (Fig. 1J) short and acute, upper lobe broader than lower one; upper internal lobe longer (Fig. 1I) than the external; median projection weak. Hind tibiae shorter than the hind femur with 28 spines on both outer and inner margins, inner spur on inner side of hind tibia (Fig. 1K) two times longer than external one. Arolium (Fig. 1L) medium.

Genitalia. Supra-anal plate (Figs. 1M, 2A) broadly angular, much wider than long with obtusely rounded apex; cercus conical, shorter than supra-anal plate, one and a half times as long as wide, with obtuse apex. Subgenital plate (Figs. 1N, 2B) long, posterior margin trilobate median lobe slightly longer lateral lobes, posterior margin setose; egg-guide broad and short, apex rounded. Spermatheca (Fig. 2C) with apical diverticulum long and cylindrical, preapical diverticulum slightly longer than apical diverticulum, sac-like with a protuberance in basal third. Ovipositor (Figs. 1O, 2D), dorsal valve broader, much shorter than lateral apodeme, more than two times longer than wide, apical tip blunt; ventral valve broad, apical tip curved and obtuse; mesial valve dilated apically with obtuse apex.

Male. Not collected.

Measurements (in mm). Length of body: 63.5; length of head: 11.4; length of pronotum: 11.7; length of antennae: 22.13; length of tegmina: 59.9; length of hind femur: 40.7; length of hind tibia: 37.2.

Distribution. India: Himachal Pradesh. *Elsewhere*: Africa.

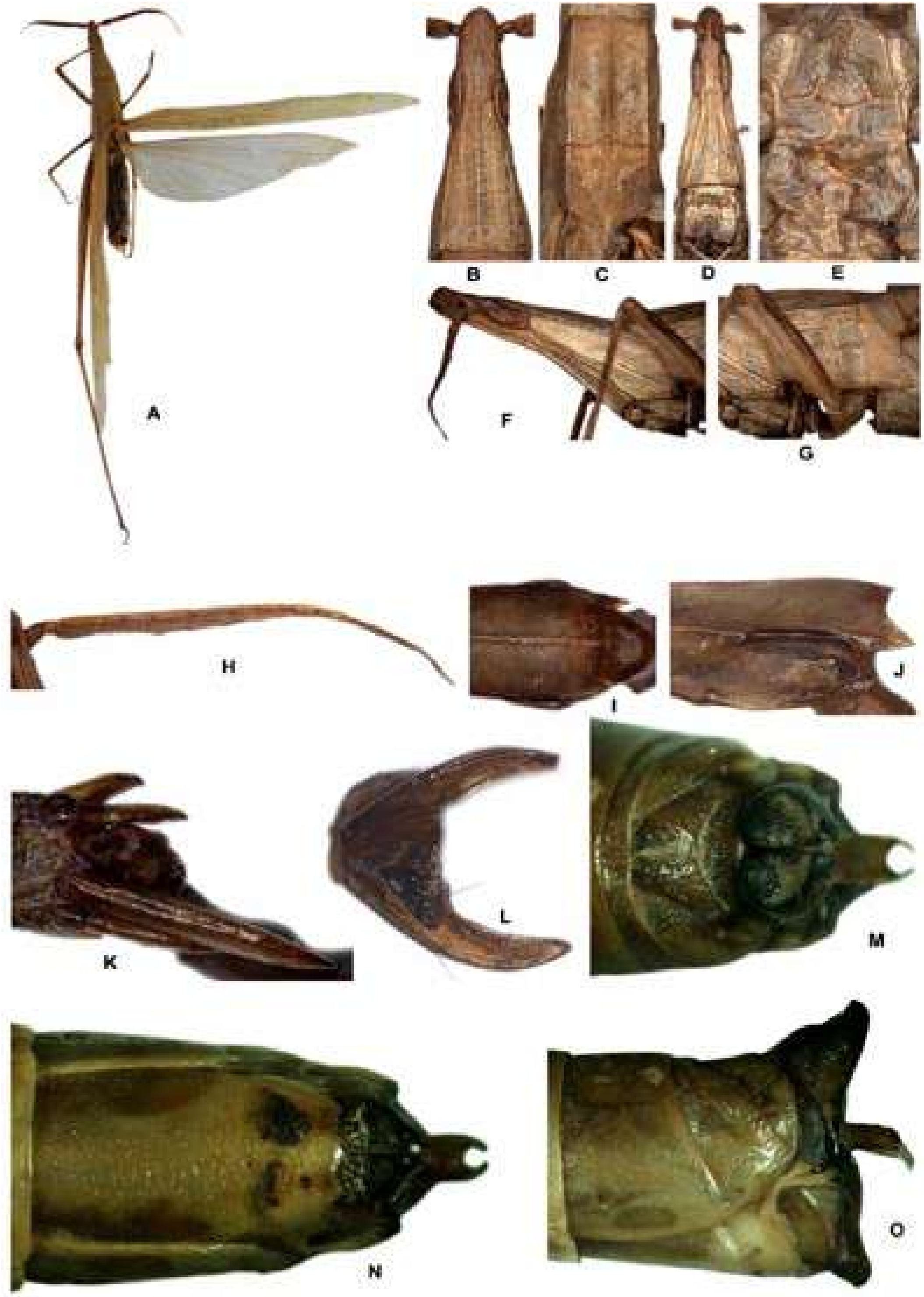

Figure 1. *Acrida acuminata* Stål, 1873. Female. A. Dorsal view, B. Dorsal view of head, C. Dorsal view of pronotum, D. Frontal ridge, E. Ventral view of sternum, F. Lateral view of head, G. Lateral view of pronotum, H. Antenna, I. Dorsal view of hind knee lobe, J. Lateral view of hind knee lobe, K. Dorsal view of apex of hind tibia, L. Dorsal view of hind arolium, M. Dorsal view of abdominal apex, N. Ventral view of abdominal apex, O. Lateral view of abdominal apex.

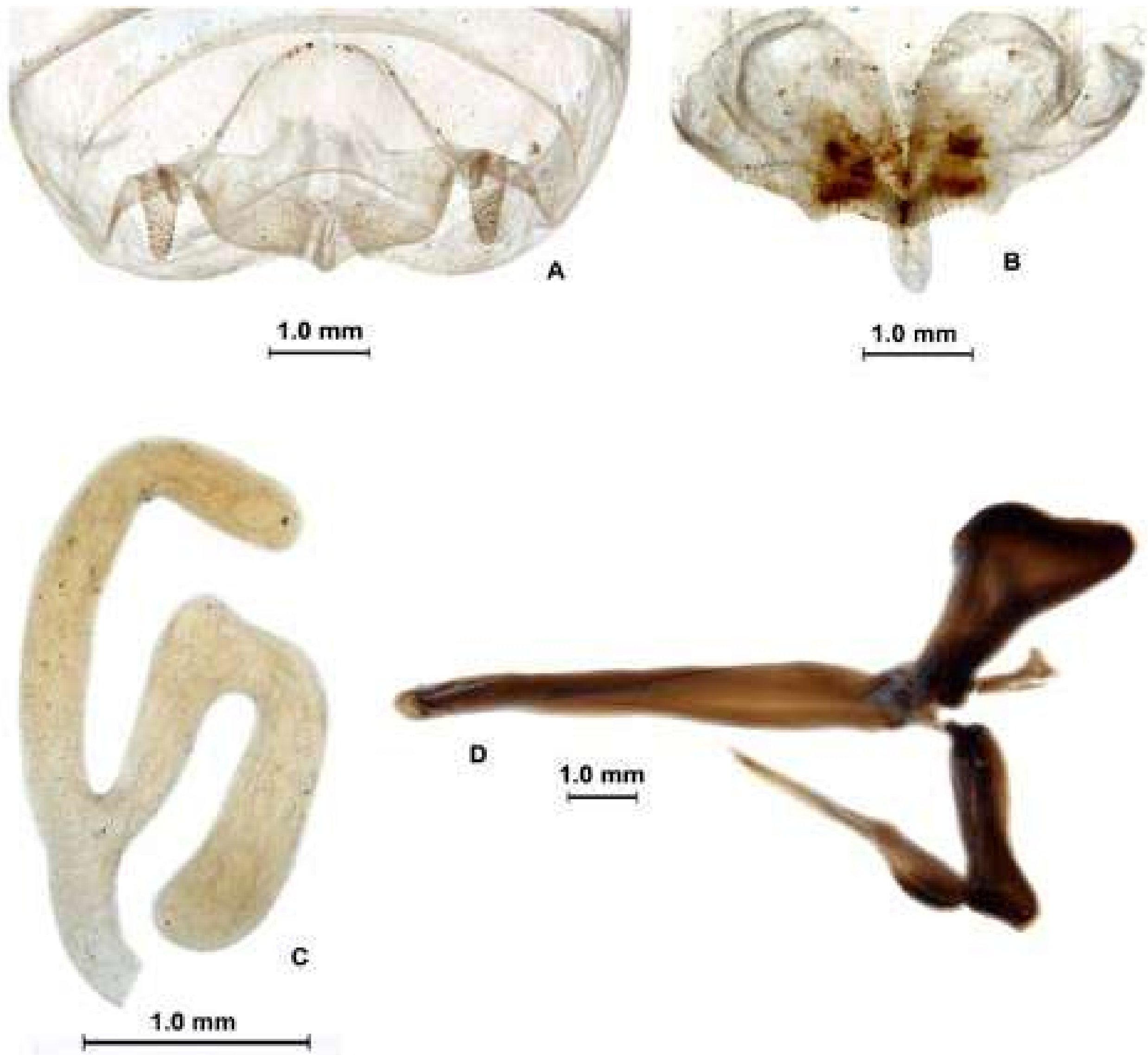

Figure 2. *Acrida acuminata* Stål, 1873. Female. A. Supra-anal plate, B. Subgenital plate, C. Spermatheca, D. Ovipositor.

Acknowledgements

The authors are highly thankful to the Director, Zoological Survey of India, Kolkata for providing the necessary facilities and encouragement. We wish to extend our gratitude to the Department of Science and Technology, New Delhi for providing financial assistance during the tenure of a major research project (Ref. No. SR/SO/AS 32/2008) being carried out on biosystematics and biodiversity of Acridoidea (Orthoptera) in North India"

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

First record of *Tabanus dorsiger* Wiedemann, 1821 (Insecta: Diptera: Tabanidae) from Andaman and Nicobar Islands, India

Koustav Mukherjee*, Atanu Naskar and Dhriti Banerjee**

Diptera Section, Zoological Survey of India
M-Block, New Alipore, Kolkata-700053
koustav.mukherjee107@gmail.com

Abstract

The fly *Tabanus dorsig*er Wiedemann, 1821 belongs to the family Tabanidae, under the infraorder Tabanomorpha and order Diptera, and act as a mechanical vector of various diseases (Maity *et al.*, 2019). While sucking blood from hosts, they transfer numerous pathogens causing vesicular stomatitis, bovine leukosis, anaemia, swine fever, and various species of trypanosomes (Foil, 1989; Krinsky, 1976). "Surra disease" or trypanosomiasis, caused by *Trypanosoma evansi* (Steel) is one of the most important diseases affecting the health and survival of a number of domestic and wild animals worldwide (Veer *et al.*, 2002). The disease has been categorized under list B diseases by the Office International des Epizooties (OIE, 2014). *Tabanus dorsiger* has been suspected as a vector of Surra disease from the Indian states of Punjab, Haryana, Rajasthan, and Himachal Pradesh. Maity *et al.*, 2019 recorded this species from Assam, Bihar, Maharashtra, Odisha, and West Bengal. However, the studies are relatively restricted, and comprehensive surveys and collections are required to determine the presence and abundance of the species in other states. As per best of our knowledge, this species has not been recorded from the Island ecosystem of the Andaman & Nicobars. During a survey in 2022 by the Diptera section in the Andaman and Nicobar Islands, 7 male and 16 female specimens of this species were documented and collected. The first report of this species from this island ecosystem is alarming for the livestock. A detailed study is essential to know the distribution pattern and seasonal abundance of *Tabanus dorsiger* which has been first time recorded from the Andaman and Nicobar Islands, India.

Keywords: Horse fly, Surra disease, Livestock, Island Ecosystem, Taxonomic study

Introduction

Tabanid flies are vectors of over 35 pathogenic agents that affect cattle, horses, and wild animals, like *Trypanosoma evansi*, which causes Surra disease or Trypanosomiasis (Desquesnes *et al.* 2013), equine infectious anaemia virus, *Anaplasma marginale*, and *T. vivax*, as well as the agents of cutaneous anthrax, tularaemia, bovine viral leucosis (Lehane 2005). In India, several illnesses are occasionally transferred to humans (Mackerras *et al.* 2008; Baldacchino *et al.* 2014). The most essential feature responsible for their role as excellent mechanical vectors of diseases is interrupted feeding, which occurs when a tabanid gets dislodged from a host and persistently seeks the closest suitable host to continue feeding (Mackerras *et al.* 2008). The protozoan parasite *Trypanosoma evansi* is mechanically transferred between wild and domestic animals by tabanids, resulting in severe death and losses in animals in endemic regions. At the same time, because they have piercing and sucking mouthparts and are persistent feeders, they may cause discomfort, loss in milk production and bodyweight in ungulates, resulting in economic loss in the dairy business (Perich *et al.* 1986; Veer 2004). Surra was first reported in camels in the Indian state of Rajasthan by Basu et al (1954). One of the significant causes of the deaths of 11 white tigers in Orissa's Nandankanan Zoo is an outbreak of Surra disease, which is mostly transmitted by tabanids and muscid flies (Veer *et al.* 2002). Around 4406 species of Tabanidae under

**Author for correspondence : atanu.diptera@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

137 genera are found worldwide (Pape and Thompson 2014), out of which 254 species in 14 genera in 3 subfamilies are so far known from India (Veer 2004).

The Andaman-Nicobar group of islands is considered to be a remarkable storehouse of biodiversity. It should come as no surprise that the Islands exhibit biodiversity of amazing range within a small geographic area given that it is located between two major biodiversity hotspots, the Indo-Burma region, and the Sundaland region, displaying faunal traits of both with high endemism. Furthermore, there has been an increase in human population and settlement in the islands, with a 10.17% increase trend according to Aadhar UIDAI, 2018, along with an increase in livestock population, modernization of animal husbandry practices, and a significant annual influx of tourists. This puts the island ecosystem at risk of various disease outbreaks, particularly arthropod-borne diseases due to its tropical location. Furthermore, because of the islands' geographical isolation, it is more difficult for mainland diseases to penetrate the islands; nonetheless, once infected, islanders are far more likely to have significantly more severe symptoms for a given disease than mainlanders. As per Mitra et al 2010, 11 species of Tabanidae have been recorded from the islands. The present paper deals with the first report of *Tabanus dorsiger* from the Andaman & Nicobar Islands taking the species count to 12, which is significant as *Trypanosoma* has now one more potential vector for its transmission in the Islands.

Materials and Methods

During a survey of Diptera fauna in the Andaman Islands (Fig 1) organised by the Diptera Section of Zoological Survey of India from 7th September to 26th September 2022 , 7 male and 16 female specimens of *Tabanus dorsiger* were collected. The collection was performed by sweep netting and preserved in 70% alcohol. The collected insects were transported to the laboratory, sorted, and pinned. Identification of adults was done with keys of Thomas (2011) and Stone (1975) and descriptions by Ricardo (1911) and Stone (1975), keeping in mind the nomenclatural changes in the Systema Dipterorum (2013) and Catalogue of Life (2014). Classification scheme of Burger and Thompson (1981) was followed with morphology and terminology adapted from McAlpine *et al.*, (1989). All the specimens were deposited with the designated repository of National Zoological Collection, Diptera Section, Zoological Survey of India, Kolkata. The photographs were taken in Leica Stereo zoom Microscope M205A.

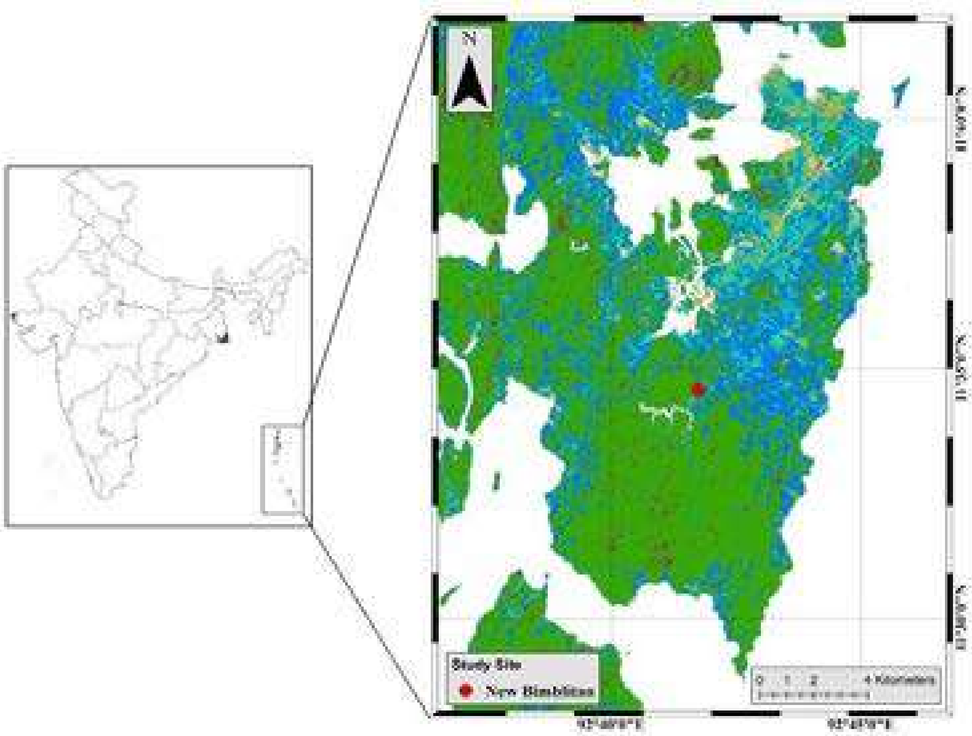

Fig 1: Map of the collection site

Results

Order Diptera Linnaeus, 1758

Suborder Brachycera Zetterstedt, 1842

Family Tabanidae Latreille, 1802

Genus ***Tabanus*** Linnaeus, 1758

Tabanus dorsiger Wiedemann (1821)

Tabanus ochrophilus Lutz, 1914

Tabanus secundus Walker, 1848

Tabanus triceps Thunberg, 1827

1821.*Tabanus dorsiger* Wiedemann, Diptera Exotica, Kiliae, pp. 43-50, 101.

Type locality: Brazil.

Materials examined: 7♂ 16♀: 11°34′17.184″ N, 92°41′42.504″ E: India, Andaman & Nicobar Islands, South Andaman, New Bimblitan, 78 m, 9.ix.2022, Coll. K.Mukherjee [NZSI].

Diagnosis (Fig 2; Fig 3)***:*** Adult fly is usually larger (14-16 mm in length) than the other two trivittate flies, *Tabanus striatus* and *Tabanus tenens*. Fore head slightly divergent above, frontal callus narrowly separated from eye margins and median callus spindle-shaped and narrowly joined to dorsal extension of frontal callus. Abdomen trivittate, mid dorsal stripe complete and broad on tergum II, sub lateral pale stripes noticeably step-like; venter uniform with grey tomentum and light pilose. Fore femur and fore tibia are uniformly orange to brown in colour but are darkened apically. Thoracic stripes are distinct. The male has a yellow tinted costal cell on the wing.

Distribution: India (West Bengal: East Midnapore, Hooghly; S 24 Paraganas; Orissa)

Elsewhere: Mexico to Argentina, Trinidad

Remarks: This species was previously known to us as *Tabanus triceps* Thunberg, 1827, later the species was synonymised as *Tabanus dorsiger* Wiedemann, 1821 due to basically same character of callus in fore head and abdominal pattern with step like sub lateral stripes in both species. This species is recorded for the first time from Andaman & Nicobar Islands.

Fig 2: Dorsal view of habitus of *Tabanus dorsiger* Wiedemann, 1821

Discussion

This report adds *Tabanus dorsiger* Wiedemann, 1821 to the list of 11 existing species from the Andaman & Nicobar Islands namely, *Chrysops fasciatus* Wiedemann, 1821; *Tabanus (Tabanus) andamanicus* (Bigot,1892); *Tabanus andamanensis* Kapoor, Grewal & Sharma, 1991; *Tabanus brunnipennis* Ricardo,1911; *Tabanus diversifrons* Ricardo,1911; *Tabanus immanis* Wiedemann,1828; *Tabanus indianus* Ricardo, 1911; *Tabanus leucohirtus* Ricardo,1909 ; *Tabanus nicobarensis* Schiner,1868*; Tabanus siamensis* Ricardo, 1911

; *Tabanus (Tabanus) striatus* Fabricus, 1787, taking the tabanid species count in the Islands to 12. Since this was a chance encounter with the species with all 23 specimens collected from a single sampling site, a directed approach to know its distribution pattern, seasonal preference & host preference must be conducted in future to access its potential risk to the people and livestock inhabiting the Islands.

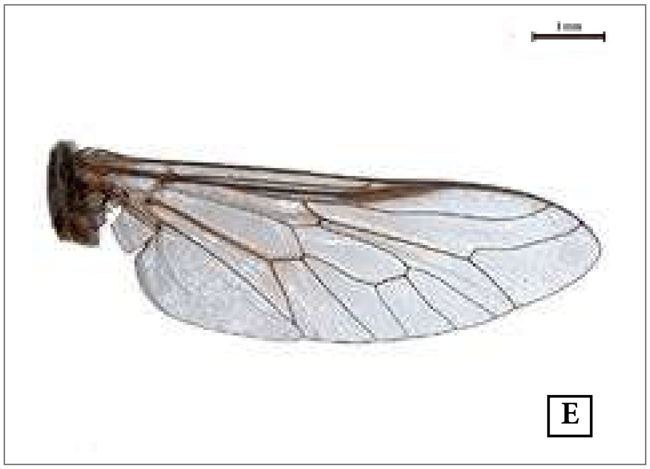

Fig 3: **A**. Lateral view of head with antennae and mouth parts **B**. Dorsal view of head with antennae **C**. Enlarged lateral view of antennae **D**. Ventral view of leg **E**. Dorsal view of wing **F**. Dorsal view of abdomen

Acknowledgement

We would like to express our gratitude and sincere thanks to Director, Zoological Survey of India, Kolkata and Dr. G.P. Mondal, Scientist-E, H.O.O, Zoological Survey of India, Kolkata. The financial assistance under the Junior research fellowship provided by the Zoological Survey of India, Govt. of India is gratefully acknowledged. We would also like thank Dr. Chandrakasan Sivaperuman, Officer-in-Charge, ZSI, Andaman & Nicobar Regional Centre, for providing us with facilities to work in the Islands.Last but not least, many thanks go to the retired scientist Mr. P. Parui and Dr. Aniruddha Maity for helping us with identification of dipteran specimen and sharing his knowledge to compile this manuscript.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Redescription of *Neoeucirrhichthys maydelli* (Teleostei: Cobitidae) from Brahmaputra drainage, Assam, Northeastern India

Bidangshri Basumatary & Yumnam Lokeshwor Singh*

Department of Zoology, Assam Don Bosco University, Tapesia gardens, Kamarkuchi, Sonapur, Assam, India –782402

Abstract

A cobitid genus *Neoeucirrhichthys*, a monotypic loach under family cobitidae, was described based on a single specimen of *N. maydelli* from Janali River (Brahmaputra River system) at Raimona, Goalpara district, Assam. Almost after four decades an attempt was made to redescribe *Neoeucirrhichthys maydelli* from Mechi River, Nepal without mentioning presence of minute maxillo-mandibular rudimentary barbel at the corner of mouth. And as the samples were not from the type locality of the original description, thus, need verification and confirmation of its taxonomic status with fresh specimens collected in and around the habitat of its type species. Recent collection of specimens from Khujia River (the vicinity of type locality of type species), the northern tributary of Brahmaputra drainage, Assam have found a population of *Neoeucirrhichthys maydelli* which is redescribed here with additional information on its morphology, anatomy and osteology. The present study reveals the presence of a lateral extension of air bladder capsule on each side which was not seen in the illustration of original description; important osteological features like neurocranium with reduced (almost absent) anterior frontal region, posterior portion of frontal bone triangular shape, no anterior preepiphysial fontanelle, posterior fontanelle triangular shape with wide base towards posterior; total vertebrae 37–38 (18-20 abdominal vertebrae; 18–19 caudal vertebrae), dorsal fin insertion between 14–15 and 16-17 vertebrae, anal fin insertion between 23–24 and 25–26 vertebrae; and caudal complex with 5 hypural and gap between epural and neural arch of first preural centrum (pc-1).

Keywords: Monotypic loach, *Neoeucirrhichthys maydelli,* redescription, Khujia River, osteology, Brahmaputra drainage

Introduction

Bănărescu & Nalbant (1968) described *Neoeucirrhichthys maydelli,* a small monotypic freshwater loach under family Cobitidae, from Janali River (Brahmaputra river system) at Raimona, Goalpara district, Assam. It is characterized by having an elongated and slightly compressed body, absence of rostral, maxillary and mandibular barbels except a minute maxillo-mandibular rudimentary barbel at the corners of mouth, and highly placed eye with very narrow interorbital space. Menon (1992) registered the same characters as mentioned by Bănărescu & Nalbant in their original description. Edds & Ng (2007) attempted to redescribe *Neoeucirrhichthys maydelli* from Mechi River, Nepal (far away from its type locality). Some of the information given by Edds & Ng are not aligned with the original description, thus, needs verification and confirmation of its taxonomic status with specimens collected in and around the habitat of its type locality.

On examination of recently collected specimens from Khujia River a northern tributary of Brahmaputra drainage, Assam include a population of *Neoeucirrhichthys maydelli.* It has been reexamined and redescribed here with the additional information on its morphology, anatomy and osteological characters.

*Author for correspondence : lokeshwor.singh@dbuniversity.ac.in
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Materials and methods

The collected specimens were fixed in 10% buffer formalin. Counts and measurements were made on the left side of the specimens, whenever possible, following Kottelat (1990). Measurements were made point to point with a dial caliper to the nearest 0.1 mm. Measurements of body parts were given as proportions of standard length (SL). Measurements of subunits of heads were given as proportions of dorsal head length (DHL) and lateral head length (LHL). Fin rays were counted under a stereozoom microscope and were confirmed through a cleared and stained specimens following Taylor & Van Dyke (1985). Vertebral counts and description of caudal complex were done from cleared and stained specimens following Sawada (1982). The detail osteological structures were observed and photographed under a Leica Stereozoom microscope using Leica Application Suite version 3.4.0. The specimens were deposited in the Assam Don Bosco University Museum of fish (ADBU-MF). Data from Bănărescu & Nalbant (1968) and Edds & Ng (2007) were used for comparison of the specimens. Gill rakers were counted from the first left side of gill arch.

Neoeucirrhichthys maydelli **Bănărescu & Nalbant, 1968**

(Figure 1A-D)

Study materials: ADBU-MF 1611/1–8 ,8 exs.,27.7-36.6 mm SL,females; ADBU-MF 1611/9, 1 exs.,33.3 mm SL, male; India: Assam: Chirang district: Khujia River at South Kajalgaon (a tributary of Brahmaputra River system), coordinate 26°.29’32.2’N 90°.29’35.27’E, altitude 72 m above sea level; Bidangshri Basumatary, 20.iii.2021. Two specimens (ADBU-MF 1611/1, 36.6 mm SL, female; ADBU-MF 1611/9, 33.3 mm SL, male) were cleared and stained for osteology.

Diagnosis

Neoeucirrhichthys maydelli is distinguished from other cobitid loaches by the absence of rostral, maxillary and mandibular barbels and presence of a rudimentary maxillo-mandibular barbel at the corner of mouth. It is further diagnosed in having the following characters: 8-9 dark brown saddles on dorsum, a series of 11-12 more or less upside down like triangular bars below mid lateral, short lateral line with 7-8 pores, and a black spot at dorsal half of caudal-fin base, neurocranium with reduced (almost absent) anterior frontal region, posterior portion of frontal bone triangular shape, no anterior preepiphysial fontanelle, posterior fontanelle triangular shape with wide base towards posterior; total vertebrae 37–38.

Description

Morphometric and meristic data as in Table 1. Body elongate, subcylindrical in cross section, slightly compressed laterally, more or less compressed towards posterior of caudal peduncle. Head compressed, triangular in lateral view with gently convex dorsal and ventral margins. Eyes large, ovoid, horizontal axis longest; highly placed entirely in dorsal half of head, with very narrow interorbital space. Suborbital spine bifid, with a low processus dorso-caudalis branch and a long medial point, extending to vertical through anterior third of eye. Slit of erectile suborbital spine extending from vertical through midway between posterior margin of posterior nares to anterior orbital margin to below vertical through middle of eye. Gills openings restricted, extending from just below posttemporal to just below base of first pectoral fin ray. Snout pointed, flaccid; anterior nostrils prolong forming a prominent tube and posterior nostril at its base (Fig. 2a). Mouth small, inferior, horse-shoe shaped (Fig. 2b). Very shallow rostral groove along anterior margin of upper lip. Both upper and lower lip moderately thick, slightly papillated; lower jaw with a weak symphyseal knob. Lower lip continuous with upper lip through a narrow flap of skin at corner of mouth. Post-labial groove along posterior margin of lower lip with a medial interruption by narrow frenum between skin of lower jaw and throat. Both rostral or maxillary barbels absent, however a short maxillo-mandibular rudimentary barbel at the corner of mouth (Fig. 2c).

Dorsal profile of body rising gently over snout to nape then abruptly elevate at nape often with sharp demarcation, then more or less straight to dorsal-fin origin and sloping gently ventrally from dorsal-fin origin to end of caudal peduncle. Ventral profile convex to anal-fin base, then sloping dorsally to end of caudal peduncle. Body depth highest at dorsal-fin origin.

Dorsal fin with 3 simple and 7½ branched rays; first branched rays longest, last branched rays extending vertically to anal fin origin; distal margin straight; origin posterior to pelvic-fin base, closer to caudal-fin base. Pectoral fin with 1 simple and 8 branched rays, reaching one third to pelvic-fin origin; margin subacuminate. Pelvic fin in advanced to dorsal-fin origin with 1 simple and 6 branched rays, reaching vent when adpressed; distal margin subacuminate; origin slightly at middle of standard length of body. Anal fin with 2 simple and 5½ branched rays, reaching midway to caudal peduncle when adpressed; distal margin straight. Caudal fin emerginate with 7+7 branched principal rays; procurrent rays in upper and lower lobe of caudal fin with 4-6 and 4 respectively.

Body covered with minute cycloid scales. Lateral line very short with 7–8 lateral pores. Intestine straight.

Osteological features. Neurocranium with reduced (almost absent) anterior frontal region, posterior portion of frontal bone triangular shape; no anterior preepiphysial fontanelle, posterior fontanelle triangular shape with wide base towards posterior end (Fig. 3a).

Branchiostegeal rays 3, long well developed, posterior free end (outer side) flattened laterally (Fig. 3b). First branchiostegeal ray articulate to ventral side posterior median of ceratohyal (ch); second ray articulate at antero-lateral of epihyal (eh); third ray articulate at median lateral side of epihyal (eh). Interhyal small elongate, articulate from inner wall of posteriormost lateral side of epihyal (eh). Gill rakers 2 in epibranch and 7 in hypobranch (Fig. 3c). Ceratobranch triangular dragger shaped with 9 pointed teeth on inner face (Fig. 3d). Bony capsule of air bladder rounded with a lateral process directed posterior (Fig. 3e).

Total vertebrae 37-38; abdominal 18-20; predorsal 14-16; caudal vertebrae 18-19. Dorsal fin insertion between 14-15 or 16-17 vertebrae. Anal fin insertion between 23-24 or 25-26 vertebrae.

Caudal complex (Fig. 3f) with 5 hypural, three in upper lobe (h3–h5) and two in the lower lobe (h1–h2). Gap between epural (e) and neural arch of first preural centrum (pc-1). Hypural-1, 2 attached to parhypural dorsally, hypural-3, 4 and 5 attached to ventral groove of pleurostylar (pls). Principal caudal fin rays lies from pleurostylar to haemal spine (hs) of the second preural centrum (pc-2). Dorsal proccurent rays supported by epeural (e) and neural spine (ns) of second preural centrum (pc-2); ventral procurent rays supported by haemal spine of second preural centrum (pc-2). Parhypural (ph) and haemal spine (hs) broad and well developed.

Sexual dimorphism. Males are with broad and thickened branched pectoral fin rays (more in 5, 6 &7) branched rays (Fig. 3g). In males, the dorsal surface of pectoral fin rays covered with elongate tubercles arranged in oblique striae (Edds & Ng , 2007).

Coloration. In 10% buffer formalin, body creamy yellow however dark yellow in 70% alcohol. Series of 8–9 dark saddles on dorsal midline, 4 on predorsal and 4–5 on postdorsal region. First saddle closer to nape, slightly faded fourth saddle at the base of dorsal-fin origin,fifth at the posterior end of dorsal-fin base, last eight or ninth slightly posterior to the caudal peduncle end. Dorsolateral surface marked with faint dark melanophores forming irregular reticulated pattern and extending dorsal third of body. Series of 11–12 horizontally elongated more or less inverted triangular shape dark blotches on flanks along horizontal myosepta. Prominent black ovoid spot on dorsal half of caudal-fin base, just above midline of caudal fin. All fin hyaline with dark melanophores forming series of transverse bands. Ventral surface creamy yellow, no pigments. Series of minute dark melanophores arranging in two horizontal rows, one just near orbit and another below former extending from tip of snout to cheek anterior to dorsal corner of operculum. Short fainted stripe between tip of snout to base of suborbital spine. Numerous small irregular dark melanophores scattered on dorsum of snout and head. Ventral region of the snout peppered with small dark melanophores.

Distribution. The present *Neoeucirrhichthys maydelli* specimens were collected from Khujia River flowing to the Champabati River (the vicinity of type locality of type species), the northern tributary of Brahmaputra River system. Bănărescu & Nalbant (1968) described it from Janali River (a tributary of Brahmaputra River system) at Raimona, Goalpara district, Assam. Edds & Ng (2007) reported it from Mechi River, Nepal. Rahman (1989) reported *N. maydelli* from Tangan River at Thakurgaon and the Meghna River drainages in Bangladesh viz. Dharla River at Kurigram, Sari River at Jaintapur and Surma River at Lubachara.

Habitat. *Neoeucirrhichthys maydelli* inhabits in cool, shallow and moderately flowing water with gravels bottom, sand, pebbles and riffles. Other species occurring with *Neoeucirrhichthys maydelli* were *Barilius barila, B. bendelensis, Puntius* sp., *Pethia* sp., *Esomus* sp., *Canthophrys* sp., *Lepidocephalichthys goalparensis, L. anandali, L. guntea, Pangio pangia* , *Psilorhynchus sucatio, P. nudithoracicus* , *Acanthocobitis* sp., *Paracanthocobitis* sp., *Schistura* sp., *Chaca chaca* , *Hara* sp., *Amblyceps* sp., *Pseudolaguvia* sp. , *Olyra* sp. , *Microphis deocata*; *Pillaia* sp., *Mastacembelus* sp., *Macrognathus* sp.; *Parambassis* sp., *Badis* sp., *Glossogobius* sp.; *Channa* sp. and different types of shrimps, snails and crabs.

Discussion.

During the description of *Neoeucirrhichthys maydelli,* Bănărescu & Nalbant (1968) stated that the lower lip is not connected to the upper lip but to its doublure, no trace of rostral or maxillary barbels, and presence of a minute rudimentary maxillo-mandibular barbel at the corner of the mouth. Edds & Ng (2007) restated the connection of upper and lower lip through its doublure (a flap of skin fringing the upper lip to which the lower lip is ostensibly attached instead of to the upper lip) but did not give any observation of the later. Close examination of the recently collected specimens from the type locality of *Neoeucirrhichthys maydelli* agrees partly with description given by Bănărescu & Nalbant (1968), Menon (1992), and Edds & Ng (2007). We strongly agree with Edds & Ng (2007) on the connection of upper lip and lower lip. Close examination on specimens from the type locality shows the presence of a minute rudimentary maxillo-mandibular barbel at the corner of the mouth as stated by Bănărescu & Nalbant (1968) and Menon (1992). Moreover, Bănărescu & Nalbant (1968) mentioned the thickening and enlargement of the branched rays of the pectoral fin (in males) showing sexual diamorphism. Edds & Ng added the presence of elongate tubercles arranged in oblique striae on thickened branched rays of pectoral fins (in males). However, our specimen resembles with the former character as mentioned by Bănărescu & Nalbant, not the later. The development of tubercles happens during breeding season in mature males in most of the cyprinid fishes. The study of osteological characters reveals the presence of spike like elongation each on the lateral sides of bony capsule of air bladder, whereas, Bănărescu & Nalbant (1968) didn't show in the diagram.

The comparison of the present specimen from the data published in the original description and the Nepalese specimen shows large similarities with small differences (Table 1). The present specimen collected from the type locality recently, showed slight differences in their fin counts from both Bănărescu & Nalbant (1968) and Edds & Ng (2007). The present specimen have more branched dorsal-fin rays (7½ vs. 7), more branched anal-fin rays (5½ vs. 5) from the original description and the Nepalese specimens; more branched pelvic-fin rays (6 vs. 5), more branched pectoral-fin rays (8 vs. 7), less branched caudal fin rays (7+7 vs. 7+8) from the Nepalese specimen. Bănărescu & Nalbant mentioned presence of rows of spots in the dorsal, pectoral and caudal fin, whereas, in the present specimen all the fins are hyaline with dark melanophores forming series of transverse bands. Though there is a very few variations in morphometry and meristic data, they are all conspecific of *Neoeucirrhichthys maydelli*.

Table legends

Table 1: Biometric data of *Neoeucirrhichthys maydelli* showing the comparative account with previous descriptions.

Figure legends

Figure 1: *Neoeucirrhichthys maydelli*, ADBU-MF 1611/2, 36.5 mm SL, female **(A)** Lateral, **(B)** Dorsal, **(C)** Ventral, **(D)** Illustrated image (redrawn) from Fig.15 of Banarescu & Nalbant (1968).

Figure 2: *Neoeucirrhichthys maydelli*, ADBU-MF 1611/2, 36.5 mm SL, female **(a)** Lateral head showing tube like anterior nostril (marking with red arrowhead), **(b)** Ventral view of head showing horse-shoe shaped mouth and median symphyseal knob (marking with red arrowhead), **(c)** Ventral view of head showing rudimentary maxillo-mandibular barbel (marking with red arrowhead). Scale bar = 1mm.

Figure 3: *Neoeucirrhichthys maydelli*, ADBU-MF 1611/9, 33.3 mm SL, male, **(a)** Dorsal view of neurocranium, **(b)** Branchiostegeal rays, **(c)** Gill rakers on first left gill arch, **(d)** A row of pharyngeal teeth on left ceratobranch, **(e)** Ventral view of air bladder capsule, **(f)** Caudal complex, **(g)** Pectoral fin showing thickened 5, 6 & 7 branched rays. Scale bar = 1 mm.

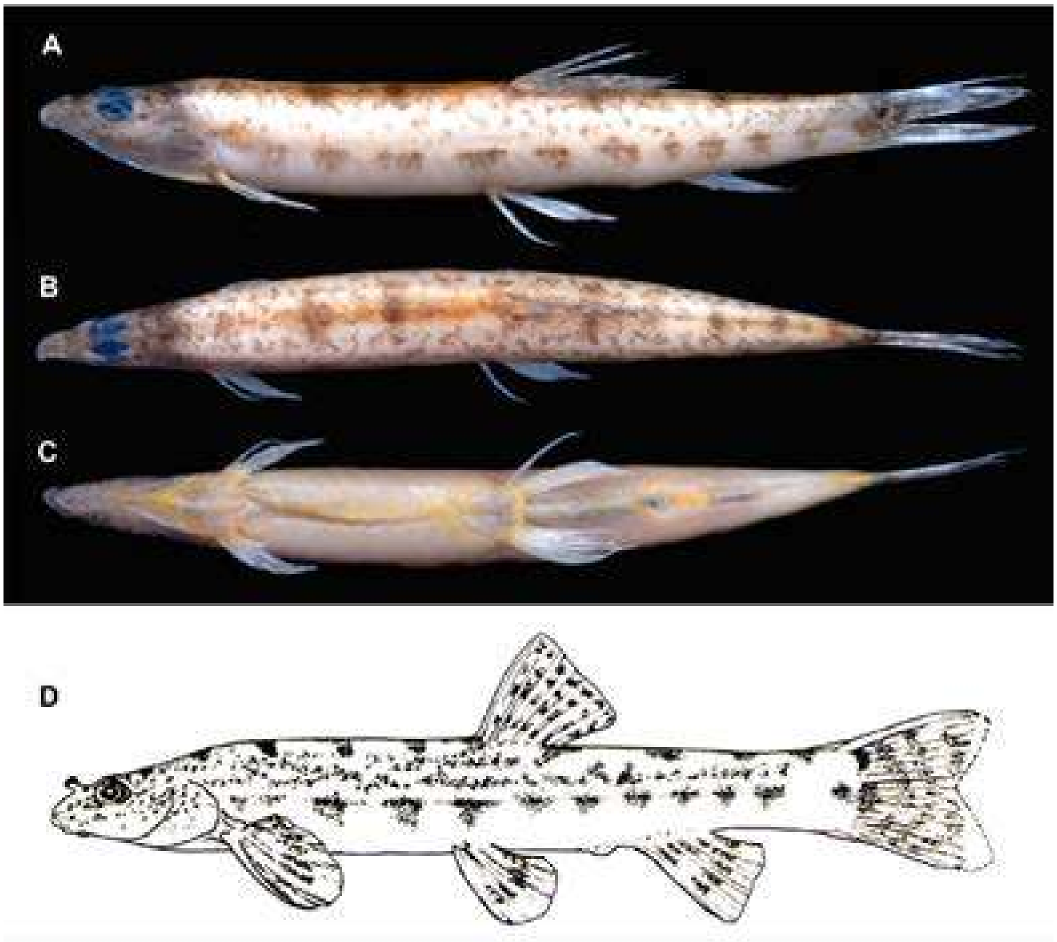
TABLE

Table 1. Biometric data of *Neoeucirrhichthys maydelli* showing the comparative account with previous description.

	ADBU-MF1611/1-9			Bănărescu & Nalbant, 1968	Edds & Ng, 2007
	N=9			Holotype	N=4
	range	means	S.D.		range
Standard length(mm)	27.7–36.6			36.0	29.4–36.2
% in Standard Length					
Body depth	11.8–13.3	12.6	0.6	13.3	10.8–12.6
Head length (dorsal)	15.1–17.0	16.5	0.7	--	--
Head length (lateral)	18.4–21.2	19.6	0.9	19.7	18.2–20.4
Head depth at nape	8.5–9.9	9.3	0.5	--	--
Head depth at eye	6.0–7.2	6.7	0.4	--	--
Length of caudal peduncle	14.5–18.4	16.4	1.4	16.9	14.6–19.6
Depth of caudal peduncle	6.3–7.6	6.9	0.5	7.5	5.9–7.1
Pre-dorsal length	52.3–56.9	54.1	1.5	50.0	51.1–54.4
Pre-pelvic length	51.3–52.4	52.0	0.4	47.7	48.6–53.4
Pre-pectoral length	20.9–22.2	21.5	0.5	--	20.2–21.5
Preanus length	68.9–72.6	70.7	1.3	--	--
Preanal length	72.6–76.6	74.2	1.4	71.7	69.6–74.5
Dorsal-fin height	15.9–18.4	17.3	0.9	--	--
Pectoral-fin length	12.9–17.0	14.1	1.5	18.5	12.4–15.1
Anal-fin depth	16.8–19.5	18.2	1.1	13.9	--
Pelvic-fin length	14.5–18.4	16.7	1.4	16.9	12.9–14.7
Caudal-fin length (both upper and lower lobe)	19.5–21.7	20.6	0.9	--	18.2–21.8
Dorsal-fin base length	12.3–14.1	13.1	0.7	11.9	9.7–12.6
Anal-fin base length	8.8–11.0	10.0	0.8	7.9	8.1–10.5
Body width (anal ori)	4.7–6.7	5.7	0.9	--	--
Body width(dorsal ori)	7.5–9.0	8.2	0.5	7.8	--
Pectoral-Pelvic fin distance	29.2–31.3	30.0	0.8	38.6	--
Pelvic-Anal fin distance	19.6–21.7	20.8	0.8	24.4	--
% in lateral head length					

	ADBU-MF1611/1-9			Bănărescu & Nalbant, 1968	Edds & Ng, 2007
	N=9			Holotype	N=4
	range	means	S.D.		range
Snout length	33.9–38.5	35.7	1.7	32.4	28.3–32.3
Eye diameter	19.2–25	21.3	2.0	19.7	15.0–16.1
Interorbital space	3.1–5.8	4.2	0.9	--	8.3–10.0
Mouth gape width	7.5–9.7	9.0	0.9	--	--
Head width max at cheek	17.8–26.2	24.1	2.9	--	--
% in dorsal head length					
Snout length	38.9–47.3	42.6	2.8	--	--
Eye diameter	22.2–28.3	25.3	2.0	--	--
Interorbital space	3.6–6.3	5.0	1.1	--	--
Mouth gape width	9.3–12.7	10.7	1.2	--	--
Head width max	23.6–30.8	28.6	2.5	--	--
Fin counts					
Dorsal-fin rays	iii,7½			iii,7	iii,7
Anal-fin rays	ii,5½			ii,5	ii,5
Pelvic-fin rays	i6			--	i,5
Pectoral-fin rays	i,8			--	i7
Principal caudal-fin rays	i7+7i			--	i,7,8,i
Procurrent rays	iv–vi/iv			--	--

FIGURES



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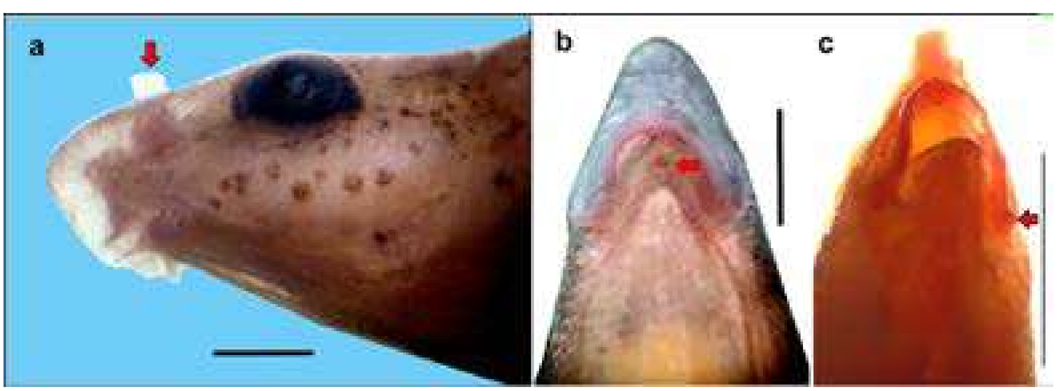

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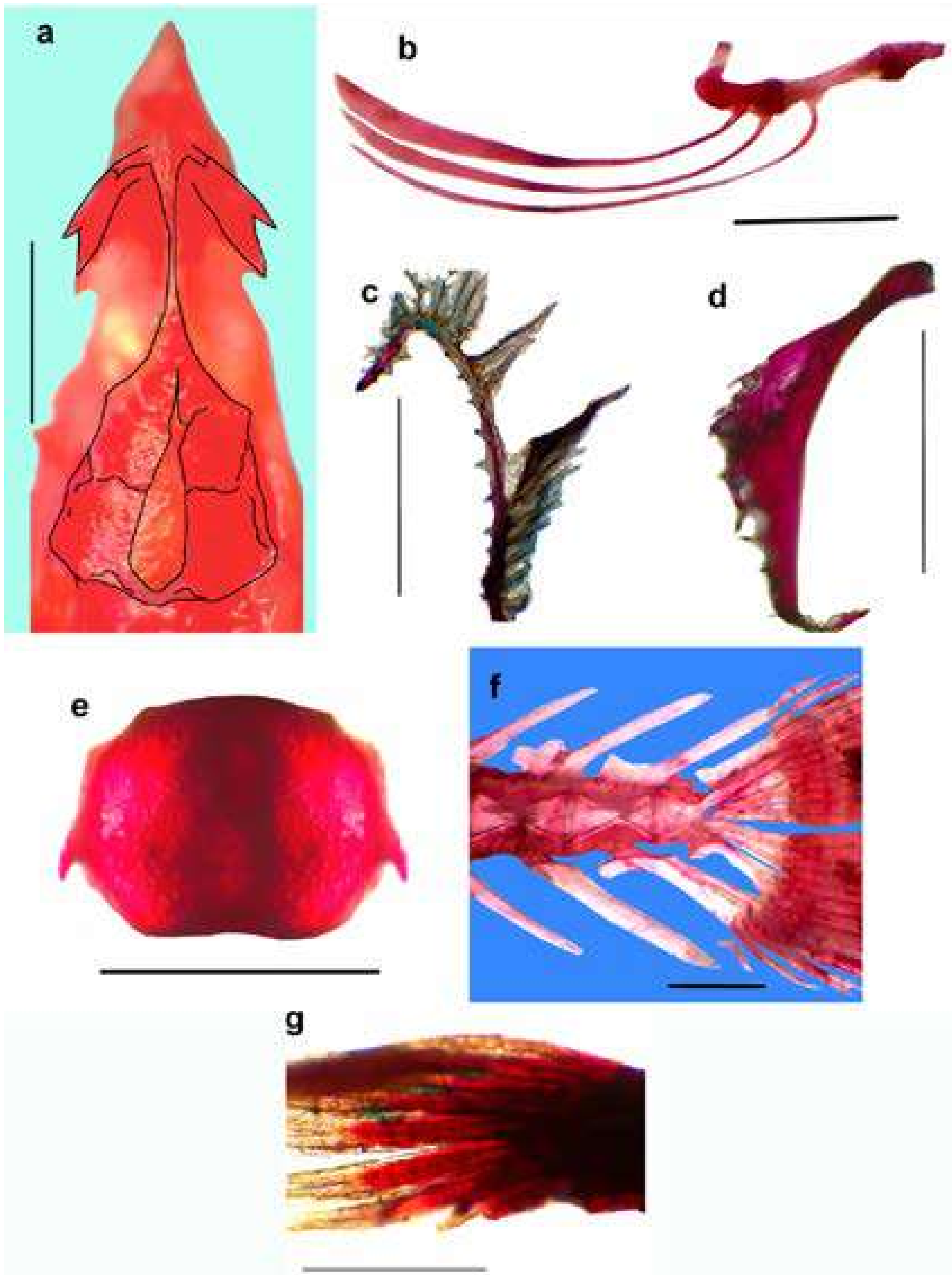

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Acknowledgement

We are very thankful to Dr. Maurice Kottelat for sharing the research papers and Fr (Dr.) Stephen Mavely, Vice Chancellor, Assam Don Bosco University for his encouragement in conducting research in Zoology Lab. We also extend our gratitude to Dr. Subhrendu Sekhar Mishra and Dr. S. S. Jadhav for their comments and suggestions while reviewing the research paper. We are very thankful to the organizers of Animal Taxonomy summit (ATS, 2023), Zoological Survey of India, Kolkata, for acceptance of the abstract of this research paper for oral presentation.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Preliminary observation on the polymorphic forms in three species of the Genus *Lepidocephalichthys* Bleeker, 1863 of Northeast India

Kangjam Velentina and Yumnam Lokeshwor*

Department of Zoology, Assam Don Bosco University, Tapesia Gardens, Sonapur, Assam 782402
Email: k.velentinad@gmail.com

Abstract

The spined loaches under the genus *Lepidocephalichthys* Bleeker, 1863 under family Cobitidae are colourful freshwater fishes with both ornamental and food values and are characterized by the presence of a sub-orbital spine and pectoral rod formed by the fused last two pectoral-fin rays in males. Out of the 9 valid species of *Lepidocephalichthys* in the Northeateastern India, three species viz. *L. berdmorei, L. guntea,* and *L. irrorata* show great polymorphic features in terms of body morphology, meristic data and colour. In view of this, the current preliminary study has been taken up to contribute in solving the existing taxonomic ambiguities by documenting the various polymorphic forms observed in *Lepidocephalichthys* of the Northeastern India. Multiple comparisons through morphometry, meristic, anatomy and osteology of the specimens collected from different river systems from different parts of the Northeast India has been employed. The present study is based on the observation of 127 specimens of *Lepidocephalichthys* collected from various region of the Northeastern India and it has revealed the presence of polymorphism in three species viz. *Lepidocephalichthys berdmorei, L. guntea* and *L. irrorata*. *Lepidocephalichthys berdmorei* has been registered with 6 polymorphs, *L. guntea* with 5 and *L. irrorata* with 2. Further understanding on their molecular characterization is suggested to confirm the taxonomic status of these polymorphs.

Keywords: Spined loaches, *Lepidocephalichthys*, Cobitidae, sub-orbital spine, polymorphism, Northeastern India

Introduction

Polymorphism can be defined as the occurrence of two or more clearly different phenotypes or forms within the same population of a species. This may be a result of the occurrence of intraspecific morphs within a single population exhibiting different niche use known as the resource polymorphism. It is wide spread over several taxa including fish, amphibians and birds and may play important roles in population divergence and speciation (Smith & Skúlason, 1996). This phenomenon can be due to the occurrence of genetic differences, phenotypic plasticity, or a combination of both (Komiya *et al.,* 2011). Phenotypic plasticity can be defined as the ability of individual genotypes to produce different phenotypes when exposed to different environmental conditions (Pigliucci *et al.,* 2006). The phenomenon of polymorphism often creates confusion in the field of taxonomy leading to certain taxonomic ambiguities demanding proper studies.

Lepidocephalichthys are the freshwater loaches belonging to the family Cobitidae which is known as the family of spined loaches characterized by the presence of three pairs of barbells, two rostral pair and one maxillary pair; a pair of flaps on lower lip, each flap with thickened inner fold ending in small, barbel-like projection; a spine below the eye and 7th and 8th rays of the pectoral fin modified and fused with or without flange known as the Pectoral rod in males (Havird & Page, 2010; Kottelat, 2017). They are widely distributed in Asia, from India to China, Vietnam, Laos, and Cambodia and south to Borneo and Java (Kottelat & Lim, 1992; Menon, 1992; Arunkumar, 2000). A total of 19 valid species are known under genus *Lepidocephalichthys* globally

*Author for correspondence : lokeshwor.singh@dbuniversity.ac.in
Article Received on: 02.04.2023 Accepted on: 24.04.2023

(Fricke *et al.,* 2023), out of which 9 species are found in the Northeastern India viz., *Lepidocephalichthys alkaia* Havird & Page, 2010*, L. annandalei* Chaudhuri, 1912*, L. arunachalensis* (Datta & Barman, 1984)*, L. berdmorei* (Blyth, 1860)*, L. goalparensis* Pillai & Yazdani, 1976*, L. guntea* (Hamilton, 1822)*, L. irrorata* Hora, 1921*, L. longipinnis* (Menon, 1992) and *L. micropogon* (Blyth, 1860). The fishes under this genus are facing taxonomic ambiguities as some of the species shows different pattern of polymorphism. There have been no studies done till date on polymorphism of the species under this genus. However, Vishwanath (2021) reported the presence of different phenotypic features in different specimens of *Lepidocephalichthys berdmorei* and *L. guntea* in the Northeastern India. Looking at recently collected *Lepidocephalichthys* species and those specimens deposited in the Assam Don Bosco University Museum of Fish we have found variations in morphology particularly in colour patterns within three species viz. *Lepidocephalichthys berdmorei, L. guntea* and *L. irrorata*. To understand their taxonomic identity and confirmation of each species, the present study has been taken up to document a preliminary observation of the polymorphic forms in these three species of the Northeastern India.

Materials and methods

Multiple comparisons of the polymorphic specimens through morphometry, meristic data, anatomy and osteology have been employed. Counts and measurements follow Kottelat (1990) and Kottelat & Freyhof (2007). Point to point measurements were made on the left side of specimens whenever possible, using dial calipers (Freemans FVD200 0-200 mm) to the nearest 0.1 mm. Fin rays were counted and scales were observed using Magnus stereo zoom microscope under transmitted and reflected light. Clearing and staining of bones followed Taylor & Van Dyke (1985) with slight modifications. Identification of bones is based on Sawada (1982) and Prokofiev (2009, 2010). The morphometry, meristic counts along with total vertebrae number, the position of dorsal fin insertion, the position of anal fin insertion, caudal complex and neurocranium structure were taken into account to group or classify as same species showing polymorphism. Variations on the number, size and pattern of blotches on lateral surface, bars on dorsum, presence and absence of stripe, presence and absence of dark patches are some of the characters seen in different samples of *L. berdmorei, L. guntea* and *L. irrorata.* The variations here are interpreted as intraspecific polymorphism. The polymorphic forms reported here are different from the sexual dimorphic forms as these forms were observed both in males and females. The study has been carried out based on the species deposited in Assam Don Bosco University Museum of Fish (ADBU-MF) Assam, India, collected from various river systems of Northeastern India. The numbers written in the parenthesis in the osteological features of Table 2 represents the frequency of observation.

Abbreviations used: ADBU-MF, Assam Don Bosco Museum of Fish, Assam, India; SL, Standard Length.

Materials examined:

Lepidocephalichthys berdmorei: ADBU-MF/5019/1/i-x, 10 exs., 55.5–82.0 mm SL; India: Manipur, Bishnupur district, Nambol bazar (Chindwin drainage system); K. Velentina, 17.x.2021. ADBU-MF/5019/4/i-ix, 9 exs., 59.0–71.7 mm SL; India: Manipur: Moreh, (Chindwin drainage system); K. Velentina, 13.xi.2021. ADBU-MF/5019/4/x-xi, 2 exs., 54.2–72.4 mm SL; India: Nagaland, Zunheboto, Tizu River (Chindwin drainage system); Nilibo A., 05.viii.2022. ADBU-MF/5019/3/i, 67.5 mm SL; India: Manipur: Bishnupur district, Nambol bazar (Chindwin drainage system); K. Velentina, 17.x.2021. ADBU-MF/5019/3/ii, 76.3 mm SL; India: Manipur: Chandel district, Moreh (Chindwin drainage system); K. Velentina, 13.xi.2021. ADBU-MF/5019/5/i-v, 5 exs., 55.5–73.6 mm SL; India: Manipur, Bishnupur district, Nambol bazar (Chindwin drainage system); K. Velentina, 17.x.2021. ADBU-MF/5019/5/vi-vii, 2 exs., 59.6–60.0 mm SL; India: Manipur, Bishnupur district, Moreh (Chindwin drainage system); K. Velentina, 17.x.2021. ADBU-MF/5019/5/viii, 72.4 mm SL; India: Nagaland, Zunheboto, Tizu River (Chindwin drainage system); Nilibo A., 04.iv.2022. ADBU-MF/5019/6/i-xii, 12 exs., 60.3–74.0 mm SL; India: Manipur, Chandel district, Moreh (Chindwin drainage system); K. Velentina, 13.xi.2021 & 05.viii.2022. ADBU-MF/5019/6/xiii-xiv, 2 exs., 54.8–77.1 mm SL; India: Nagaland, Zunheboto, Tizu River (Chindwin drainage system); Nilibo A., 04.iv.2022. ADBU-MF/5019/2/i-iv, 4 exs., 54.8–84.4 mm SL; India: Nagaland, Zunheboto, Tizu River (Chindwin drainage system); Nilibo A., 04.iv.2022 & 05.viii.2022.

Lepidocephalichthys guntea: ADBU-MF 5021/1/i-ix, 9 exs., 46.8–60.8 mm SL; India: Assam, Niz Jhaprabari, Assam, Udalguri district, Bhorla river (Brahmaputra drainage system); Sushmita M., 15.x.2021 & 07.x.2022. ADBU-MF 5021/1/x-xii, 3 exs., 46.4–53.4 mm SL; India: Meghalaya, North Garo Hills, Rajasimla, Dudhnoi River, Rongkil stream (Brahmaputra drainage system); Wimarithy K. Marak, 24.ix.2022. ADBU-MF 5021/1/xii-xxi, 9 exs., 38.2–61.4 mm SL; India: Meghalaya, North Garo Hills, Resu, Damring River, Chidrang stream (Brahmaputra drainage system); Wimarithy & party, 05.x.2021 & 22.iii.2022. ADBU-MF 5021/2/i-ix, 9 exs., 39.4–48.1 mm SL; India: Meghalaya, North Garo Hills, Resu, Damring River, Chidrang stream (Brahmaputra drainage system); Wimarithy & party, 05.x.2021 & 22.iii.2022. ADBU-MF 5021/2/x-ix, 10 exs., 46.0–57.4 mm SL; India: Meghalaya, Chidrang stream (Brahmaputra drainage system); Wimarithy A Marak, 07.x.2022. ADBU-MF 5021/3/i-ii, 2 exs., 61.0–65.9 mm SL; Assam, Chirang district, Khujia river (Brahmaputra drainage system); Bidangshri B., 15.x.2021. ADBU-MF 5021/3/iii-xv, 13 exs., 40.0–56.5 mm SL; India: India: Meghalaya, North Garo Hills, Resu, Damring River, Chidrang stream (Brahmaputra drainage system); Wimarithy & Party, 05.x.2021 & 07.x.2022. ADBU-MF 5021/3/xvi-xix, 4 exs., 38.4–49.2 mm SL; India: Meghalaya, North Garo Hills, Rajasimla, Dudhnoi River, Rongkil stream (Brahmaputra drainage system) Wimarihthy K. Marak; 24.ix.2022. ADBU-MF 5021/3/ xx, 46.4 mm SL; India: Meghalaya, West Garo Hills, Edenbari, Ganol River (Barak–Surma–Meghna drainage system); Rikkambe, 24.ix.2022. ADBU-MF 5021/4/i, 42.0 mm SL; India: Assam, Chirang district, Khujia River (Brahmaputra drainage system); Bidangshri B., 22.iii.2022. ADBU-MF 5021/4/ii-iv, 3 exs., 47.4–56.2 mm SL; India: Meghalaya, North Garo Hills, Resu., Damring River, Chidrang stream (Brahmaputra drainage system); Wimarithy & Party, 22.iii.2022. ADBU-MF 5021/5/i-ix, 9 exs., 33.0–43.5 mm SL; India: Meghalaya, North Garo Hills, Rajasimla, Dudhnoi River, Rongkil stream (Brahmaputra drainage system); Wimarithy K. Marak, 24.ix.2022.

Lepidocephalichthys irrorata: ADBU-MF/5020/1/i-vi, 6 exs., 32.1–34.9 mm SL; ADBU-MF/5020/2/i-v, 5 exs., 26.0–37.0 mm SL; India: Manipur, Bishnupur district, Moirang, Loktak lake (Chindwin drainage system); K. Velentina, 03.iii.2022.

Results and discussion

The present study documented the phenomenon of polymorphism in three lepidocephalid loaches out of the total 9 occurring in the Northeastern India viz., *Lepidocephalichthys berdmorei*, *L. guntea* and *L. irrorata* as mentioned in Table 1. The meristic and the osteological data of these three species showing the phenomenon of polymorphism on the basis of which they have been grouped as same species even though they show various morphological differences Table 2. The list of the polymorphic characters observed in *Lepidocephalichthys berdmorei, L. guntea* and *L. irrorata* respectively are shown in Table 3–5.

Polymorphs in *Lepidocephalichthys berdmorei*. On the examination of 49 specimens of *Lepidocephalichthys berdmorei* collected from various part of the Chindwin drainage system in the Northeastern India, revealed six polymorphic forms (Table 2 & Fig. 2 A –F). The first group of species comprises 10 specimens and is characterized with 6–14 dark brown blotches on the flank along the horizontal myosepta superimposing above light grey stripe (Fig. 2A–i & ii). The second group of species includes 11 specimens and is characterized in having smaller spots on the flank along horizontal myosepta superimposing above a thin light grey stripe and small irregular spots on flank above and below the midlateral line (Fig. 2B). The third group of species includes 2 specimens having a unique features like the absence of blotches or spots however a distinct stripe on flank along horizontal myosepta and the presence of irregular interconnected reticulated stripe and spots on dorsolateral above lateral line (Fig. 2C). The fourth group of specimens are with regularly arranged dark brown saddles on dorsum represented by 8 specimens (Fig. 2D) but absent in many of them. The fifth group of specimens are without bars on dorsum, just heavily speckled with dark spots and are represented by 14 specimens (Fig. 2E). The sixth polymorph of *Lepidocephalithys berdmorei* is represented by 4 specimens showing the presence of a dark stripe along the midline of caudal fin (Fig. 2F). The sixth polymorph of *Lepidocephalichthys berdmorei* has the appearance of *L. alkaia* however differ from it in the absence of dark bars on dorsum (vs. presence of numerous bars; 8–10 predorsal, 8–10 postdorsal). No major variations have been observed in the meristic and osteological data of these 6 polymorphs of *Lepidocephalichthys berdmoeri* (Table 2). Thus, a preliminary confirmation of six polymorphic forms of *L. berdmorei* have been found in the Northeastern India however a more elaborate study with their molecular data is needed for further understanding of this species group and to provide a proper taxonomic distinction of it from *Lepidocephalichthys alkaia*.

Polymorphs in *Lepidocephalichthys guntea*. On the examination of 73 specimens of *Lepidocephalichthys guntea* collected from various part of the Northeastern India revealed the presence of five different polymorphs (Table 4; Fig. 3 A–E). The first polymorph is represented by 21 specimens and is characterized by the presence of a broad dark stripe along horizontal myosepta on the flank appearing the superimposition of closely arranged blotches on dark background stripe and irregularly arranged reticulated dark marking on dorsum and dorsolateral portion of flank leaving a wide space without marking just above midlateral stripe (Fig. 3A–i & ii). This form is common in males; however, it has also been observed in females. The second polymorph was registered from 19 specimens and can be distinguished in having a series of dots or spots along the horizontal midlateral stripe (Fig. 3B–i & ii). The third polymorph was registered form 20 specimens and can be characterized by the presences of blotches on the horizontal myosepta of the flank with various irregularly arranged reticulated patches above or below the midlateral stripe (Fig. 3C i–iii). This group again shows differences in the appearance according to the blotch number and the pattern of patches present. The fourth group polymorph, consists of 4 specimens, is characterized by having various dark patches on the body, some forming blotches but not necessarily all (Fig. 3D). The fifth groups of polymorph have been observed from 9 specimens appears to be juvenile and is characterized in having a series of dots on along the horizontal myosepta of the flank with no blotches or dark patches (Fig. 3E). This form is concluded to be a juvenile form based on the larger fin length as compared to the standard length.

Polymorphs in *Lepidocephalichthys irrorata*. The examination of 11 specimens of *Lepidocephalichthys irrorata* has revealed the presence of two polymorphic forms. The first group of polymorph was registered from 6 specimens and characterized by the presence of pale yellowish-white body with very light brown fainted spots (Fig. 4A). The second polymorph was registered from 5 specimens and characterised with pale-olivaceous body speckled with numerous dark spots (Fig. 4B). Moreover, it is known to have 2 rostral pair of barbels and one maxillary pair like all the other *Lepidocephalichthys*. The examination on the recent collection of *Lepidocephalichthys irrorata* from the same type locality showed the differences in the barbel numbers and structure in some group of specimens. However, due to lack of molecular and biological work as well as limited availability of samples, we could not conclude the identity of these two forms as polymorphic or a different species.

The polymorphic forms of *Lepidocephalichthys berdmorei*, *L. guntea* and *L. irrorata* are grouped separately based on the osteological data including the vertebrae count, fin insertions, neurocranium structure and caudal complex. The morphometric data and meristic data as well as the distinct diagnostic characters are also taken into account. Multiple comparisons and studies of the specimens collected from different river systems of Northeast India in different seasons have been carried out to conclude the existence of these polymorphic forms. The reasons for the existence of these polymorphic forms might be due to differences in food habits, the habitat including the environmental factors such as water quality, or may also be an outcome of the adaptation strategies to the changing environment. However, the current study carried out cannot come up to a conclusion as to why these polymorphic forms occur in this genus. This paper mainly aims on documenting the existence of these polymorphic forms. Therefore, additional works on molecular level as well as biological studies including habitat analysis are required in order to give them a proper taxonomic distinction as polymorphic forms which will eventually help in describing new taxa under the genus *Lepidocephalichthys*.

FIGURES

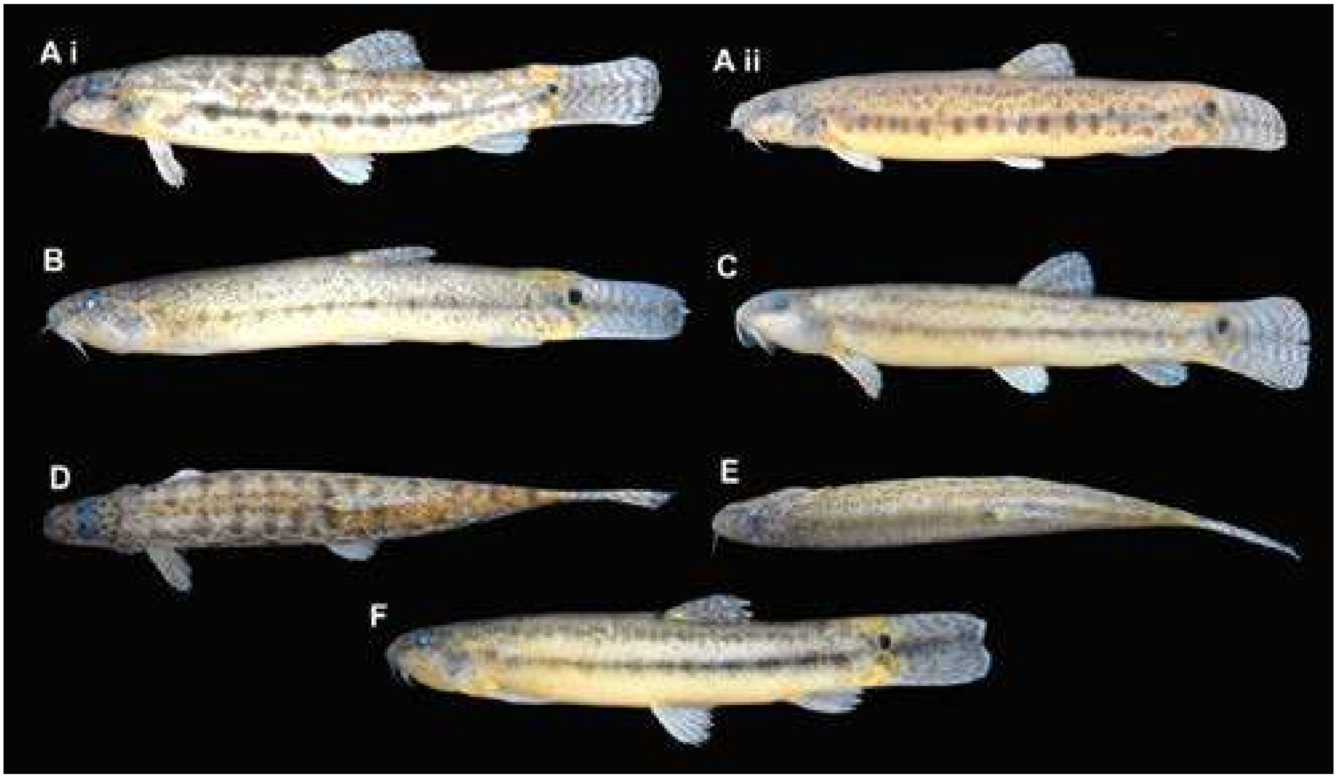

Figure 1. Polymorphic forms of *Lepidocephalichthys berdmorei* **(A i)** ADBU-MF 5019/1/i, 55.5 mm SL, lateral view; **(A ii)** ADBU-MF 5019/1/ii, 69.8 mm SL, lateral view; **(B)** ADBU-MF 5019/4, 60.5 mm SL, lateral view; **(C)** ADBU-MF 5019/3, 66.4 mm SL, lateral view; **(D)** ADBU-MF 5019/5, 55.5 mm SL, dorsal view; **(E)** ADBU-MF 5019/6, 63.12 mm SL, dorsal view; **(F)** ADBU-MF 5019/2, 63.3 mm SL, lateral view.

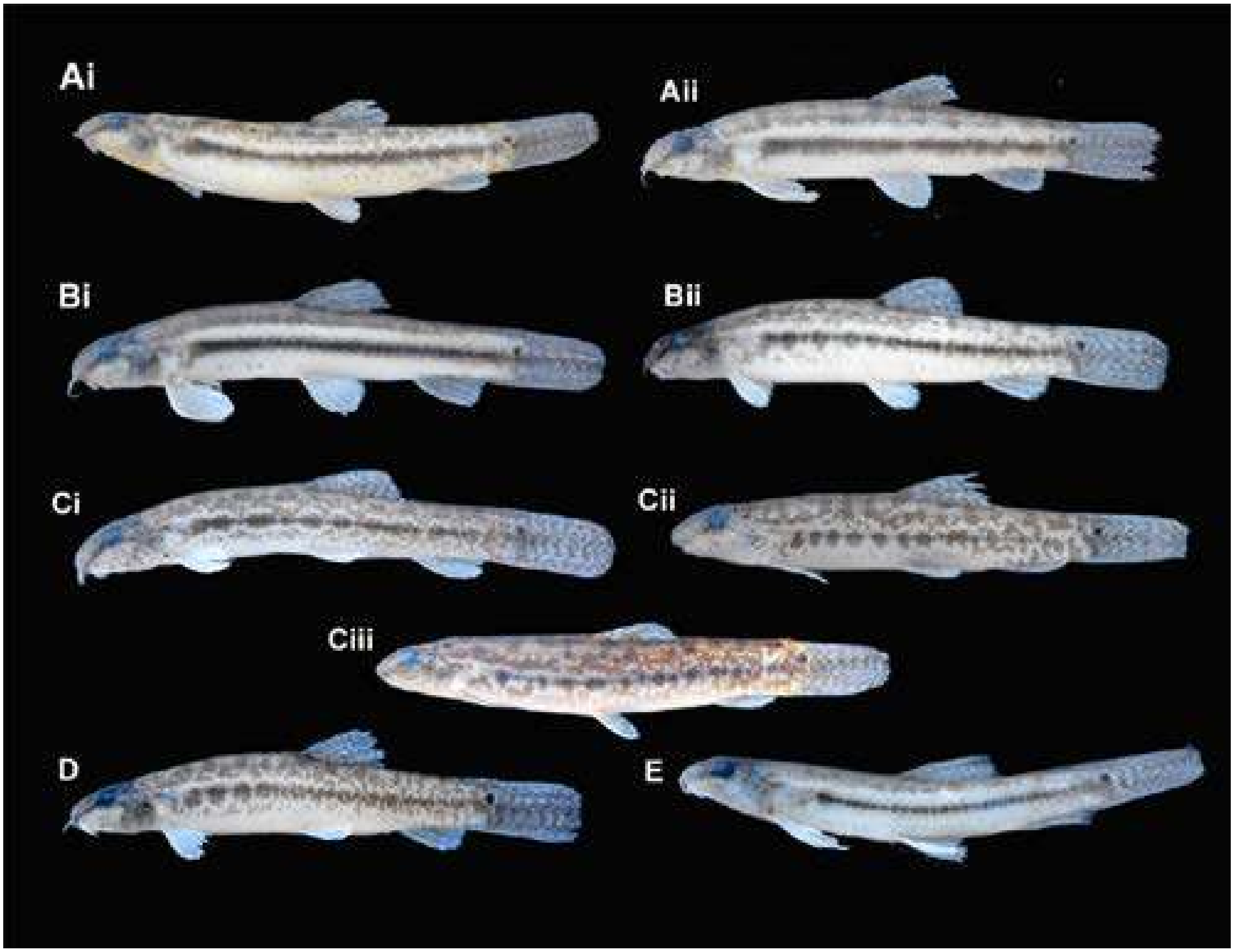

Figure 2. Polymorphic forms of *Lepidocephalichthys guntea* **(A i)** ADBU-MF 5021/1/i, 60.0 mm SL, lateral view; **(A ii)** ADBU-MF 5021/1/ii, 51.0 mm SL, lateral view; **(B i)** ADBU-MF 5021/2/i, 56.2 mm SL, lateral view; **(B ii)** ADBU-MF 5021/2/ii, 50.6 mm SL, lateral view; **(C i)** ADBU-MF 5021/3/i, 53.1 mm SL, lateral view; **(C ii)** ADBU-MF 5021/3/ii, 41.5 mm SL, lateral view; **(C iii)** ADBU-MF 5021/3/iii, 65.0 mm SL, lateral view; **(D)** ADBU-MF 5021/4, 50.3 mm SL, lateral view; **(E)** ADBU-MF 5021/5, 40.6 mm SL, lateral view.

Figure 3. Polymorphic forms of *Lepidocephalichthys irrorata* **(A)** ADBU-MF 5020/1, 28.9 mm SL, lateral view; (B) ADBU-MF 5020/2, 29.0 mm SL, lateral view.

TABLES

Table 1. Lepidocephalid loaches under genus *Lepidoephalichthys* of Northeast India exhibiting polymorphism and their distribution. **BAR-SUR-MEGH —** Barak-Surma-Meghna drainage system, **CHIN** — Chindwin drainage system, **BRAH** — Brahmaputra drainage system, '+' indicates presence, ' ' indicates absence.

	BAR-SUR-MEGH	**CHIN**	**BRAH**	**Polymorphism visible**
Genus *Lepidocephalichthys* Bleeker, 1863				
1. L. alkaia Havird & Page, 2010	–	+	–	–
2. L. berdmorei (Blyth, 1860)	+	+	–	+
3. L. guntea (Hamilton, 1822)	+	–	+	+
4. L. irrorata Hora, 1921	–	+	–	+
5. *L. arunachalensis* (Datta & Barman, 1984)	–	–	+	–
6. L. goalparaensis Pillai & Yazdani, 1976	–	–	+	–
7. *L. annandalei* Chaudhuri, 1912	–	–	+	–
8. *L. longipinnis* (Menon, 1992)	–	–	+	–
9. L. micropogon (Blyth, 1860)	–	+	–	–

Table 2. Meristic and osteological data of three *Lepidocephalichthys* from the Northeastern India showing polymorphism viz; *Lepidocephalichthys berdmorei, L. guntea* and *L. irrorata.*

	L. berdmorei ADBU-MF/5019/1-6 N=6	*L. guntea* ADBU-MF/5021/1-9 N=9	*L. irrorata* ADBU-MF/5020/1-2 N=2
Meristic data			
Dorsal fin counts	3/6½	3/6½–7½	2/7
Pectoral fin counts	1/7	1/7–8	1/6
Pelvic fin counts	1/6–7	1/5–6	1/6
Anal fin counts	2–3/5½	3/5½	2/5
Caudal fin counts	14–15	14–15	14
Osteological data			
Total vertebrae	38(2), 39 (2), 40(2)	35(2), 36(5), 37(2)	39(2)
Abdominal vertebrae	19(3)–20(3)	17(1), 18(6), 19(2)	26(2)
Caudal vertebrae	18(2), 19(2), 20(2)	16(1), 18(7), 19(1)	13(2)
Predorsal vertebrae	15(2)–16(4)	12(1), 13(7), 14(1)	13(2)
Dorsal-fin insertion	15–16(2),16–17(4)	12–13(1), 13–14(7), 14–15(1)	13–14(2)
Anal-fin insertion	27–28(3), 28–29(3)	24–25 (5), 25–26(3), 26–27(1)	22–23(2)

Table 3. List of the polymorphic characters observed in *Lepidocephalichthys berdmorei.*

Sl. No.	Polymorphic character
1	Distinct dark brown blotches on flank along horizontal myosepta superimposing above light grey stripe, blotches varying in no. (6-14), various irregular patches on dorsolateral portion above mid- lateral line (Fig. 2A–i & ii).
2	Smaller size spots on flank along horizontal myosepta superimposing above very thin light grey stripe, small irregular spots on flank above and below mid- lateral line (Fig. 2B).
3	No distinct blotches but a distinct stripe on flank along horizontal myosepta, irregular interconnected reticulated strips and spots on dorsolateral above horizontal myosepta (Fig. 2C).
4	Regularly arranged olivaceous dark brown saddles on dorsum (Fig. 2D).
5	No saddles on dorsum, just mottled with dark spots (Fig. 2E).
6	A dark stripe along the midline of caudal fin (Fig. 2F).

Table 4. List of the polymorphic characters observed in *Lepidocephalichthys guntea.*

Sl. No.	Polymorphic character
1	Appearance as a broad dark stripe along horizontal myosepta, appearing the superimposition of closely arranged blotches on dark background stripe. Irregularly arranged reticulated dark marking on dorsum and dorso lateral portion of flank leaving a wide space without any marking just above midlateral stripe (Fig, 3A i & ii).
2	With series of dots or spots along the horizontal midlateral stripe (Fig. 3B–i & ii).
3	Blotches on lateral surface with various patches (Fig. 3C i–iii).
4	Various dark patches on the body some forming blotches (Fig. 3D).
5.	Series of dots on the mid-lateral surface (juvenile) (Fig. 3E).

Table 5. List of the polymorphic characters observed in *Lepidocephalichthys irrorata.*

Sl. No.	Polymorphic character
1.	Pale yellowish-white body with very light brown colour spots (Fig. 4A).
2.	Pale-olive colour body speckled with numerous dark spots (Fig. 4B).

Acknowledgement

Both the authors are very thankful to Fr (Dr) Stephen Mavely, Vice Chancellor, Assam Don Bosco University for his encouragement in conducting research in Zoology Lab. Both the authors also would like to thank Dr. Jaya Kishor Seth and Dr. Bikramjit Sinha for all their valuable suggestions and guidance through their review process. The first author is thankful to the research fellows for their moral support. Both the authors are very thankful to the organizers of Animal Taxonomy summit (ATS, 2023), Zoological Survey of India, Kolkata, for acceptance of the abstract of this research paper for oral presentation.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Morphology of three species belonging to genus *Cletomorpha* Mayr, 1866 (Hemiptera: Coreidae) with special reference to male genitalia

Susmita Khanra, Swetapadma Dash and Amartya Pal
Zoological Survey of India, M-Block, New Alipore, Kolkata-7000531, West Bengal, (Email:susmitakhanra.7258@gmail.com, oasisnainital@gmail.com, amartyapal08@gmail.com)

Abstract

A study on morphological characters of three Indian species pertaining to genus *Cletomorpha* Mayr, 1866, has been undertaken with detailed illustration of male genitalia. A taxonomic key and checklist to Indian species of *Cletomorpha* is also provided.

Keywords: Taxonomy, Coreidae*, Cletomorpha,* West Bengal, morphometry, genitalia.

Introduction

The genus *Cletomorpha* Mayr, 1866 (Hemiptera: Coreidae) includes 22 species; out of them, four are distributed in India: *C. raja* Distant, 1901; *C. hastata* (Fabricius, 1787); *C. benita* Kirby, 1891; and *C. walker* Kirby, 1891 (Distant, 1902; Pravakar, 2013; Coreoidea Species File, 2023). This genus is widely distributed in the Ethiopian and Indo-Malayan regions. Distant (1902) mentioned 5 species in this genus including two Indian species, *C. raja* and *C. hastata*. Another species, *C. walkeri* was reported by Prabakar (2013). Paulson *et al.* (2020) recorded one of the species of *Cletomorpha, C. benita* as a pest from Vadodara, Gujarat. In very recent study Kushwaha *et al* (2023) provides redescription of *C. benita*. However, there is no detailed study of genitalia of this particular species *C. benita*. The present paper aims to study comparative morphological characters with male genitalia of the three Indian species of this genus *Cletomorpha* Mayr, 1866. Another Indian species *C. walkeri* has been studied from literature only.

Material and Methods

The specimens were collected from shrubs with the help of an insect net. The collected bugs were put in the glass vials, containing 70% ethyl alcohol in the field. After returning to the laboratory of Zoological Survey of India the bugs were stretched, air dried, pinned and stored in the insect cabinet for taxonomic study. Identification of the species was made following the keys and characters as given by Distant (1902), Bergroth (1924), and Blotte (1935). All the studied specimens were from the National Zoological Collection of Zoological Survey of India, Kolkata, specifically from West Bengal (Mahananda Wild Life Sanctuary, Buxa Tiger Reserve and Bethuadahari Wildlife Sanctuary). The photographs were taken using Leica M205A stereomicroscope with a coupled Leica DMC 4500 camera and processed in LAS V4.12 software to perform morphometric measurements. Male genitalia were dissected following the methodology given by Ahmad (1986).

The internal contents were cleared after thoroughly washing it in distilled water for 2–3 times and with the help of fine forceps. All measurements are given in millimetres. List of abbreviations used B – blade, BP – basal plate, C – conjunctiva, GP – gonoporal process, OM – outer margin, P – pivot, St – stem, T – theca, V – vesica, VAM – ventroanterior margin, VPM – ventroposterior margin, VSA – ventral sclerotized appendages.

*Author for correspondence :
Article Received on: 02.04.2023

Accepted on: 24.04.2023

Results

Taxonomic Account

Family Coreidae Leach, 1815

Subfamily Coreinae Leach , 1815

Genus *Cletomorpha* Mayr, 1866

1866. *Cletomorpha*: Mayr Zoologischer Theil, Zweiter Band, 1. Abtheilung, B. Part 2. 120

***Cletomorpha hastata* (Fabricius, 1787)**

1787. *Cimex hastata:* Fabricius. *Mant*. 2:287

Material examined: 2 male, Laltang Tower, Laltang Beat, South Range, Mahananda Wild Life Sanctuary, Darjeeling, 26.811818N, 88.524573E, 25.iii.2018, Coll: M.E.Hassan & party.

Male genitalia:
Outer margin of pygophore is subrounded, Ventroanterior part is concave, middle portion is broad then substraight, ventroanterior margin is bilobed having a small prominent notch in middle (Fig: 4) ; Paramere long and slender, upper outer margin of stem subrounded and lower portion is straight and inner margin "U" shaped, hairs present on stem, blade long and thin (Fig: 5); aedaegus highly sclerotized with broad phallosoma and small leaf shaped conjunctiva, vesica sclerotized , moderately thick with two long coil. (Fig 6)

***Cletomorpha raja* Distant, 1901**

1901. *Cletomorpha raja* : Distant. *Ann. Mag. Nat. Hist*. 7 7(41):423-424

Material examined: 1 male, camp 12, SRVK Beat, Damanpur East Range, Buxa Tiger Reserve, Alipurduar, West Bengal, 26.37763N, 89.35463E, 27.iii.2018, Coll. M.E. Hassan & party

Male genitalia:

Outer margin of pygophore is rounded with a concavity posteriorly, ventroposterior margin bilobed with wavy middle (Fig: 10); Paramere elongated, upper portion of stem with small hairs, upper outer margin is rounded and lower outer margin and inner margin of stem is concave, blade short and thick.(Fig: 11); aedaegus sclerotized and narrow towards apex, phallosoma large and conjunctiva with a pair of triangular ventral appendages, vesical with two short and broad coils.(Fig: 12)

***Cletomorpha benita* Kirby, 1891**

1891.*Cletomorpha benita*: Kirby, *Journal of the Linnean Society, Zoology* 24 149– 150:96-97.

Material examined: 1 male, Pundia Beat, West Range, Mahananda Wildlife Sanctuary, Darjeeling, West Bengal, 26.834898N, 88.350541E, 8.xi.2017, Coll. M.E. Hassan & party; 3 male, station 1(near gate), Bethuadahari Wildlife Sanctuary, Nadia, West Bengal, 23.597834N, 88.392702E, 6.xii.2021, Coll.S. Khanra.

Male genitalia:
Pygophore with outer margin substraight, becomes a little broad posteriorly. Ventro-posterior margin or lip bilobed with very strong median inflexion, hair present on posterior margin (Fig: 16); Paramere elongated, blade long and thick, broad in middle, outer and inner margin sinuate. Stem elongated, prominent hair present upper portion of stem, sub straight in medial front portion and roundish in medial back portion, lower part of stem is straight (Fig: 17). Aedaegus with Phallosoma long and thin, Conjunctiva with two sclerotized ventral appendages; vesica with two coils and a pair of long leaf shaped highly sclerotized ventral appendages present near vesica. Basal plate with pivot (Fig: 18).

The genus *Cletomorpha* Mayr, 1866 is distinguished from its closely allied genus *Cletus* Stal 1860 by presence of acutely and exteriorly produced connexival segment. Among the four Indian species of this genus *C.raja* and *C. hastata* is redescribed by Gupta and Singh, 2013. These two species is widely distributed in India. Paulson *et al.* (2020) recorded *C. benita* as a pest from Vadodara, Gujarat and Kushwaha *et al* (2023) reported this species from Mizoram. The present study reported *C. benita* first time from West Bengal. Among the four Indian species of genus *Cletomorpha*, three species such as *C.raja, C.hastata, C.benita* are available in National Zoological Collection of Zoological Survey of India, another one *C. walkeri* have been studied from literature only. Main distinguishing character of different species of *Cletomorpha* is marking present on corium. In case of *C. raja* a broad whitish band present on corium, but in *C. hastata* only a pale fascia present on corium which differ from *C. benita* having three prominent macular spot on corium and in C. walker only a single spot present on corium. Genital structure is also different among these species. Outer margin of pygophore of *C. raja* is more or less oval shaped and having prominent concavity posteriorly which is absent in other two species. Besides outer margin of *C. benita* is rounded and *C. hastata* is sub straight. Anterior portion of blade of paramere of *C. hastata* is more curved compared to other two species. In case of *C. benita* hair numerous in number and distributed in the two third region upper outer margin of paramere stem. But in *C. raja* hair is comparatively less, shorter and distributed in the one third region upper outer margin of paramere stem.

Key to the species of *Cletomorpha* Mayr, 1866 of India

1 Anterolateral side of pronotum without spine --2

- Anterolateral side of pronotum with several short strong spines -------------------------- ***C. hastata* (Fabricius, 1787)**

2 Corium having spot ---3

- Corium having a prominent band -- ***C. raja* Distant, 1901**

3 Corium having three macular spot -- ***C. benita*/Kirby, 1891**

- Corium having a single spot --- ***C.walkeri*/Kirby, 1891**

Table 1. A checklist of Indian species of *Cletomorpha*Mayr, 1866

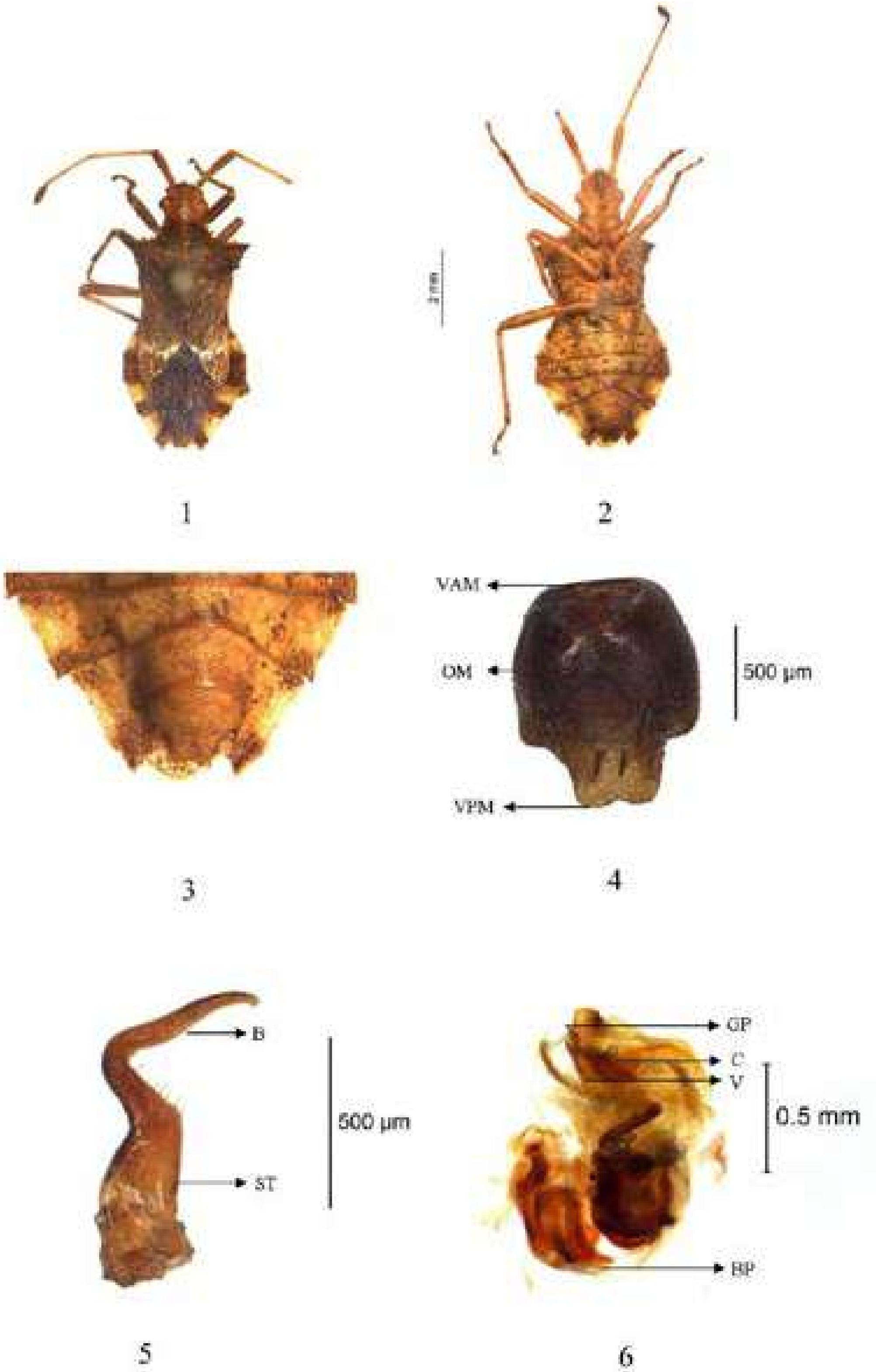
SL No.	Species name	Distribution (India)	Distribution (Elsewhere)
1	*C. raja* Distant, 1901	Assam, (Distant 1902, Basu&Mitra, 1994, Basu et al, 1999, 2000, Basu&Mitra 2003), Himachal Pradesh (Gupta & Singh 2013), Manipur (Basu & Mitra 2004),Meghalaya (Basu*et al*, 1999,2000 Basu & Mitra 2003) Sikkim (Distant 1902, Basu & Mitra, 1994, Basu *et al*, 1999, 2000, Basu & Mitra 2003,) Tripura (Basu*et al*, 2000), Uttrakhand (Gupta & Singh 2013), West Bengal (Basu&Mitra, 1994, Basu*et al*, 1999, 2000, Basu&Mitra2003, Gupta & Singh 2013, Pravakar 2013)	Myanmar (Distant 1902, Basu *et al,*1999, 2000, Basu & Mitra 2003, Gupta & Singh 2013), Pakistan (Gupta & Singh 2013).
2	*Cletomorpha hastata* **(Fabricius, 1787)**	Chhattisgarh (Hassan *et al,* 2019), Himachal Pradesh (Gupta & Singh 2013, Hassan et al, 2019), Haryana (Gupta & Singh 2013), Maharashtra (Distant, 1902, Basu *et al* 1999, Gupta & Singh 2013, Pravakar 2013, Hassan et al, 2019), Madhya Pradesh (Hassan *et al,* 2019), Meghalaya (Basu*et al,* 1999) Punjab (Gupta & Singh 2013), West Bengal (Distant, 1902, Basu*et al* 1999, Gupta & Singh 2013, Pravakar 2013, Hassan *et al,* 2019)	Bangladesh. (Ahmad & Rub 2006), Pakistan (Distant 1902, Basu*et al*, 1999, Ahmad & Rub 2006,Gupta & Singh, 2013, Hassan *et al*, 2019),
3	*Cletomorpha benita* Kirby 1891	Gujarat (Paulson *et al.* 2020), Mizoram Kushwaha *et al* (2023), West Bengal (new record).	Malaysia ,Myanmar (China 1926), Indonesia (Blote 1935),
4	*Cletomorpha walkeri* Kirby 1891	West Bengal (Distant 1908,Pravakar 2013).	Myanmar (Distant 1908), Sri Lanka (Pravakar 2013).

Table 2. Comparison of The Morphological Characters of Indian Species of Genus *Cletomorpha* Mayr, 1866

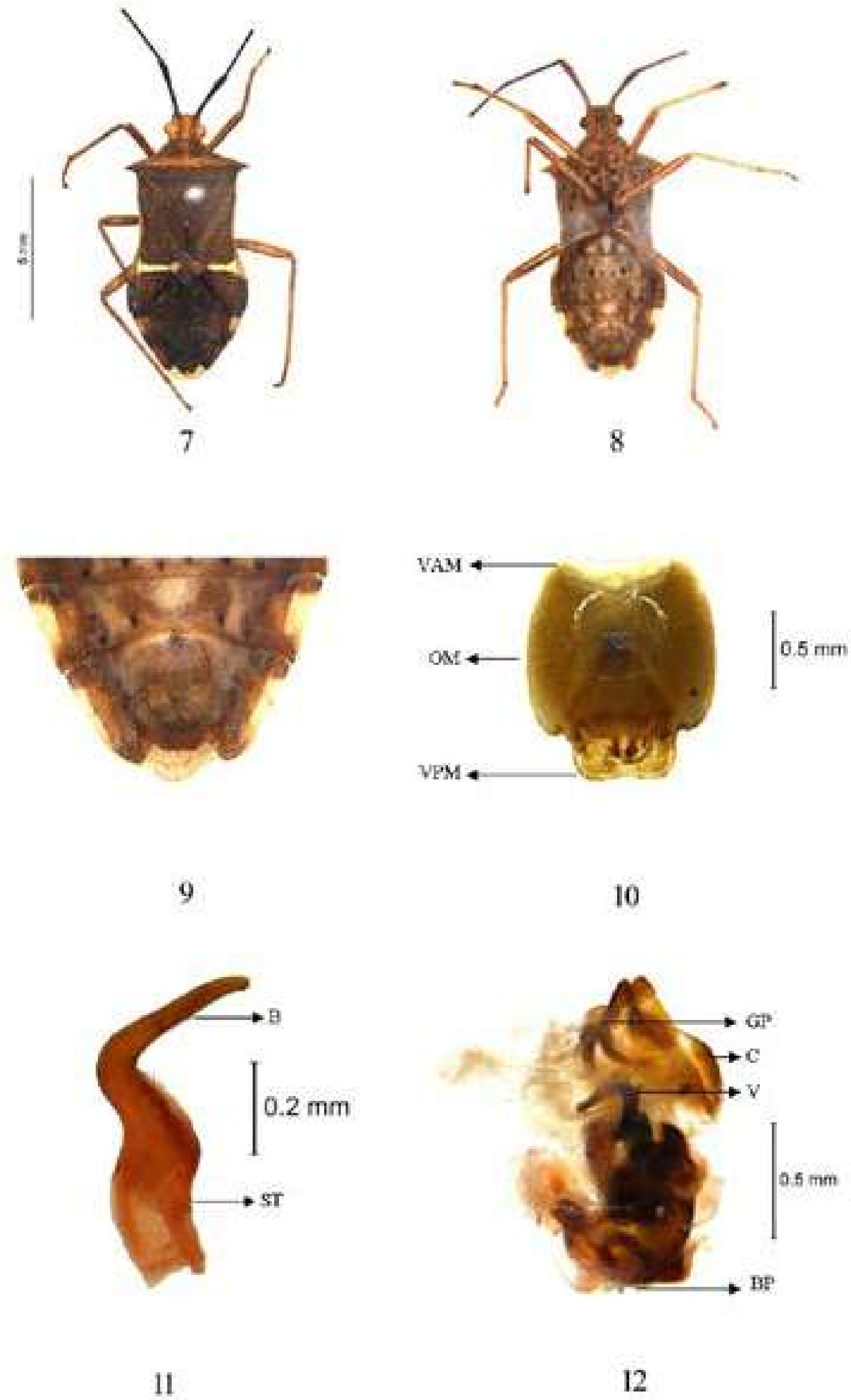
Characters	*Cletomorpha raja*	*Cletomorpha hastata*	*Cletomorpha benita*	*Cletomorpha walkeri*
Basal part of antennae	Without any spine.	With a spine.	With a spine.	With a spine.
Anterolateral part of Pronotum	Without spine.	With a number of small acute spines.	Without spine.	Without spine.
Pronotal angle	Acutely produced spine & its apices recurved.	Spine small acute and straight.	Spine acute and slightly bent downward.	Very acute and straight.
corium	With very prominent transverse band.	With a pale fascia.	With three prominent macular spot.	With a single spot.
Ventral part of Abdomen	Having scattered spot.	Having patch.	Having clumsy spot.	Having scattered spot.

Discussion

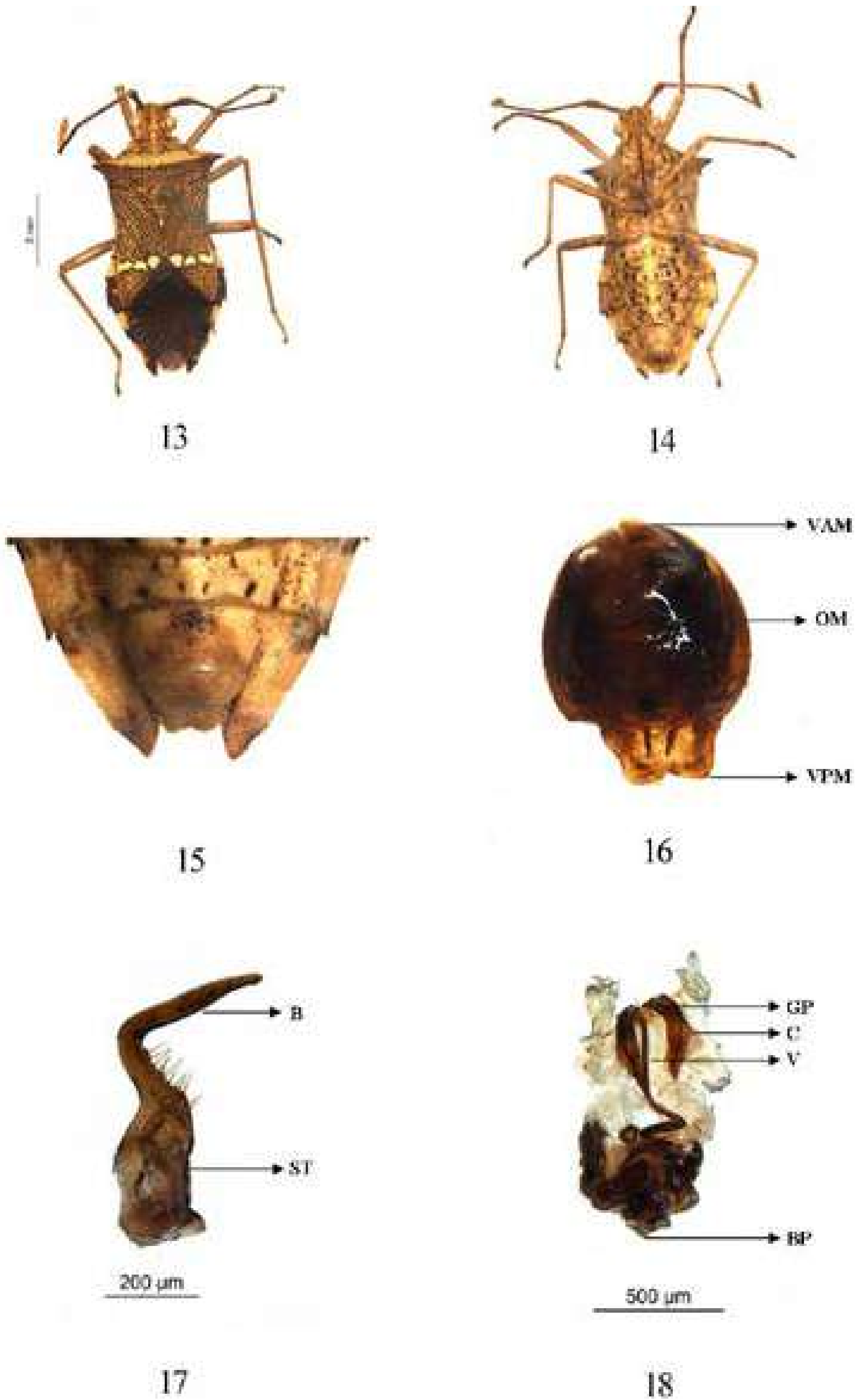
The genus *Cletomorpha* Mayr, 1866 is distinguished from its closely allied genus *Cletus* Stal 1860 by presence of acutely and exteriorly produced connexival segment. Among the four Indian species of this genus *C.raja* and *C. hastata* is redescribed by Gupta and Singh, 2013. These two species is widely distributed in India. Paulson *et al.* (2020) recorded *C. benita* as a pest from Vadodara, Gujarat and Kushwaha *et al* (2023) reported this species from Mizoram. The present study reported *C. benita* first time from West Bengal. Among the four Indian species of genus *Cletomorpha*, three species such as *C.raja, C.hastata, C.benita* are available in National Zoological Collection of Zoological Survey of India, another one *C. walkeri* have been studied from literature only. Main distinguishing character of different species of *Cletomorpha* is marking present on corium. In case of *C. raja* a broad whitish band present on corium, but in *C. hastata* only a pale fascia present on corium which differ from *C. benita* having three prominent macular spot on corium and in C. walker only a single spot present on corium. Genital structure is also different among these species. Outer margin of pygophore of *C. raja* is more or less oval shaped and having prominent concavity posteriorly which is absent in other two species. Besides outer margin of *C. benita* is rounded and *C. hastata* is sub straight. Anterior portion of blade of paramere of *C. hastata* is more curved compared to other two species. In case of *C. benita* hair numerous in number and distributed in the two third region upper outer margin of paramere stem. But in *C. raja* hair is comparatively less, shorter and distributed in the one third region upper outer margin of paramere stem.



Figures 1-6. *Cletomorpha hastata* (Fabricius, 1787). 1. Habitus (Dorsal view). 2. Habitus (Ventral view). 3. External genitalia. 4. Pygophore. 5. Paramere. 6. Aedaegus.



Figures 7-12. *Cletomorpha raja* Distant, 1901**.** 7. Habitus (Dorsal view). 8. Habitus (Ventral view). 9. External genitalia. 10. Pygophore. 11. Paramere. 12. Aedaegus.



Figures 13-18. *Cletomorpha benita* Kirby, 1891**.** 13. Habitus (Dorsal view). 14. Habitus (Ventral view). 15. External genitalia. 16. Pygophore. 17. Paramere. 18. Aedaegus.

Acknowledgements

The authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India for encouragements and laboratory facilities. We are greatly thankful to Dr. C. Raghunathan, Divisional-in-charge, Entomology Division, Zoological Survey of India for his valuable suggestions and support. Authors are also thankful to all the officers and staffs of Hemiptera section for their helpful co-operation.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Morphological discrepancies of three *Garra* (Teleostei: Cyprinidae) in Arunachal Pradesh, India- a possible evolutionary process

Bungdon Shangningam[1]*, Shibananda Rath[2], Asha Kiran Tudu[3] & Laishram Kosygin[4]

[1] Wildlife & GIS Section, Zoological Survey of India, Prani Vigyan Bhawan, Kolkata-700053

[2,3,4]Freshwater Fish Section, Zoological Survey of India, 27 JL Nehru Road, Kolkata-700016

**Email: bdshangningam@gmail.com*

Abstract

The present study appraises the discrepancies patterns of morphometry for the first time on the three species of *Garra. Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* were collected from various locations of the Siang River in Arunachal Pradesh, India. The results of the morphological analysis revealed that *G. arunachalensis*, *G. birostris,* and *G. quadratirostris* hold many similar characteristics compared to the type species, which confirms its speciation. However, they parade distinct variations in morphological and meristic characters which indicate genetic variation as time lapsed. Certain morphometric characters overlapped. Hence the variations in many morphometric characters point towards a possible continuous evolutionary process. Details of the morphological discrepancies of the three species and possible hypotheses of climatic, geographical, and habitat changes are discussed.

Keywords: Pisces, Cypriniformes, *Garra*, Variations, Brahmaputra drainage

Introduction

The oxygen-rich mountainous streams of Northeast India form an ideal habitat for the genus *Garra* (Shangningam *et al.*, 2019). The snout modification viz., development of the proboscis, distribution pattern of the tubercles, and the transverse lobe are of taxonomic significance in distinguishing species of the genus. Based on the snout morphology, Nebeshwar and Vishwanath (2013) described *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* from the Brahmaputra River drainage of Arunachal Pradesh. Furthermore, on the basis of the snout and oromandibular morphology, Nebeshwar and Vishwanath (2017) has categorized the genus *Garra* occurring in India, Sri Lanka, China, and Southeast Asia into five distinct aspects: snout smooth; snout with a transverse lobe; snout with a proboscis and transverse lobe; snout with a pair of rostral flaps and snout with a pair of rostral lobes.

A collection of fishes from the Siang River, a tributary of the Brahmaputra River drainage in Arunachal Pradesh, India included three species viz., *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris.* Further detail examination revealed morphometric variations from the original description directing towards a possible continuous evolutionary process. Hence, the present study appraises the discrepancies patterns of morphometry on *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* for the first time.

Material and Method

The specimens were collected from the Siang River, a tributary of the Brahmaputra drainage, upper Siang district, Arunachal Pradesh, India. Specimens were fixed in 10 %formalin and subsequently transferred to 70 % ethanol for storage. GPS coordinates and elevations of the sampling sites were recorded using a Garmin Oregon750GPS. Measurements were taken point-to-point, with digital calipers, on the left side of the specimens, and recorded to the nearest 0.1mm. Counts, measurements, and terminology follow Nebeshwar & Vishwanath (2013).

*Author for correspondence :
Article Received on: 02.04.2023

Accepted on: 24.04.2023

Gular disc terminology follows Kottelat (2020). Counts for dorsal and anal-fin rays follow Kottelat (2001). Fin rays and the number of scales were counted using a Leica stereo-zoom microscope. Head length and measurements of the body are expressed as a percent of standard length (% SL). Specimens are deposited in the Zoological Survey of India, Freshwater Fish Section, Kolkata, India.

Systematic accounts

Class Actinopterygii

Order Cypriniformes

Family Cyprinidae

Genus *Garra* Hamilton, 1822

Garra arunachalensis **Nebeshwar & Vishwanath, 2013**

(Fig. 1)

Material examined. ZSI FF 9259, 2 exs, 152.1-161.8 mm SL, India: Arunachal Pradesh: upper Siang District, Gobuk village, Siang River: 28. 576831 N, 95.145417 E: Coll. S. D. Gurumayum, 20 December 2021.

Diagnostic characters. *Garra arunachalensis* belongs to the members of the snout with a proboscis and transverse lobe species group. It is characterized in having an elongate body, slightly compressed laterally, more compressed in the region of caudal peduncle. Snout with a transverse lobe with 17-18 small- to medium-sized tubercles and a prominent quadrate proboscis. Dorsal fin with iii, 8 rays, origin midway between snout tip and caudal-fin base. Pectoral fin with i, 15 rays, reaching beyond midway to pelvic-fin origin when adpressed. Pelvic fin with i,8 rays, reaching beyond midway to anal-fin origin, origin closer to anal fin origin than to pectoral-fin origin. Anal fin short with iii 5 rays, origin closer to caudal-fin base than to pelvic-fin origin. Anus closer to anal-fin origin than to pelvic-fin origin. Caudal fin forked, tip of lobes pointed; lower lobe slightly longer. Lateral line complete with 35 scales. Circumpeduncular scale rows 12. Predorsal scales 12. Chest and belly scaled. One long axillary scale at the base of pelvic fin, its tip reaching posterior end of pelvic-fin base.

Distribution. *Garra arunachalensis* is distributed in Upper Siang, West Siang, East Kameng and Lower Divang valley districts of the upper Brahmaputra basin in Arunachal Pradesh.

Garra birostris **Nebeshwar & Vishwanath, 2013**

(Fig. 2)

Material examined.ZSI FF 9258, 2 exs, 117.1-123.4 SL, India: Arunachal Pradesh: upper Siang District, Gobuk village, Siang River: 28. 576831 N, 95.145417 E: Coll. S. D. Gurumayum, 20 December 2021.

Diagnostic Characters. *Garra birostris,* a member of the snout with a proboscis and transverse lobe species group. It is distinguished from its congeners in the following: snout morphology with a transverse lobe with 16-17 small- to large-sized uni- to tetracuspid acanthoid tubercles; a prominent bilobed proboscis, moderately elevated upwards, each lobe forwardly protruding and tapering; the tip of each lobe with a large, anteriorly-directed tri- or tetracuspid acanthoid tubercle; the anterior margin of the proboscis sharply delineated by a deep groove from the depressed rostral surface; 1-2 small tubercles on the lateral margin of the proboscis. Dorsal fin with iii, 8 rays; its origin nearer to snout tip than to caudal-fin base, inserted anterior to vertical from pelvic-fin origin. Pectoral fin with 1, 14 rays, reaching beyond midway to pelvic-fin origin when adpressed; length slightly shorter than head length. Pelvic fin with 1, 8 rays, reaching beyond midway to anal-fin origin, origin closer to anal fin origin than to pectoral-fin origin. Anal fin short with iii, 5 rays. Caudal fin forked; lobe tips pointed; lower lobe slightly longer; tenth ray shortest. Lateral line complete, with 34 scales. Circumpeduncular scale rows 16. Predorsal scales 11 scales regularly arranged, same size as flank scales. Chest and belly scaled. One long axillary scale at the base of the pelvic fin, its tip reaching beyond the posterior end of pelvic-fin base.

Distribution. *Garra birostris* is widely distributed in Upper Siang, West Kameng, and Papum Pare districts of the upper Brahmaputra basin in Arunachal Pradesh.

Garra quadratirostris **Nebeshwar & Vishwanath, 2013**

(Fig. 3)

Material examined. ZSI FF 9260, 2 exs, 95.7-107.6 mm SL, India: Arunachal Pradesh: upper Siang District, Gobuk village, Siang River: 28. 576831 N, 95.145417 E: Coll. S. D. Gurumayum, 20 December 2021.

Diagnostic characters. *Garra quadratirostris* is distinguished from its congeners in having the following combination of characters: snout morphology with a prominent transverse lobe with 13-14 small to large-sized tubercles; a prominent quadrate proboscis, moderately elevated towards the anterior margin of the proboscis truncate, and sharply delineated from the depressed rostral surface by a narrow transverse groove; and small to medium-sized tubercles on the margins of the proboscis in a single row. Dorsal fin with iii, 8 rays, origin inserted anterior to vertical from pelvic-fin origin. Pectoral fin with 1, 15 rays, reaching beyond midway to pelvic-fin origin when adpressed; length equal or shorter than head length. Pelvic fin with 1, 8 rays, reaching beyond midway to anal-fin origin, surpassing anus; second branched ray longest, not extending to the base of anal fin; origin closer to anal fin origin than to pectoral-fin origin, inserted below the base of third branched dorsal-fin ray; distal margin almost truncate or slightly convex. Anal fin short with iii, 5 rays, reaching the base of caudal fin; distal posterior margin straight; origin closer to caudal-fin base than to pelvic-fin origin. Anus closer to anal-fin origin than to pelvic-fin origin. Caudal fin forked; tip of lobes pointed; lower lobe slightly longer. Lateral line complete with 37 scales. Circumpeduncular scale rows 12. Predorsal 11 scales regularly arranged same size as flank scales. Chest and belly scaled.

Distribution. *Garra quadratirostris*is widely distributed in Upper Siang, West Kameng, and Papum Pare districts of the upper Brahmaputra basin in Arunachal Pradesh.

Results and Discussion

Nebeshwar & Vishwanath (2013) described *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* from the Brahmaputra River Drainages of Arunachal Pradesh, India (Fig. 4) in having a prominent proboscis, a transverse lobe on the snout with tubercles and black spots on the base of the dorsal-fin rays. *Garra arunachalensis* is distinguished in having a prominent quadrate proboscis with two large unicuspid acanthoid tubercles, one on each anterolateral marginal corner and one small tubercle in between; and in the absence of an anterolateral lobe. *Garra birostris* is distinguished in having a prominent bilobed proboscis with one large tri- or tetracuspid acanthoid tubercle on each lobe, and a distinct black spot at the upper angle of gill opening. *Garra quadratirostris* is distinguished in having a prominent quadrate proboscis with three or four small- to medium-sized tubercles on the anterior margin, and a faint blackish spot immediately anterior to the upper angle of the gill opening.

These three species are abundantly present in various water bodies of the Brahmaputra River drainage of Arunachal Pradesh, India. They slightly differ in their morphological features but certain characters overlap each other. Morphometric measurement values obtained for the three species of *Garra* are shown in Table 1. *Garra arunachalensis* exhibited distinct variations in the morphological character such as head depth, caudal peduncle depth, dorsal fin base length, dorsal fin length, pre pectoral length, eye diameter, and other minor variations in meristic. *G. birostris* shows distinct variations in the morphological character such as head depth, caudal peduncle depth, dorsal fin base length, pelvic anal distance, pre-anus length, vent to anal fin origin pre pectoral length, and a few variations in meristic including caudal peduncle and lateral line scale count. *G. quadratirostris* also depicts distinct variations in the morphological character such as body depth, body width at anal-fin origin, and a few minute variations in meristic including lateral line scale count.

Many fish species are now facing increasing threats by exploitation, pollution, habitat destruction, dispersal barriers, overfishing, and ongoing climatic changes that bring modified novel move variable and extreme condition as well as selection regimes. Changes in the river connectivity associated with removal of dispersal barriers such as dams and construction of fishways together with compensatory breeding and supplemental stalking impact on gene flow and selection. However, this in terms affects dynamics genetic structure, and genetic diversity evolutionary potentials (Tamario *et al.*, 2019). The statement given is true for migratory fishes but this might also importantly factor in evolutionary process for non-migratory fishes like *Garra.* Further, harvesting can induce rapid evolution in animal populations yet the role of economic change in buffering or enhancing that response is poorly understood (Gobin *et al.*, 2018). Human activity can induce rapid evolutionary change in animal populations with resulting ecological consequences and impacts on society (Hendry *et al.*, 2017). Sometimes evolution is also evident owing to heavy pollution and changes in the food habitats. Intensive and trait-selective mortality of fish can cause an evolutionary change in the range of life history and behavior traits. This change might in terms alter the sub-cardian system due to co-evolutionary mechanism and co-related selection response both at behavioral and molecular levels with a note on effects on daily physiological processes and behavior output (Sbragaglia *et al.*, 2020).

Darwin's competitive speciation of the gradual expansion into a new niche occurs in response to competitive pressure within the old niche. So, the variation observed in the present *Garra* species may lead to a new species in the course of the ontogeny changes. Expansion of the population niche and adaptation to novel resources may result in sympatric speciation. Variations in size and shape may be influenced by various factor which include habitat changes, water temperature, food habitat, genetic variation, maturity, and adaptive characteristics of fishes. Often, this character may lead to species changes and tends to new species. There is the probability that after repeated changes, natural selection of fitness arises. Hence, the reported three species of *Garra* maybe in an evolutionary process, to the patterns of morphological variation in the primary range of the species.

Table 1. Morphometric variation for *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris.*

	Garra arunachalensis		***Garra birostris***		***Garra quadratirostris***	
	ZSI FF 9259	Nebeshwar & Vishwanath (2013)	ZSI FF 9258	Nebeshwar & Vishwanath (2013)	ZSI FF 9258	Nebeshwar & Vishwanath (2013)
Standard Length	152.1-161.8	84-140	117.1-123.4	40-143	117.1-123.4	73-132
% SL						
Body Depth	20.3-28.7	22.3-25.4	18.0-18.2	21.3-24.6	17.6-18.2	20.3-28.2
Head Length	25.1-25.5	24.6-27.1	21.6-22.9	22.8-25.3	24.1-25.3	23.8-26.7
Head Depth	14.9-15.6	17.1-18.8	14.6-15.4	16.8-18.4	15.2-16.6	15.9-18.7
Body width at anal fin origin	8.8-10	9.6-12.6	7.9-10.3	9.7-11.5	7.1-8.8	11.0-12.5
Caudal Peduncle depth	13.1-13.2	11.7-12.9	8.6-12.6	12.7-14.4	12.6-13.4	12.9-14.4
Dorsal-fin base Length	19.7-19.8	16.4-17.6	15.9-16.6	17.5-19.7	16.3-17.2	17.1-18.4
Dorsal-fin Length	25.2-26	16.4-20.1	23.5-25.0	21.7-27	24.0-25.1	24.1-27.1
Pectoral-fin Length	21.6-23.9	22.3-26.5	19.8-20.9	21.0-23.9	13.5-23.8	21.0-24.6
Prepectoral Length	22.1-23.5	21.4-21.9	19.9-21.8	20.5-23.8	21.5-25.0	19.8-23.3
Pelvic-anal distance	24.8-25.3	24.1-26.9	22.8-23.7	25.7-30.0	24.2-25.1	23.7-26.1
Pre anus length	71.1-72.1	69.6-75.0	68.0-69.3	71.1-73.0	67.9-68.7	66.8-72.3
Vent to anal fin origin	19.9-21.5	19.0-25.0	39.7	21-30	37.1-39.6	37-44

Figure 1. *Garra arunachalensis*, ZSI FF 9259, 161.8 mm SL, Siang River near Gobuk village, Upper Siang District, Arunachal Pradesh, India.

Figure 2. *Garra birostris,* ZSI FF 9258, 123.4 SL, Siang River near Gobuk village, Upper Siang District, Arunachal Pradesh, India.

Figure 3. *Garra quadratirostris*, ZSI FF 9260, 95.7, Siang River near Gobuk village, Upper Siang District, Arunachal Pradesh, India.

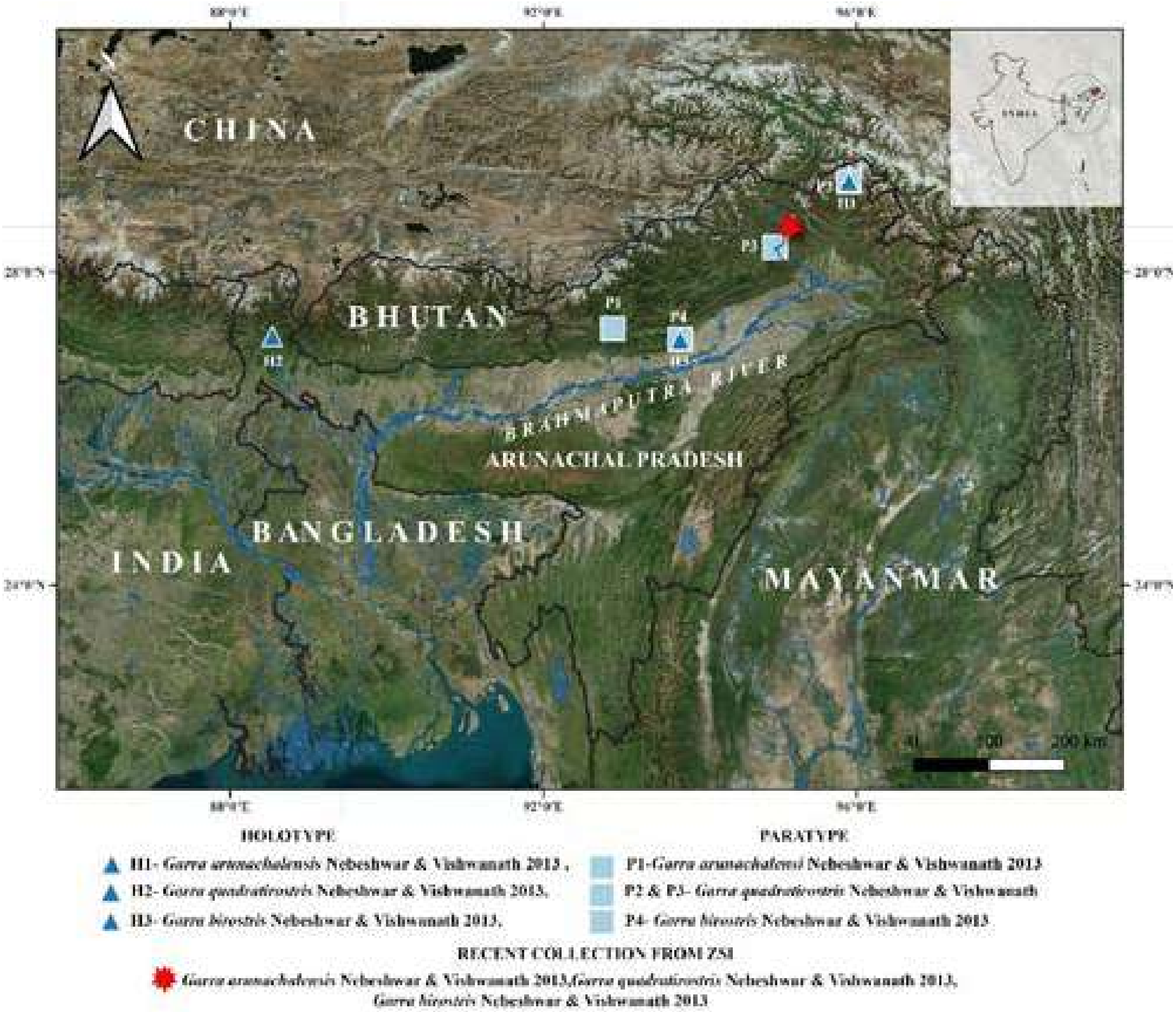

Figure 4. Distributional map of *Garra arunachalensis, G. birostris* and *G. quadratirostris.*

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Comparative Morphometric Studies of The *Habrobracon hebetor-brevicornis* and *Bracon lefroyi-greeni* Complexes of Braconid Wasps (Hymenoptera: Braconidae: Braconinae)

Longjam Roni Kumar Singh[1]* and Dulal Chandra Ray[2]

[1]Zoological Survey of India, M- Block, New Alipore, Kolkata 700053
[2]Department of Ecology and Environmental Science, Assam University, Silchar, Assam 788801; raydulal@yahoo.co.in

Abstract

The accurate identification of parasitoids is of immense importance to biological control programs. Despite their economic importance and commonly occurring, the taxonomy of *Habrobracon hebetor-brevicornis* and *Bracon lefroyi-greeni* complexes is difficult and currently confused being cryptic and occurring as distinct populations as well as groups of populations. Thus, there exists confusion in species recognition and the diagnosis of the appropriate host can dramatically affect the outcome of a biological control program. This study focuses on the morphometric variations in females of five biotypes in each complex associated with different hosts and localities. Statistical analyses, such as Unweighted Pair-Group Method Arithmetic Average (UPGMA) cluster analysis, Canonical Discriminant Analysis and Predictive Discriminant Analysis were used to analyse the complexes, and these also enabled the identification of taxonomically important characters in differentiating the population and grouping. The evidence presented here rationalizes the confusion between the species complexes, and the additional morphological characters brought out here will help to resolve the taxonomic complexity.

Keywords: Biocontrol, parasitoid, biotypes, character, complex, identification, morphometrics

Introduction

Hbrobracon hebetor-brevicornis Complex

The species of the *Habrobracon hebetor-brevicornis* and *Bracon lefroyi-greeni* complexes are parasitoids of economically important insect pests and have considerable potential as biological control agents. Despite their economic importance and commonly occurring, the taxonomy of these is difficult and currently confused as these occurred as complexes and distinct populations as well as groups of populations. It is essential to bring out the complexity, delineate, and explore their complexities through detailed study, especially of morphometrics.

The species of the *Habrobracon hebetor-brevicornis* complex are economically important worldwide for the biological control of lepidopteran insect pests. They are polyphagous, larval ectoparasitoids and sometimes overlap among the populations parasitizing the various host species (Puttarudriah and Channa Basavanna, 1956). The complex consists of two morphologically similar species: *H. hebetor* (= *Bracon hebetor* Say, 1836) and *H. brevicornis* (= *Braco brevicornis* Wesmael, 1838), which has led to confusion in species recognition and also in synonymization. Cushman (1922) first attempted to clarify the species identity of *B. juglandis* Ashmead, 1889 (= *H. hebetor*) and *H. brevicornis*, relying upon the variations in antennal segments, i.e., with 13-15 segments in the former and that of later with 17-19 segments. Cushman did not mentioned *H. hebetor* and their relationship with *H. juglandis*. Later, Muesebeck (1925) refer the character used by Cushman (1922) that distinguished *H. juglandis* from *H. brevicornis* and the original description of *H. hebetor*, which led to synonymized *H. juglandis* with *H. hebetor* and provided a key (under the genus *Microbracon*). Lal (1947) studied the identity of the complex species reared from various hosts at the Indian Lac Research Institute (= National Institute of Secondary Agriculture), Namkum,

*Author for correspondence : lucicrohn@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Ranchi, Jharkhand and at the Imperial Agricultural Research Institute (= Indian Agricultural Research Institute), New Delhi. He shows the confusion prevailing and comes to the conclusion that these species can be separated with Muesebeck's key (1925), with a slight modification in the female antennal segments of *H. brevicornis* (16-21 segments). Cherian and Margubandhu (1951) followed Muesebeck's work and retained these as two distinct species. Puttarudriah and Channa Basavanna (1956) studied the species complex by deploying morphology i.e., colour, antennal segments, genitalia, and biology and concluded that the two names should be synonymized. However, Narayanan *et al.* (1958) suggested that it is a complex of more than two species. In the meantime, Chawla and Subba Rao (1965) further studied the identity of *H. hebetor-brevicornis* complex using the paper chromatography technique and suggested that the complex consists of two distinct species.

The species taxonomy of the complex is thus difficult, hardly discernible and currently confused. Some authors believed these are identical and *H. brevicornis* is a junior synonym of *H. hebetor* (Papp, 2008, 2012; Yu *et al.*, 2012; Ameri *et al.*, 2013). At the same time, some treated these as two distinct species (van Achterberg and Polaszek, 1996; van Achterberg and Walker, 1998; Haider *et al.*, 2004; Sheeba and Narendran, 2007; Ehteshami and van Achterberg, 2012). However, most biologists frequently used the name *H. brevicornis* (sometimes under the genera *Bracon* or *Microbracon*) ignoring the existence of complexity at the species level (Krishnamurti and Appana, 1944; Dharmarju, 1952; Subba Rao and Kumar, 1960; Deka, 1969; Sarup *et al.*, 1971; Mathai, 1972; Jacob *et al.*, 1980; Mathew *et al.*, 1980; Narendran *et al.*, 1981; Abbas, 1982; Ram *et al.*, 1982; Sudheendrakumar *et al.*, 1982; Jayanth and Nagarkatti, 1985; Ghosh *et al.*, 1993; Nasser and Abdurahiman, 1998; Mohapatra and Mohapatra, 2003; Venkatesan *et al.*, 2009; Srivastava *et al.*, 1997; Mohanty *et al.*, 2000; Rukhsana and Sebastian 2015). Recently, molecular identification of the two species had been done for the populations from Barbados and the United States by Heimpel *et al.* (1997), Egypt by Bakr *et al.* (2003), India by Rukhsana and Sebastian (2015), Thailand and Japan by Chomphukhiao *et al.* (2018) and from Germany, Egypt, Japan, Spain, Thailand, United States, Uzbekistan, and Barbados by Kittel and Maeto (2019). This study reviewed their status as distinct species.

***Bracon lefroyi-greeni* complex**

Bracon greeni Ashmead, is an important larval parasitoid of lac insect predator, *Eublemma amabilis* Moore (Lepidoptera: Noctuidae) and *Syncola pulverea* (Meyrick) (Lepidoptera: Blastobasidae) (Varshney, 1976). *Bracon lefroyi* (Dudgeon and Gough) is also a larval parasitoid of spotted bollworms of cotton, *Earias insulana* Boisduval, *E. vittella* (Fabricius (Lepidoptera: Noctuidae) and pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) (Sharma *et al.*, 2000; Naik *et al.*, 2018). *Bracon greeni* and *B. lefroyi* are very similar to each other in general appearance and morphology, and it is often difficult to separate them. The species complexity had been studied using selected morphological characters viz., colour, antennal segment, wing veins, etc. Lal (1939) established that there is not a single constant morphological character by which this complex species can be distinguished and concluded that *B. greeni* and *B. lefroyi* are two biological races of the same species. Till now no valid key for identification is available, however, Sheeba and Narendran (2013) keyed out these as distinct species in their key to the Indian species of *Bracon*, but their description is quite confusing since some taxonomic attributes of *B. greeni* written in *B. lefroyi* (such as ovipositor length) and *B. lefroyi* was considered near *B. albolinetus* Cameron, which had been transferred to the genus *Amyosoma*.

Thus, there exists confusion in species recognition and the diagnosis of appropriate host strains can dramatically affect the outcome of a biological control program against a specific host species. Hence, the present study focuses on the morphometric variations in females of five biotypes in each complex associated with different hosts and localities, on the basis of one meristic and 14 ratio characters.

Materials and Methods

The present study is based on the specimens from the National Pusa Collection (NPC), Division of Entomology, Indian Agricultural Research Institute, New Delhi (studied during 2012-2015). In addition, specimens from the Biological Control Laboratory, Division of Entomology, IARI, New Delhi and Central Institute for Cotton Research (CICR), Nagpur, Maharashtra, received by Dr. V.V. Ramamurthy for observations have been included.

Selection and preparation of samples

Fresh specimens collected and received were examined under a Leica M205FA stereozoom microscope and mounted on pointed triangular cards with a very small amount of water-soluble glue using a Leica EZ4 stereozoom microscope. Care was taken to spread the legs and wings so as to expose all the taxonomic characters of importance. The specimens were labelled with data of locality, host, date and name of the collector. The museum specimens were individually examined under the stereozoom microscope to confirm their uniformity and suitability for morphometrics. Physical conditions like cleanliness, completeness and amenability for measurement were the criteria utilized for the selection of specimens. Such good specimens of nearly uniform nature and complete with the least variability were randomly selected irrespective of the identity of species and grouped into various biotypes pertaining to the various hosts and localities and their numbers as indicated (Table 1).

Selection and measurement of characters

The general morphological characters illustrated by van Achterberg (1979) were utilized. Both males and females are equally taxonomically important, though females are most relied upon for authentic generic and species identification. Taxonomic characters especially ovipositor sheath length had been earlier relied upon greatly (van Achterberg and Quicke, 1992). Literature on the taxonomic descriptions of Braconidae as a whole was also consulted for the selection of characters (van Achterberg, 1979, 1992, 1993; Quicke, 1982, 1987). Thus, a total of 15 and 13 quantitative characters were measured in 52 specimens from *H. hebetor-brevicornis* (23) and *B. lefroyi-greeni* (29) complexes, respectively, for the analysis of morphometrics. The biotypes with codes NPECT, belonging to the *B. lefroyi-greeni* and DECOR, belonging to *H. hebetor-brevicornis* complex species group, were used as outgroups in the respective species complex analyses. The quantitative characters were of two kinds: meristic and ratios (Table 2) and data were transformed using $\log_{10}(x+1)$.

While studying so, care was taken to ensure the specimens were always in the same plane and angle to ensure uniformity and concordance of values. Individual specimens were examined carefully under the stereozoom microscope at 50× for the selected measurements. The measurements in terms of ocular values were tabulated and these were further calibrated using a stage micrometer, and then used for the statistical analyses.

Statistical analyses

The pattern of morphometrics was analysed using the following multivariate statistical approaches: (i) The average-linkage-between-groups method, often called UPGMA (Unweighted Pair-Group Method Arithmetic Average) using Euclidean distance is a simple agglomerative (bottom-up) hierarchical clustering method; (ii) Canonical Discriminant Analysis (CDA) (or Canonical Discriminant Function Analysis in SPSS) is a dimension-reduction technique. CDA was carried out to assess the canonical variables that provide maximal separation between the groups, and (iii) Predictive Discriminant Analysis (PDA) is a predictive classification technique which is concerned with classifying observations into one of several groups. PDA was used to determine the potential misclassification of specimens or populations. Statistical analysis was performed with SPSS Version 20.0 (SPSS Inc, Chicago, IL, USA) for Windows.

Results

A. *Habrobracon hebetor-brevicornis* complex

(i) UPGMA

The linkage distance among the biotypes of the complex based on morphometrics is indicated in Fig. 1 by an UPGMA dendrogram. This shows a main cluster including all the biotypes except NPECT (outgroup) in another cluster. The main cluster was subdivided into two subclusters, the first included two biotypes DELIR and DEANT. In the second subcluster two biotypes NEUBA and DECOR are very closely clustered and DEEAR biotype is separated from the previous two biotypes.

(ii) Canonical discriminant function analysis

The eigenvalues indicated that the first two canonical variate pairs provide a summary of the discrimination abilities with 95.9% of the total variation and the first two canonical correlations (0.99 and 0.99) are very high and these imply that these two correlations are important (Table 3). Individual specimens are projected on the first two canonical axes (CV1 and CV2) which contain the highest percentage of variability. NPECT specimens are clearly separated along the first two canonical axes from the DEARI, FEARI, DBRIN, NPECT and NEUBA and are in the III quadrant (Fig. 2). DELIR specimens are in I quadrat with weakly discriminated from the specimens of DEANT. Most of the specimens of the NEUBA and DECOR form a uniform cluster with weakly separated DEEAR and are in IV quadrant.

Biotypes NEUBA, DECOR and DEEAR are clearly separated from DELIR and DEANT specimens along the first two canonical axes. Class mean for NEUBA, DECOR and DEEAR are 9.73, 9.12 and 11.44, and for DELIR and DEANT are 6.58 and 5.72 along the 1st canonical axis (Table 4). And for the 2nd canonical axis, class mean for NEUBA, DECOR and DEEAR are -4.95, -5.93 and -2.50, and for DELIR and DEANT are 7.57 and 10.70, respectively. Taxonomic characters which contribute to the greatest extent to the discrimination of specimens of NEUBA, DECOR and DEEAR from DELIR and DEANT specimens along the 1st canonical axis are: number of antennal segments (ALN), length of 2nd flagellar segment: width of 2nd flagellar segment (F2L/F2W), length of 3rd radius sector: length of 2nd radius sector (SR1/3-SR) and length of ovipositor sheath: length of metasoma (OL/ML) (Table 4). On the 2nd canonical axis are: number of antennal segments (ALN), length of antenna: length of head and mesosoma (AL/HML), transverse diameter of eye: length of temple (EL/TML), length of 1st flagellar segment: width of 1st flagellar segment (F1L/F1W), length of 2nd flagellar segment: width of 2nd flagellar segment (F2L/F2W), length of 2nd radius sector: length of 1st radius sector (3-SR/r), length of 2nd radius sector: length of 1st intercubitus (3-SR/2-SR).

iii) Predictive discriminant analysis

The classification matrix of discriminant analysis in Table 5 shows the number and percentage of correctly placed specimens in the studied populations. All the specimens of biotypes DECOR, DEEAR, DELIR and DEANT are correctly placed. However, it is mixed classified with the specimens of NEUBA biotype, ex. *Eublemma amabilis* from Namkum, Ranchi, Jharkhand biotype. An overall 96.4% of original grouped cases got correctly classified.

B. *Bracon lefroyi-greeni* complex

(i) UPGMA

The UPGMA dendrogram (Fig. 3) shows a main cluster including all the biotypes except DECOR (outgroup) in another cluster. The main cluster included four biotypes (DEARI, FEARI, NEUBL and DBRIN) at a considerable distance from NPECT. In this subcluster of the two biotypes, DEARI and FEARI are very closely clustered with NEUBL, and DBRIN biotype is separated from the previous three biotypes.

(ii) Canonical discriminant function analysis

The eigenvalues indicated that the first two canonical variate pairs provide a summary of the discrimination abilities with 96.0% of the total variation and the first two canonical correlations (0.99 and 0.96) are very high and these imply that these two correlations are important (Table 6). Individual specimens are projected on the first two canonical axes (CV1 and CV2) which contain the highest percentage of variability. NPECT and DBRIN are clearly separated along the first two canonical axes from DEARI, FEARI and NEUBL specimens. Class mean for NPECT and DBRIN are 2.074 and 3.244, and for DEARI, FEARI and NEUBL are -5.484, -5.922 and -4.347, along the 1st canonical axis, respectively (Table 7). On the 2nd canonical axis, class mean for NPECT and DBRIN are -5.732 and -4.887, and for DEARI, FEARI and NEUBL are 2.426, 2.562 and 0.381, respectively. Taxonomic characters which contribute to the greatest extent to the discrimination of specimens of NPECT and DBRIN from DEARI, FEARI and NEUBL specimens along the 1st canonical axis: length of 1st flagellar segment: width of 1st flagellar segment (F1L/F1W), length of 2nd flagellar segment: width of 2nd flagellar segment (F2L/F2W), and length of ovipositor sheath: length of metasoma (OL/ML). On the 2nd canonical axis are: length of 1st flagellar segment: width of 1st flagellar segment (F1L/F1W) and length of 2nd flagellar segment: width of 2nd flagellar segment (F2L/F2W).

DECOR specimens are clearly separated along the first two canonical axes from the DEARI, FEARI, DBRIN, NPECT and NEUBL and are in the I quadrant (Fig. 4). NPECT specimens are in IV quadrat with weakly discriminated from the specimens of DBRIN. Most of the specimens of the DEARI and FEARI form a uniform cluster with partial overlapping with NEUBL and are in II quadrant.

iii) Predictive discriminant analysis

The specimens of two biotypes NPECT, ex. *Pectinophora gossypiella* from Nagpur and DBRIN from Delhi (NPC) are correctly placed (Table 8). With other three biotypes such as DEARI, ex. *Earias fabia, E. insulana* from Delhi (NPC), FEARI, ex. *E. insulana* from Faisalabad, Pakistan (NPC) and NEUBL, ex. *Eublemma amabilies* from Ranchi (NPC) show the lowest percentage of correctly placed i.e., 42.8, 80.0, 62.5, respectively. An overall 75.8% of original grouped cases were correctly classified.

Discussion

***Habrobracon hebetor-brevicornis* complex**

This species complex consists of two morphologically similar species viz., *Habrobracon hebetor* and *H. brevicornis*. The species taxonomy of the two has been confused for many years. Some authors believed that these are identical but some treated them as distinct species. van Achterberg and Polaszek (1996) treated these as distinct and provided a key for identification, with the morphology viz., number of antennal segments and forewing veins 3-SR and r. But most biologists frequently used the name *B. brevicornis* (sometimes under the genera *Bracon* or *Microbracon*) ignoring the existence of complexity at the species level. This made more confusion about the identity and is not allowed in the case of these parasitoids considering their importance in insect pest control.

The present study focuses on the morphometric variations in females of five biotypes of different hosts and localities. Using numerical methods we showed a clear distinction between the species of *H. hebetor* and *H. brevicornis* reared or bred from the host (see Table 1). The taxonomic character which has the greatest contribution to the distinction of NEUBA, DÉCOR and DEEAR biotypes from the biotypes DELIR and DEANT on both axes are: number of antennal segments (ALN) and length of 2nd flagellar segment: width of 2nd flagellar segment. The number of antennal segments for NEUBA, DÉCOR and DEEAR biotypes has 12-14 segments (= *H. hebetor*, Fig. 5a) and that of DELIR and DEANT have 15-21 segments (= *H. brevicornis*, Fig. 5b), which was used as an important diagnostic character in *H. hebetor and H. brevicornis* (van Achterberg and Polaszek (1996). Besides this characters: length of antenna: length of head and mesosoma (AL/HML), length of 2nd radius sector: length of 1st radius sector (3-SR/r) has an important contribution to the discrimination of both groups, which support the work of van Achterberg and Polaszek (1996).

***Bracon lefroyi- greeni* complex**

The parasitoids, *Bracon greeni* and *B. lefroyi* are very similar to each other in general appearance and morphology so it is often difficult to separate them. Nevertheless, the complex species were studied using limited selected morphological characters, colours, antennal segments, wings veins, etc. Lal (1939) stated that there is not a single constant morphological character by which this complex species can be distinguished and he believes that these two *B. greeni* and *B. lefroyi* are two biological races of the same species.

The taxonomic character which has the greatest contribution to the distinction of DBRIN and NPECT biotypes from the other biotypes are: length of 1st flagellar segment: width of 1st flagellar segment, length of 2nd flagellar segment: width of 2nd flagellar segment and length of ovipositor sheath: length of metasoma (OL/ML). The length of the ovipositor sheath of DBRIN, ex. pest of brinjal from New Delhi, is shorter than the length of metasoma (i.e. 0.5-0.85), thus supporting the original description of *B. greeni* (Ashmead, 1896; cf. Ramakrishna Ayyar, 1928; Fig. 6c). Whereas, NPECT, ex. *Pectinophora gossypiella* from Nagpur, the length of ovipositor sheath is as long as or longer than length of metasoma (i.e. 1.0-1.), showing the character of *B. lefroyi* (Fig. 6d), thus supporting the works of Brues (1920) and Ramakrishna Ayyar (1928). However, the other three biotypes such as DEARI, ex. *Earias fabia, E. insulana* from Delhi (NPC), FEARI, ex. *E. insulana* from Faisalabad, Pakistan (NPC) and NEUBL, ex. *Eublemma amabilies* from Ranchi (NPC) show similar affinities with NPECT biotype in terms of length of ovipositor sheath, but differ in having ocello-ocular line: transverse diameter of posterior ocellus = 2.0-2.6 (vs 1.5-1.7 in NPECT biotype); transverse diameter of eye: length of temple = 1.7-2.3 (vs 2.8-3.2).

The evidence presented here rationalizes the confusion between these complexes and shows the aggregation of similar species occurring as distinct populations as well as clusters of populations with the presence of overlapping characters and the utility of the selected characters for the characterization of species or populations. Multivariate analyses enabled the identification of taxonomically important characters, which will help to resolve the taxonomic complexity of the *H. hebetor-brevicornis* and *B. lefroyi- greeni* complexes under studied and other populations as well.

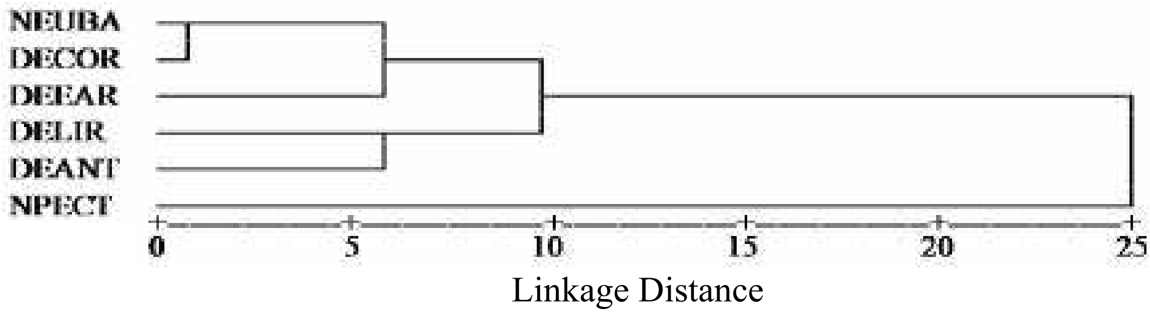

Figure 1 . UPGMA dendrogram of generalized distances between the *H. hebetor-brevicornis* complex.

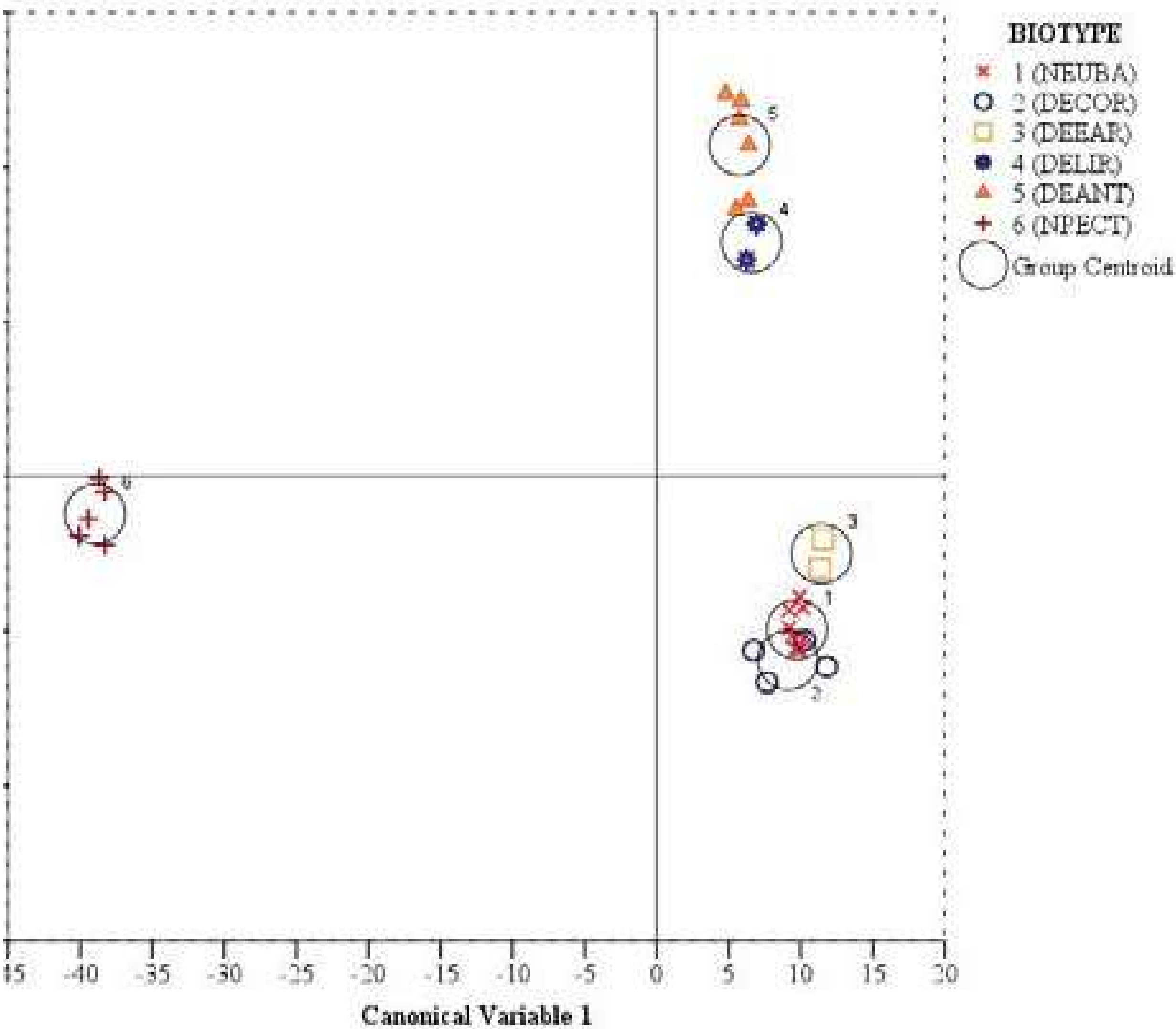

Figure 2. Plot of biotypes on the first two canonical axes of class means (*H. hebetor-brevicornis* complex*)*.

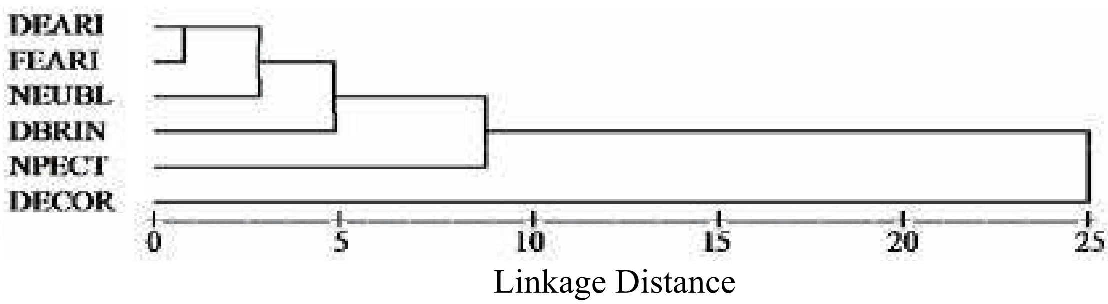

Figure 3. UPGMA dendrogram of generalized distances between the *B. lefroyi-greeni* complex.

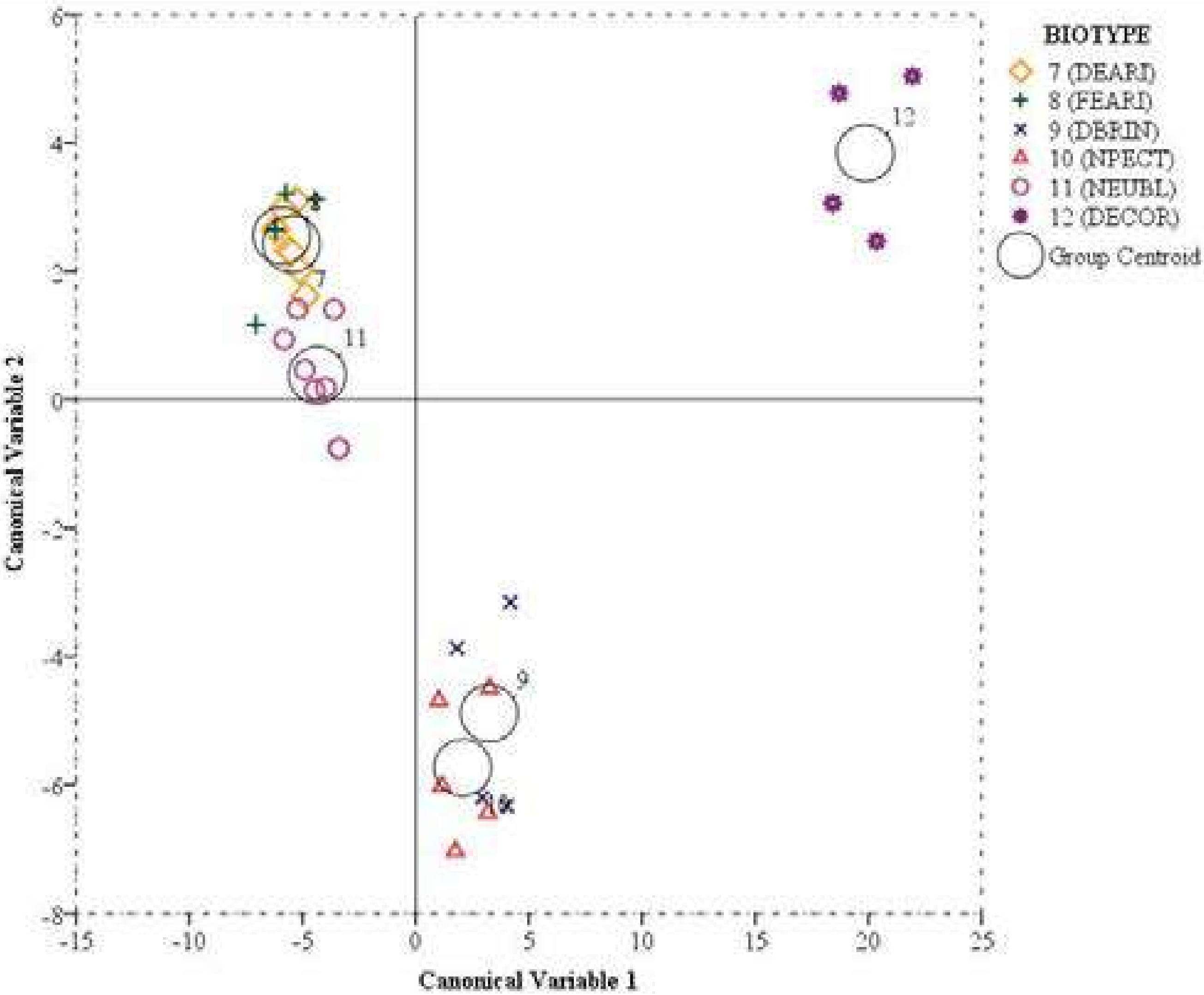

Figure 4. Plot of biotypes on the first two canonical axes of class means (*B. lefroyi-greeni* complex).

Table 1. Details of species, biotype codes, hosts, and localities of the material examined of *Habrobracon hebetor-brevicornis* and *Bracon lefroyi-greeni* complexes

Species	Biotype code	Number of specimens	Host	Locality
B. hebetor-brevicornis complex	NEUBA	9	*Eublemma amabilis* Moore (Lepidoptera: Noctuidae)	Namkum, Ranchi, Jharkhand (NPC)
	DECOR	4	*Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae)	I.A.R.I., New Delhi
	DEEAR	2	*Earias* sp. (Lepidoptera: Noctuidae)	New Delhi (NPC)
	DELIR	2	*Liriomyza* sp. (Lepidoptera: Agromyzidae)	Delhi (NPC)
	DEANT	6	*Antigastra catalaunalis* (Lepidoptera: Crambidae)	Delhi (NPC)
B. lefroyi-greeni complex	DEARI	7	*Earias* sp., *E. fabia* (Stoll), *E. insulana* (Boisduval) (Lepidoptera: Noctuidae)	Delhi (NPC)
	FEARI	5	*E. insulana* (Boisduval) (Lepidoptera: Noctuidae)	Faisalabad, Pakistan (=Lyallapur, Punjab) (NPC)
	DBRIN	4	Pest of brinjal, host not defined	Delhi (NPC)
	NPECT	5	*Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)	Nagpur, Maharashtra
	NEUBL	8	*Eublemma amabilis* Moore (Lepidoptera: Noctuidae)	Namkum, Ranchi, Jharkhand (NPC)

Table 2. List of characters for morphometrics

Character no.	Character code	Type	Description
C1	ALN	Meristic	Number of antennal segments
C2	AL/HML	Ratio	Length of antenna: length of head and mesosoma
C3	POL/OD	Ratio	Posterior ocellar line: transverse diameter of posterior ocellus
C4	OOL/OD	Ratio	Ocello-ocular line: transverse diameter of posterior ocellus
C5	EL/TML	Ratio	Transverse diameter of eye (in dorsal view): length of temple
C6	F1L/F1W	Ratio	Length of 1stflagellar segment: width of 1stflagellar segment
C7	F2L/F2W	Ratio	Length of 2ndflagellar segment: width of 2ndflagellar segment
C8	3-SR/r	Ratio	Length of 2nd radius sector: length of 1st radius sector
C9	3-SR/2-SR	Ratio	Length of 2nd radius sector: length of 1stintercubitus
C10	SR1/3-SR	Ratio	Length of 3rd radius sector: length of 2nd radius sector
C11	SC+R1/1r-m	Ratio	Length of metacarpella: length of basella
C12	1r-m/2-SC+R	Ratio	Length of basella: length of 2ndcostella sector
C13	1-M/M+CU	Ratio	Length of 2ndmediella sector: length of 1stmediella sector
C14	OL/ML	Ratio	Length of ovipositor sheath: length of metasoma
C15	TBL/BTL	Ratio	Length of hind tibia: length of hind basitarsus

Table 3. Summary of Canonical Discriminant Functions (*H. hebetor-brevicornis* complex)

Sl. No.	Eigenvalues	% of Variance	Cumulative %	Canonical Correlation
1	423.652	85.1	85.1	.999
2	53.806	10.8	95.9	.991
3	12.987	2.6	98.6	.964
4	4.534	0.9	99.5	.905
5	2.666	0.5	100.0	.853

Table 4. Standardized Canonical Discriminant Function Coefficients with class means of canonical variables based on discriminant function for measurements of 15 morphological characters (*H. hebetor-brevicornis* complex)

Character	Canonical variable	
	CV1	CV2
ALN	**-1.265**	**1.243**
AL/HML	0.381	**1.645**
POL/OD	0.277	-0.001
OOL/OD	-0.047	-0.034
EL/TML	-0.121	**-1.071**
F1L/F1W	0.500	**1.959**
F2L/F2W	**1.108**	**-2.113**
3-SR/r	-0.985	**-1.957**
3-SR/2-SR	0.085	**2.221**
SR1/3-SR	**1.306**	0.921
SC+R1/1r-m	0.786	-0.726
1r-m/2-SC+R	0.425	-0.713
1-M/M+CU	-0.189	0.767
OL/ML	**-2.553**	-0.932
TBL/BTL	0.474	-0.772
Biotype	Class means (group centroids)	
NEUBA	9.733	-4.950
DECOR	9.121	-5.935
DEEAR	11.441	-2.503
DELIR	6.589	7.574
DEANT	5.770	10.705
NPECT	-38.953	-1.217

Table 5. Classification matrix of Discriminant Analysis for correctly placed specimens (*H. hebetor-brevicornis* complex)

	Predicted Group Membership						
Biotype	**NEUBA**	**DECOR**	**DEEAR**	**DELIR**	**DEANT**	**NPECT**	**Total**
NEUBA	8	1	0	0	0	0	9
(%)	88.9	11.1	0.0	0.0	0.0	0.0	100.0
DECOR	0	4	0	0	0	0	4
(%)	0.0	100.0	0.0	0.0	0.0	0.0	100.0
DEEAR	0	0	2	0	0	0	2
(%)	0.0	0.0	100.0	0.0	0.0	0.0	100.0
DELIR	0	0	0	2	0	0	2
(%)	0.0	0.0	0.0	100.0	0.0	0.0	100.0
DEANT	0	0	0	0	6	0	6
(%)	0.0	0.0	0.0	0.0	100.0	0.0	100.0
NPECT	0	0	0	0	0	5	5
(%)	0.0	0.0	0.0	0.0	0.0	100.0	100.0

Table 6. Summary of Canonical Discriminant Functions (*B. lefroyi-greeni* complex)

Sl. No.	Eugenvalues	% of Variance	Cumulative %	Canonical Correlation
1	80.663	81.3	81.3	0.994
2	14.594	14.7	96.0	0.967
3	2.206	2.2	98.2	0.829
4	1.333	1.3	99.5	0.756
5	0.463	0.5	100.0	0.562

Table 7. Standardized Canonical Discriminant Function Coefficients with class means of canonical variables (*B. lefroyi-greeni* complex)

Character	Canonical variable	
	CV1	CV2
POL/OD	0.051	0.279
OOL/OD	-0.870	0.211
EL/TML	0.559	-0.921
F1L/F1W	**2.065**	**-2.596**
F2L/F2W	**-2.201**	**2.377**
3-SR/r	0.154	0.112
3-SR/2-SR	-0.593	-0.203
SR1/3-SR	0.957	0.594
SC+R1/1r-m	0.799	0.588
1r-m/2-SC+R	0.552	0.417
1-M/M+CU	0.039	0.927
OL/ML	**-1.092**	0.443
TBL/BTL	0.514	-0.307
Biotype	Class means (group centroids)	
DEARI	-5.484	2.426
FEARI	-5.922	2.562
DBRIN	3.244	-4.887
NPECT	2.074	-5.732
NEUBL	-4.347	0.381
DECOR	19.857	3.842

Table 8. Classification matrix of Discriminant Analysis for correctly placed specimens (*B. lefroyi-greeni* complex)

	Predicted Group Membership						
Biotype	**DEARI**	**FEARI**	**DBRIN**	**NPECT**	**NEUBL**	**DECOR**	**Total**
DEARI	3	2	0	0	2	0	7
(%)	42.8	28.6	0.0	0.0	28.6	0.0	100.0
FEARI	1	4	0	0	0	0	5
(%)	20.0	80.0	0.0	0.0	0.0	0.0	100.0
DBRIN	0	0	4	0	0	0	4
(%)	0.0	0.0	100.0	0.0	0.0	0.0	100.0
NPECT	0	0	0	5	0	0	5
(%)	0.0	0.0	0.0	100.0	0.0	0.0	100.0
NEUBL	2	1	0	0	5	0	8
(%)	25.0	12.5	0.0	0.0	62.5	0.0	100.0
DECOR	0	0	0	0	0	4	4
(%)	0.0	0.0	0.0	0.0	0.0	100.0	100.0

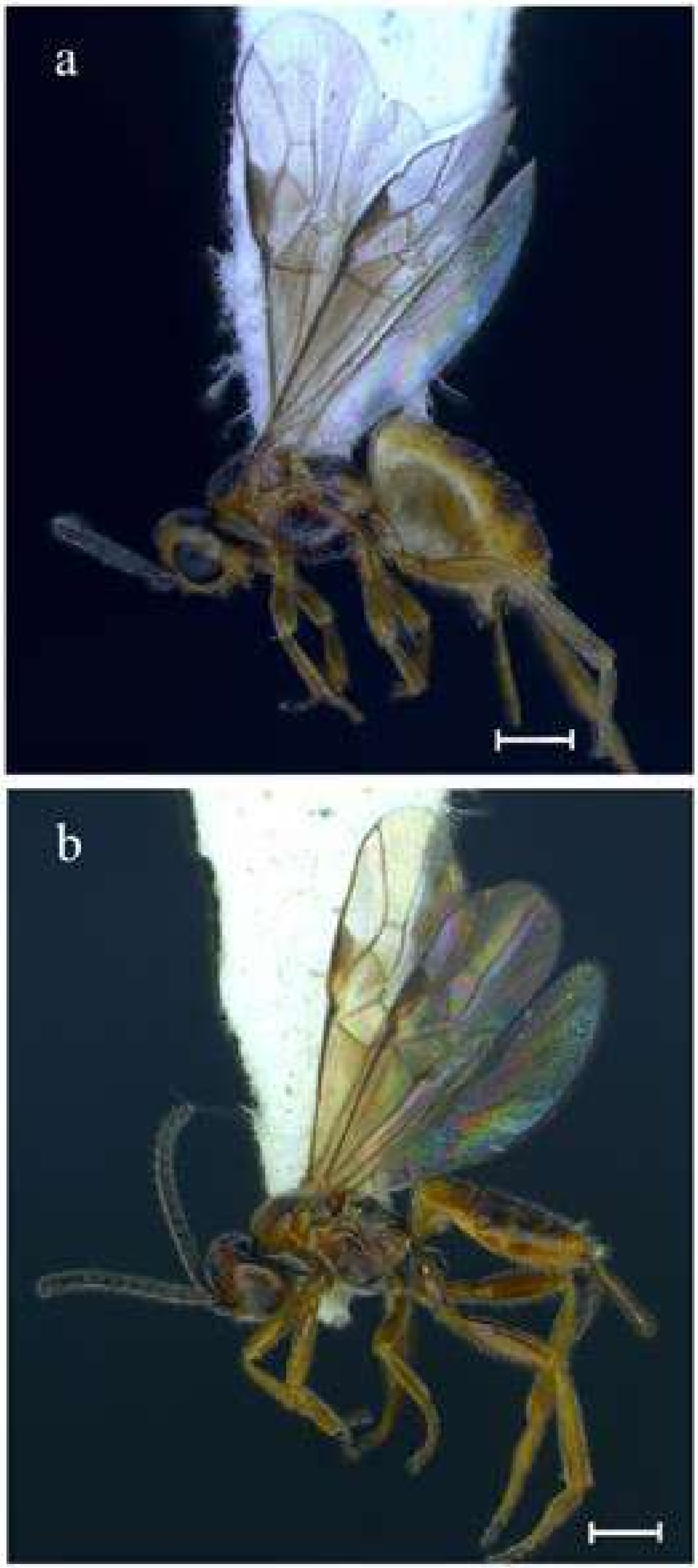

Figure 5(a–b). Lateral habitus, female. a) *Habrobracon hebetor* (Say); b) *Habrobracon brevicornis* (Wesmael); Scale bar = 0.5 mm.

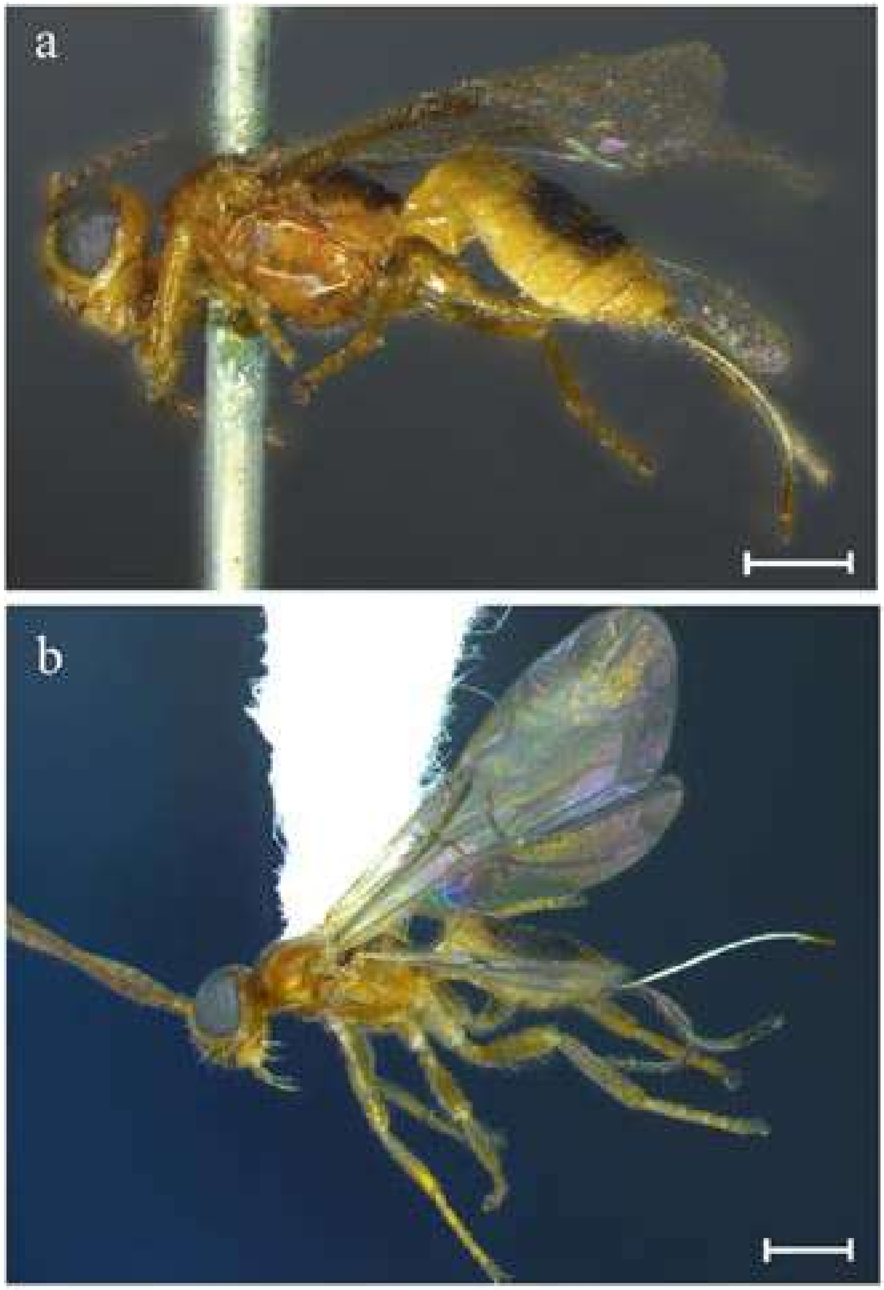

Figure 6(a–b). Lateral habitus, female. a) *Bracon greeni* Ashmead; b) *Bracon lefroyi* (Dudgeon and Gough); Scale bar = 0.5 mm.

Acknowledgements

The authors gratefully acknowledge the Director, Zoological Survey of India, Kolkata for the support. The senior author wishes to extend his gratitude to the Zoological Survey of India, Kolkata for financial assistance through the Post-Doctoral Research Fellowship. This contribution forms part of the PhD thesis of the senior author under the guidance of Dr. D.C. Ray, Professor, Department of Ecology and Environmental Science, Assam University, Silchar. This work was accomplished with the co-supervision of Prof. V.V. Ramamurthy, Ex. National Coordinator, ICAR Network Project on Insect Biosystematics, Division of Entomology, Indian Agricultural Research Institute, New Delhi.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Revalidation of *Schizothorax chivae* from the Chindwin River basin, Northeastern India

Nilibo A[1], Yumnam Lokeshwor[1]*, Yengkhom Chinglemba[2], Yumnam Rameshwori[2] & Ningombam Ibungo Singh[3]

[1]*Department of Zoology, Assam Don Bosco University, Tapesia Campus, Kamarkuchi, Assam, India - 782402*

[2]*Department of Zoology, Manipur University, Canchipur, Imphal West, Manipur, India - 795003*

[3]*Department of Zoology, United College, Lambung, Chandel district, Manipur, India - 795127*

Abstract

Schizothorax chivae Arunkumar & Moyon, a cold-water cyprinid fish under family Cyprinidae, from Chiva River (Chindwin basin), Manipur, needs taxonomic validation as the authors did not registered in the research paper in Zoobank, a mandatory for online publication of journal as per ICZN electronic publication amendment (ICZN 2012: 1–7) in addition to articles 8.1.1–8.1.3 of ICZN (1999). The study on its type species from the museum specimens, the type species were found un-catalogued though mentioned in the research paper and there have been a lot of ambiguities in terms of its meristic and morphometric features. With fresh collection of specimens and the re-examination of type species, *Schizothorax chivae*" is redescribed here. The redescription is based on its morphological, meristic, and some of the osteological features. A drastic difference in morphometric and meristic data of the type species comparing to data from its original publication have been observed. Erratic representation of data creates more puzzle at the time of identification. Thus proper taxonomic procedure should be maintained at the time of identification and description of a species.

Keywords: *Schizothorax chivae*, redescription, Cyprinidae, Zoobank, re-examination

Introduction

Arunkumar & Moyon (2016) described a new species as *Schizothorax chivae* from Chindwin river basin of Manipur by distinguishing from its congeners of characters viz. lateral line scales, predorsal scales, scale rows between lateral line of base of dorsal fin and base of ventral fin respectively, in percentage of head length of interorbital space and snout length. *Schizothorax chivae* adapts in cold water bodies with an altitude of 236m above sea level (asl) as compared to other schizothorid fishes generally adapting to an altitude above 920m asl. The species needs a taxonomic validation as the authors did not registered the original research paper in Zoobank, a mandatory for online publication of journal as per ICZN electronic publication amendment (ICZN 2012: 1–7) in addition to articles 8.1.1–8.1.3 of ICZN (1999). The study on its type species for verification, the paratypes were un-catalogued though mentioned in the research paper and a lot of ambiguities have been revealed at the time of examination of type species in terms of its meristic and morphometric features. Attempts were made to collect species from its type locality but could not be found. However, two species from two different locality probably syntypes from the same river basin have been collected and studied for its taxonomic status. With this fresh collection of specimens and the re-examination of type species are deposited in the Manipur University Museum (NH/MUM), *Schizothorax chivae* is redescribed here through morphological, meristic, and some of the osteological features. The 5 paratypes have been

*Author for correspondence : lokeshwor.singh@dbuniversity.ac.in
Article Received on: 02.04.2023
Accepted on: 24.04.2023

registered in the same museum and its catalogue number is given here.

Material and methods

General counts and measurements follow Kottelat (2001). Measurements were made point to point with a dial calliper to the nearest 0.1 mm on the left side of the specimens whenever possible. Measurements of body parts were given as proportions of standard length (SL). Measurements of subunits of heads were given as proportions of dorsal head length (DHL) and lateral head length (LHL). Fin rays were counted under a stereozoom microscope and were confirmed through a cleared and stained specimens following Taylor & Van Dyke (1985). Vertebral counts and description of caudal complex were done from cleared and stained specimens following Sawada (1982). Freshly collected specimens were deposited in Manipur University Museum of Fish (MUMF). Gill rakerswere counted from the first left side of gill arch. The five paratypes have been registered in Manipur University Museum (NH/MUM).

Results

***Schizothorax chivae Arunkumar & Moyon*, 2016**

(Fig. 1 A-D)

Material examined

50/NH/MUM**,** 174.6 mm SL, holotype, female**;** India: Manipur: Chandel district: Chiva River at Khongjon village (Chindwin Basin), 24⁰15′3″N 94⁰17′59″E, alt. 236 m above sea level; W. Alphonsa Moyon and party, 4 April, 2015. 51/NH/MUM, 5 exs., 104.5–149.5 mm SL, paratypes; data same as holotype. MUMF 2843, 103.8 mm SL, syntype; India: Manipur: Ukhrul district: Thoubal River upper reach at Hundung village (Chindwin basin); Abdul Hei, 10 December 2010. MUMF 18092, 101.9 mm SL, syntype; India: Manipur: Tengnoupal district: Okta River at Tengnoupal (Chindwin basin); Thangliankhai & Augustni, 10 February 2021. One specimen (MUMF 18092, 101.9 mm SL) was cleared and stained for osteology.

Diagnosis: *Schizothorax chivae* is distinguished from its congeners in having a dark brown stripe at caudal peduncle with a broad base at caudal-peduncle base from which tapering towards anterior reaching vertical to the level of middle of dorsal fin, a wide head (14.3–15.2% SL), 3 simple and 7½–8½ branched dorsal-fin rays, 2 simple and 5½ branched anal-fin rays, 15 branched pectoral-fin rays, 90–91 lateral line scales, 35–38 predorsal scales, 28 circumpeduncular scales row, first gill arch with 3+11 rakers, 11 anal-fin base scales, 16.5–17 transverse scale rows above lateral line, a long anal fin (20.0–23.6% SL) reaching caudal peduncle end when adpressed, and a wide interorbital distance (8.5–9.9% SL).

Description

A comparative morphometric data of *Schizothorax chivae* from its original description is shown in Table 1. Body moderately arched and elongate; predorsal region subcylindrical in cross section, slightly compressed (ratio of body depth to body width at dorsal-fin origin 0.9–1.5 times), thereafter compressed gently to posterior end of caudal peduncle. Body profound depth at dorsal-fin origin (21.6–24.7% SL). Dorsal profile arched to dorsal-fin origin then gently sloping down towards caudal peduncle. Ventral profile slightly arched; rounded chest and abdomen in cross section; more or less straight up to anal-fin base then slanting abruptly up to posterior of anal-fin base, thereafter more or less straight towards caudal-fin base. Head smooth and moderate; snout moderately compressed with 8–19 visible tubercles, rounded from dorsal view (blunt from lateral view); height less than length (ratio of head depth at nape to dorsal-head length and to lateral-head length 0.8–0.9 times and 0.7–0.8 times respectively). Mouth inferior, transverse and slightly arched; lips fleshy, continuous; upper and lower lip well developed, papillated. Rostrum and upper lip well demarcated with a deep groove, rostral caps lightly covering upper lip ventrally. Right and left labial fold of lower lip deeply incised, central labial shallow incision, papillated. Anterior margin of lower mandible covered with horny sheath, not sharp edge. Barbel two pairs, a short rostral and a bit longer maxillary barbel. Nostril closer to eye than tip of snout, a flap lip like structure partitioned between anterior and posterior nostril. Eyesmoderately large (20.6–24.4% HL); not visible from ventral, closer to snout than posterior end of lateral head length. Interorbital space convex,width 39.9–50.2% HL.

Dorsal fin with 3*–4 simple and 7½*–8½ branched rays; distal margin concave; dorsal fin originating slightly ahead of ventral fin origin; posterior margin of last simple dorsal-fin ray serrated with 18–21 antrorse denticles. Pectoral fin acuminate, triangular shape with 2 simple and 14–15* branched rays; anterior margin slightly convex, posterior distal margin straight; first branched ray longest, length shorter than lateral head length; reaching midway to pectoral-pelvic distance when adpressed. Pelvic fin short with 2 simple and 9* branched rays; anterior margin with convex tip, distal margin straight; reaching half way to pelvic-anal distance when adpressed not reaching anus. Anal fin long, acuminate with 2 simple and 5½* branched rays; long with curve posterior margin, reaching caudal-fin base. Caudal fin forked with 9+8* principal branched rays.

Body covered with small cycloid scales; breast and belly before pectoral-fin tip naked, smooth. Thick epidermis embedded on thoracic area. Lateral line complete with 90*–91 scales; running on horizontal midline of each flank. Transverse scales row between lateral line and dorsal-fin origin 16–17, scales between pelvic-fin origin to lateral line 13–14. Predorsal scales 33–38; dorsal-fin base scales 16 and anal-fin base scales 11. Scales along anal sheath enlarged with 22, encircling on both side of vent; commencing from midway between pelvic-anal distance and extended up to end of anal-fin base.

Osteological features: Total vertebrae 47; abdominal vertebrae 30, and caudal vertebrae 17. Outer side of first gill arch with 14* rakers (3 epibranch and 11 hypobranch). Pterygiophore of first simple dorsal fin in between 16thand 17thvertebrae, pterygiophore of last branched dorsal fin in between 23rdand 24th vertebrae. Pterygiophore of first simple anal fin in between 31stand 32nd vertebrae and pterygiophore of last branched ray in between 35thand 36th vertebrae. Caudal procurrent rays 4 each in both dorsal and ventral lobe of caudal fin.

Colour: Colour in fresh (Fig. 3)**:** Body bluish grey above lateral line. A faint dark blotch at posterior end of caudal peduncle. Lateral line scales appears a dark blue stripe. An elongated dark blue patches below the eye on flank extending to and confluence at snout from both the flanks. Ventral and ventrolateral portion of head or below lateral line creamy white. Opercle tinged light golden. All fins golden red with dusky white posterior margin. Principal rays of branched caudal fin tinged golden brown.

Colour in 10% buffered formalin: Body colour faded; a dark brown stripe at caudal peduncle with a broad base at caudal peduncle base from which tapering towards anterior reaching vertical to the level of middle of dorsal fin. Dorsum and dorsolateral region above lateral line dark brown. Dorsal half of operculum, dorsum head, tip of snout and its lateral flank dark brown. Ventral and ventrolateral surface of head or body below lateral like creamy white. All fins yellowish cream except dorsal and caudal-fin rays tinged dusky.

Sexual dimorphism: Males are smaller than females with more tubercles on snout.

Discussion

The original description of *Schizothorax chivae* Arunkumar & Moyon, 2016, has a lot of taxonomic ambiguity starting from materials and methods till publication. The normal patterning of taxonomic characterization was not following properly like uncataloguing of paratypes, variation on the morphometry and meristic count upon verification of the type specimens, and violation of ICZN electronic publication amendment (ICZN 2012: 1–7) in addition to articles 8.1.1–8.1.3 of ICZN (1999) for non registry of the research paper in Zoobank. Although the type species is already mentioned in the original research paper yet the paratypes are found uncatalogued. Now the paratypes are registered and the species is revalidating through verification of type species and newly collected fresh specimen.

There are 10 valid *Schizothorax* species all over India, of this 4 species have been reported from different river basins of the Northeastern India. The Brahmaputra River basins has 3 valid species viz. *Schizothorax molesworthi* (Chaudhuri, 1913), *S. progastus* (McClelland, 1839) and *S. richardsonii* (Gray, 1832). *Schizothorax chivae* is the only single species known from Chindwin River basin Manipur and is distinguished from the species of the Brahmaputra River in having a dark brown stripe at caudal peduncle with a broad base at caudal peduncle base from which tapering towards anterior reaching vertical to the level of middle of dorsal fin. *Schizothorax chivae* is further distinguished from *S. progastus* in its branched dorsal-fin rays (8½ vs. 8), pectoral-fin rays (ii.14–15 vs. i.16), pelvic-fin ray (ii.9 vs. i.10), anal-fin rays (ii.5½ vs. iii.5), principal caudal-fin rays (17 vs. 19), number of lateral lines scales (90–91 vs. 104–114), lateral transverse scales row between dorsal-fin origin and lateral line (16–17 vs. 20–21), number of gill rakers (14 vs. 11–12) as well as circumpeduncular scale row (28 vs. 64); from *S. richardsonii* in its simple and branched pectoral-fin rays (ii.14–15 vs. i.15–16), simple pelvic-fin rays (ii vs. i), anal-fin rays (ii.5½ vs. iii.5), and number of lateral transverse scales row between dorsal-fin origin as well as lateral line (16–17 vs. 25); and from *S. molesworthi* in its branched dorsal-fin rays (8½ vs. 8), pectoral fin rays (ii.14–15 vs. i.14), simple pelvic-fin ray (ii vs. i), anal-fin rays (ii.5½ vs. iii.5), number of lateral line scales (90–91 vs. 98), transverse scales row between dorsal-fin origin to lateral line (16–17 vs. 27) as well as circumpeduncular scale row (28 vs. 44).

Schizothorax chivae is also distinguished from *S. kumaonensis* described from the Ganga River system in having lesser lateral line scales (90–91 vs. 94–100), more simple- and lesser branched pectoral-fin rays (ii.14–15 vs. i.17), lesser simple and more branched anal-fin rays (ii. 5½ vs. iii.5), lesser lateral transverse scales row between dorsal-fin origin and lateral line (16–17 vs. 23), and lesser transverse scales row between pelvic-fin origin to lateral line (13–14 vs. 31).

Schizothorax chivae is further distinguished from the species from Yunnan Province, China, the adjacent river basin of Irrawaddy River system viz. *S. heteri, S. leukus, S. nudiventris,* and *S. heterophysallidos* in having a dark brown stripe at caudal peduncle with a broad base at caudal peduncle base from which tapering towards anterior reaching vertical to the level of middle of dorsal fin, number of lateral line scales (90–91 vs. 94–105 in *S. leukus,* 99-115 in *S. nudiventris,* 96-124 in *S. heterophysallidos*) as well as transverse scales row between dorsal-fin origin and lateral line (16–17 vs. 24–33 in *S. heteri,* 26-34 in both *S. leukus* and *S. nudiventris,* 21-27 in *S. heterophysallidos*).

Arunkumar & Moyon (2016) concluded that species of *Schizothorax richardsonii* (Gray) mentioned by Sharma (1989) and Singh (1998) collected from the Chindwin basin in Manipur, is *S. chivae* species because of the position of dorsal fin which is close to tip of snout and in presence of a convex interorbital space. Further, they have given a strong concluding remark that all the specimens collected from Chindwin basin of Manipur mentioned by various workers viz. Sharma (1989), Singh (1998), and Selim (1998), will be *Schizothorax chivae*. This statement is more hyperbolic and controversial. Arunkumar and Moyon's examined specimens used for comparison in the description of *Schizothorax chivae* appeared to be taken out from the Ph.D. thesis of Sharma (1989), Singh (1998), and Selim (1998). We found these anomalies after examining the respective Ph.D. thesis of previous workers. Such controversial conclusion without proper verification and observation of the specimens creates problems in taxonomy and diversity studies. We disagree to their conclusion being mentioned and cannot be concluded, since all the other species of *Schizothorax* mentioned by Sharma, Singh, and Selim from the Chindwin basin might be a different species and need to be verified, with freshly collected specimens from the locality mentioned by them, by using proper taxonomic tools and techniques.

Comparative materials:

Schizothorax beipanensis: Data from Yang *et al.* (2009); *Schizothorax heteri*: Data from Yang *et al.* (2009); *Schizothorax heterophysallidos*: Data from Yang *et al.* (2013); *Schizothorax kumaonensis*: Data from Tilak (1987); *Schizothorax leukus*: Data from Yang *et al.* (2013).

Schizothorax molesworthi: ZSI F 7735/1, 182 mm SL; Yembung, 1100 ft. Altitude, Abor country, Arunachal Pradesh (collection through Abor expedition); *Schizothorax nudiventris*: Data from Yang *et al.* (2009); *Schizothorax progastus*: Data from Kullander *et al.* (1999) and Tilak (1987); *Schizothorax richardsonii*: Data from Kullander *et al.* (1999) and Tilak (1987).

FIGURES

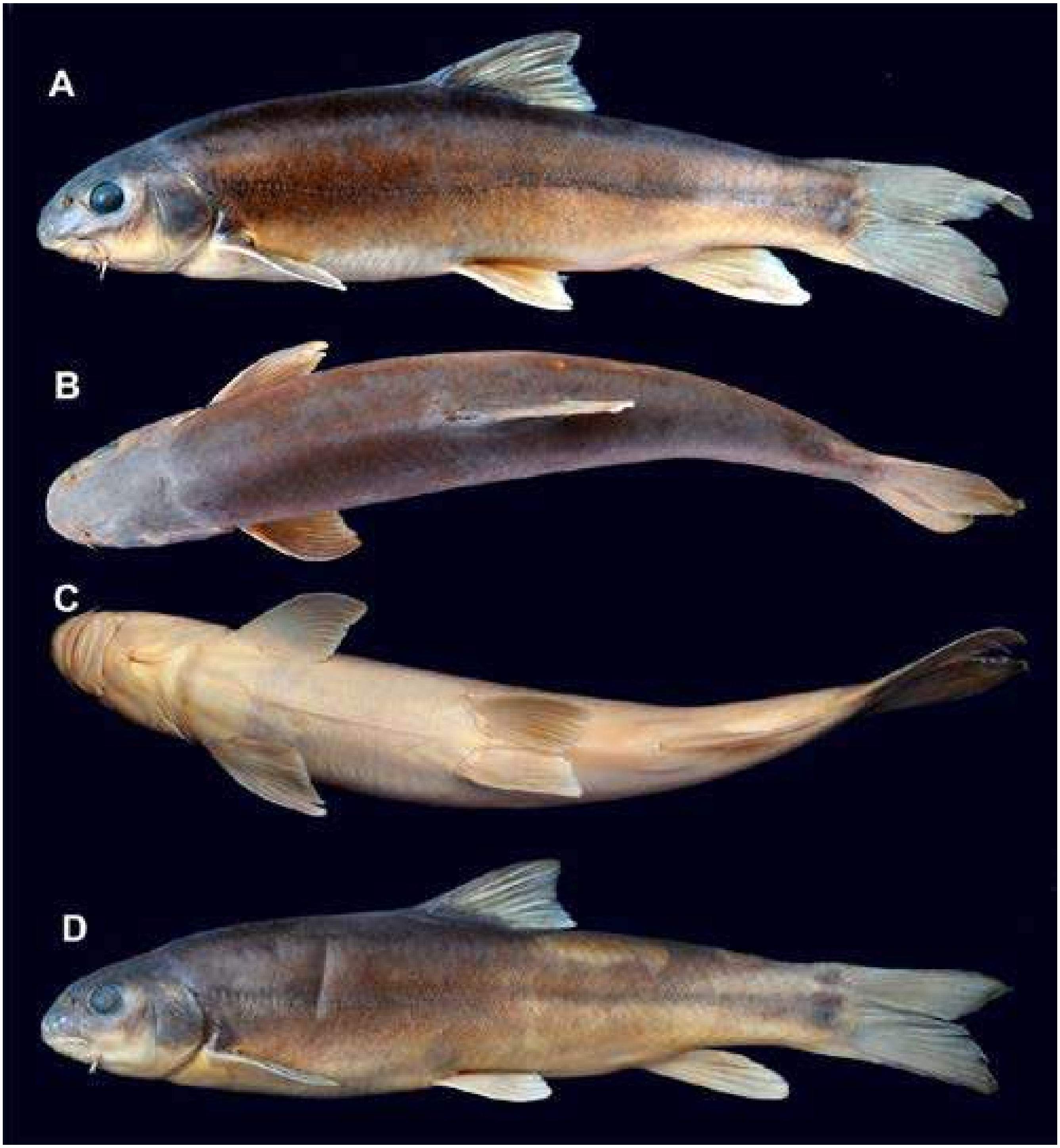

Figure 1: *Schizothorax chivae*, 50/NH/MUM**, holotype,** 174.6 mm SL, female, **A.** lateral, **B.** dorsal, **C.** ventral; **D.** 51/NH/MUM, **paratype**, 148.8 mm SL, lateral.

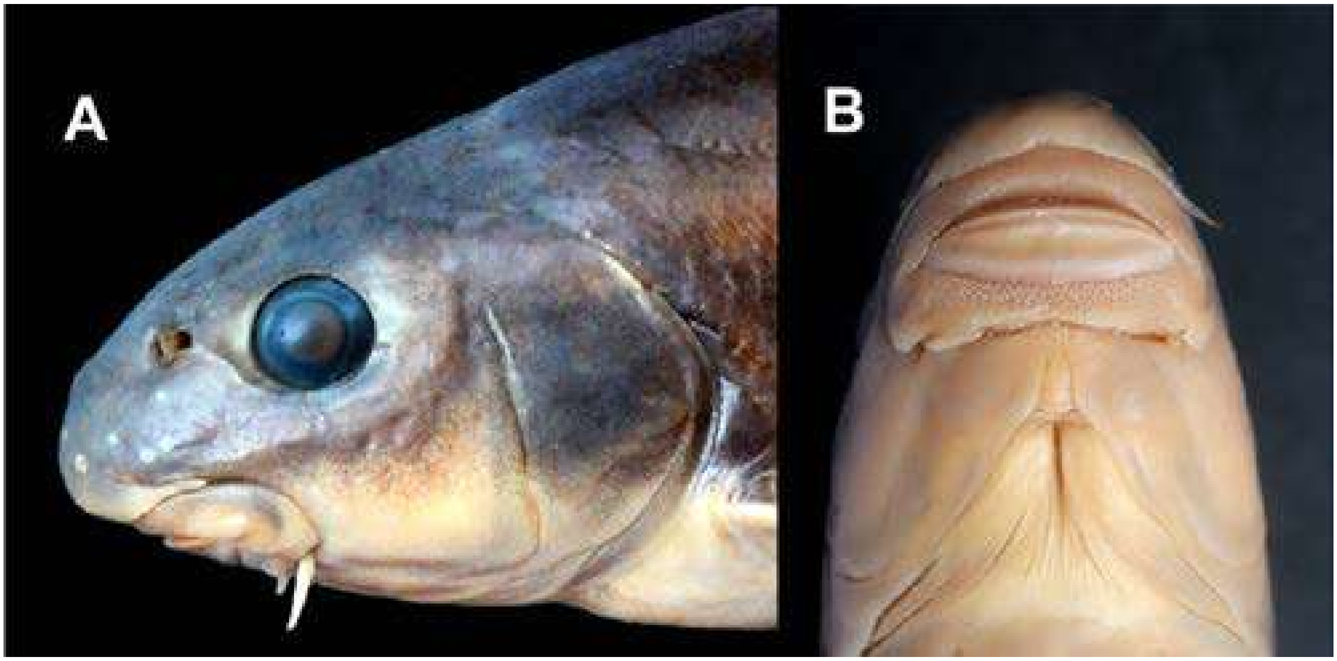

Figure 2: *Schizothorax chivae*, 50/NH/MUM**, holotype,** 174.6 mm SL, female, **A.** lateral head; **B.** ventral head showing lip.

Figure 3: *Schizothorax chivae*, MUMF 18092, 101.9 mm SL, lateral view (fresh specimen).

Table 1: Comparative account of *Schizothorax chivae* Chindwin basin Manipur showing the ambiguities in morphometry and meristic.

	Recent observation on Arunkumar & Moyon's collection		Fresh collection	Arunkumar & Moyon, 2016	
	Holotype 50/NH/MUM	Paratype (n=5)	Syntype (n=2)	Holotype 50/NH/MUM	Paratype (n=6)
Standard length (mm)	174.6	104.5–149.5	101.9–102.8	184.1	75.0–159.4
% in SL					
Body depth	24.0	22.0–24.7	21.6–24.7	21.7	23.9–25.4
Head length (dorsal)	18.9	18.2–20.0	17.8–20.8	17.6	17.2–19.3
Head length (lateral)	22.7	21.3–24.6	21.6–24.5	21.7	22.3–25.0
Head height at nape	15.9	15.6–17.5	15.1–18.4	16.6	15.7–17.3
Snout length	9.0	7.7–9.0	5.4–9.3	8.4	7.8–8.6
Eye diameter	4.0	3.8–4.7	3.9–4.9	--	--
Inter orbital space	9.5	8.5–9.9	5.1–8.8	--	--
Caudal peduncle length	15.4	13.9–17.8	15.0–17.3	17.4	18.0–18.3
Caudal peduncle height	10.7	10.1–10.8	11.4–12.0	10.7	9.5–10.9
Predorsal length (pdl)	49.0	47.3–49.5	47.4–50.6	48.5	47.4–50.9
Prepectoral length	22.4	21.1–23.3	--	--	--
Prepelvic length (pvl)	49.9	48.8–52.2	53.3–54.5	49.5	50.2–51.1
Preanus length	73.6	71.7–74.7	76.2–77.4	71.8	70.4–75.6
Preanal length	74.3	72.4–75.2	78.4–78.7	73.0	71.4–77.4
Mouth gap width	9.3	7.9–9.6	--	--	--
Dorsal-fin height	21.2	20.9–23.7	19.5–26.7	19.9	18.0–20.1
Pectoral-fin length	16.4	16.4–18.9	16.1–20.3	15.4	15.4–18.7
Pelvic-fin length	15.6	15.1–16.8	14.2–17.2	13.6	14.1–15.6
Anal-fin depth	21.9	20.0–23.6	--	--	--
Caudal-fin length (upper lobe)	23.2	23.2–28.4	--	21.7	23.9–25.4
Caudal-fin length (lower lobe)	22.2	22.2–27.5	--	--	--
Caudal-fin middle branched ray length	10.5	10.5–14.3	--	--	--
Dorsal-fin base length	14.2	13.4–16.8	--	--	--
Anal-fin base length	7.5	6.8–8.6	--	--	--

	Recent observation on Arunkumar & Moyon's collection		Fresh collection	Arunkumar & Moyon, 2016	
	Holotype 50/NH/MUM	Paratype (n=5)	Syntype (n=2)	Holotype 50/NH/MUM	Paratype (n=6)
Head width (max)	14.3	14.3–15.2	--	--	--
Pelvic-anal distance	21.0	16.7–23.5	--	--	--
Body width (dorsal ori)	16.1	14.4–16.3	13.8–16.0	14.5	14.3–15.1
Body width (anal ori)	10.1	8.5–10.3	8.2–8.7	11.2	9.5–11.3
% in HL (dorsal)					
Head depth at nape	83.68	83.7-93.8	72.43–88.5	81.2	77.1-78.5
Head depth at eye	69.18	65.2-73.0	58.54–70.22	76.6	69.4-74.6
Snout length	47.73	41.7-49.3	41.9–44.5	38.5	34.4-35.5
Eye diameter	21.08	20.6-24.4	23.3–23.6	18.3	19.7-21.4
Inter orbital space	50.21	45.1-50.2	39.9–42.5	43.0	37.1-40.8
Mouth gap width	48.76	42.3-48.8	--	37.5	37.5-40.6
Head width (max)	75.37	73.0-79.8	--	66.2	62.8-70.1
% in prepelviclength to predorsal length	98.2	91.5-98.6	--	98.1	94.4 – 99.6
Scales count					
Lateral line scales	90	90-91	--	--	83-90
circumpeduncular scale rows	28	28	--	--	--
Predorsal scales	35	35-38	--	--	33-35
Dorsal-fin base scales	16	16	--	--	--
Anal-fin base scales	11	11	--	--	--
Tubercles on snout	12	8-19	--	--	--
Meristic count					
Dorsal-fin rays	iii,7½	iii,7-8½	iii-iv, 7½–8½		iii,7-8
Pectoral-fin rays	i,15	i,15	ii, 14–15		i,14
Pelvic-fin rays	i,9	i,9	ii, 9		i,6
Anal-fin rays	ii,5½	ii,5½	ii, 5½		ii,6
Caudal-fin rays	9+8	9+8	9+8		8+8
Vertebrae	47	47	47		47
First gill arch	3+11=14	3+11=14	3+11=14		14–18

Acknowledgement

We are very thankful to Dr. L. Kosygin, Scientist E, Zoological Survey of India Kolkata and Dr. O. Ranjit Singh, Curator, Manipur University Museum, Canchipur for sharing information and allowing us to see their specimens in respective museums. We (the first two authors) extend our gratitude to Rev Fr (Dr) Stephen Mavely, Vice Chancellor, Assam Don Bosco University to conduct research in Zoology Lab.We are also very grateful to both the reviewers for our manuscript viz. Dr. BD Shangningam Anal and Dr. Mrinal Kumar Das for their valuable suggestions and comments. We also extend our thankfulness to the organizing committee of Animal Taxonomy Summit 2023, Zoological Survey of India, Kolkata for giving acceptance of abstract for this research paper to participate in oral presentation.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Comparative analysis on Sclerite Morphometry: a useful tool in the soft corals *Lobophytum* sp. (Sarcophytidae: Octocorallia: Anthozoa) identification from Andaman and Nicobar Islands, India

S. Rajendra* and C. Raghunathan

Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata 700 053, West Bengal

Abstract

Soft corals are sessile, marine benthic organisms that play an important role in the coral reef ecosystem. The identification of soft coral species is challenging due to their morphological deviations. Octocorals are one of least studied groups in Indian waters due to a lack of expertise. A total of 60 species under the genus *Lobophytum* have been identified across the world's oceans while India shares a total of 21 species including 18 species from the Andaman and Nicobar Islands. During the study, *Lobophytum* specimens were collected from coral reef regions of the Andaman and Nicobar Islands employing SCUBA-diving and hand-picking methods. Specimens were distinguished with lobate, plate-like, or capitate with a prominent stalk and dimorphic, fully retractile polyps into thick coenenchyme. Species were identified by extracting sclerites from various regions of the colony with 5% sodium-hypochlorite (capitulum surface and interior, base surface, and interior) examined under a stereo-zoom microscope. Sclerite structure and measurements, as well as type composition, have been examined in ten *Lobophytum* species in this study. In different regions of the same colony, the structural composition of each species sclerites varies. Sclerites of various shapes like club-shaped, rod-shaped, spindle-shaped, shuttles, capstans, dumbbells, cylindrical, barrel-shaped, irregular-shaped, and cross-shaped were observed in ten *Lobophytum* species. The colony morphology also plays a role in taxonomy and species arrangement in systematics. Aside from colony morphology, zooid arrangement in the colony is also important for species identification. The colour of the colonies does not have a proper role in species identification because they show a variety of colours due to their symbiosis with zooxanthellate microalgae. The colony colours are determined by zooxanthellate concentration, temperature, depth, and other environmental factors. However, after preservation, most colonies turn white, beige white, or cream in colour. Hence, Sclerite morphometric is a very useful characteristic for species identification in the *Lobophytum* species.

Keywords: Taxonomy, finger leather coral, lobes, octocoral, Andaman

Introduction

Octocorals are commonly called as alcyonarians belonging to the Octocorallia subclass of the Anthozoa class of Cnidaria which consist of 3597 nominal species from the world's oceans (WoRMS, 2023). The subclass Octocorallia distinguished from other subclass by the presence of eight tentacles and eight mesenteries (Daly *et al.*, 2007). They are one of the significant benthic components in coral reef ecosystem by providing microhabitats to many invertebrates and vertebrates (Lau *et al.*, 2019). They are widely distributed in tropical and subtropical waters, and from intertidal to reef slope region whereas few pennatulaceans can be found at greater depths up to 6400 m (Pérez *et al.*, 2016). Formerly,

*Author for correspondence : rajenzsi1992@gmail.com
Article Received on: 02.04.2023

Accepted on: 24.04.2023

since 1981 the subclass Octocorallia was classified under three distinct orders named as Helioporacea (Blue corals), Pennatulacea (Sea pens) and Alcyonacea (soft corals, sea fans and sea whips) (Bayer, 1981; Fabricius and Alderslade, 2001; Daly *et al.*, 2007). Recently, the systematics of Octocorallia has updated based on the phylogenomics (McFadden *et al.*, 2022). According to the recent classification, Octocorallia classified into two orders, Malacalcyonacea (46 families) and Scleralcyonacea with (36 families) (McFadden *et al.*, 2022, WoRMS, 2023). Apart from phylogenomics, the traditional taxonomy considered several characters as important to classify octocorals such as colony morphology, presence or absence of an internal skeletal axis, axis composition i.e. whether solid calcium carbonate or proteinaceous axis, axis with little to no calcified material, colonies with or without a skeletal axis or axial-like layer formed by sclerites, polyps surrounded in a fleshy mass of coenenchyma or connected basally by stolons or membranes and solitary polyps (Studer, 1887; Grasshoff, 1999, Hickson, 1930; Bayer, 1981; Fabricius and Alderslade, 2001). Octocoral tissue embedded with small calcium carbonate tissue with mineral form small aggregates of skeletal elements called sclerites (Thomson and Simpson 1909; Fabricius and Alderslade, 2001). These sclerites play an important role for identification of octocoral species (Conci, *et al.*, 2021; Tentori and van Ofwegen, 2011).

Soft corals are among the most diverse and successful members of the subclass Octocorallia of class Anthozoa. They are without a skeletal axis, colonies lobate, plate-like or capitate with a conspicuous stalk, not highly branched. Polyps monomorphic or dimorphic, fully retractile into thick coenenchyme. Polyp has rod shaped scleties, spindles, clubs and scales, often arranged as collaret and/or points but sometimes absent. The species under the genus *Lobophytum* are commonly called as devils hand corals or devils hand leather corals because of the capitulum modified as lobes or crests seems to be finger like projections in capitulum with short wide stalk or encrusting. Sclerites of surface layer are clubs; sclerites of interior are capstans and spindles. Colour of colonies light yellow, beige, brown, greenish. Polyps often white. There are about 60 species reported from world's seas while India contributes 21 species including 18 species from Andaman and Nicobar Islands. The current paper aims to present different types of sclerites in the *Lobophytum* species with their morphometrics and their role in identification of species.

Material and methods

Collection and Preservation of specimens

Soft corals, *Lobophytum* specimens were collected from intertidal regions to subtidal regions of the Andaman and Nicobar Islands. The surveys of subtidal regions were attained through employing snorkelling and self-contained underwater breathing apparatus (SCUBA) from intertidal to shallow water subtidal depth up to 25m. The *in-situ* photographs were taken by a Canon G15 camera with underwater housing. All the collected specimens were fixed in 4% buffered-formalin in seawater, rinsed with freshwater, and, after 24 hours, placed in 70% alcohol for long-term preservation. *Ex-situ* photographs were taken in the lab by a Canon G15.

Preparation of sclerites

Sclerites were extracted by removing a thin layer of tissue from the surface and interior of the capitulum or lobes and stalk or base and placed in a boiling tube or watch glass. Few drops of 5% sodium hypochlorite solution were added and allowed for 10 to 15 minutes to dissolve the tissue sometimes it may take an hour and leave the sclerites intact. The sclerites were rinsed thoroughly with distilled water and once with a 70% ethanol and transferred by dropper to an ordinary slide for study by following Fabricius and Alderslade (2001). These sclerites are examined under stereo-zoom microscope (LEICA M 205A, DFC 5000) for taxonomic identification. The identification was done by using literature of von Marenzeller (1886), Moser (1919), Tixier-Durivault (1956, 1957, 1966, 1970a &b), Verseveldt (1971, 1983), Verseveldt and Tursch, (1979), Verseveldt and Benayahu (1983), and Alderslade and Shirwaiker (1991) while the classification was adopted according to Bayer (1981), and McFadden *et al.* (2022) and records of valid names based on World Record of Marine Species (2023).

Results and Discussion

A total of ten species of *Lobophytum* species are used to study the comparative morphometrics of both colony and sclerites viz., *Lobophytum altum* Tixier-Durivault, 1956, *L. catalai* Tixier-Durivault, 1957, *L. crassum* von Marenzeller, 1886, *L. crebriplicaltum* von Marenzeller, 1886, *L. hirsutum* Tixer-Durivault, 1956, *L. pauciflorum* (Ehrenberg, 1834), *L. pusillum* Tixier-Durivault, 1970, *L. sarcophytoides* Moser, 1919, *L. schoedei* Moser, 1919 and *L. variatum* Tixier-Durivault, 1957.

Colony morphology: Generally common types of morphology were observed in all ten collected species. However, because this group lacks a skeletal axis, colonies are spread and supported by a hydroskeleton and sclerites which made of calcium carbonate and other minerals. Colony shape is primarily influenced by substrate depth and type, including rock, sand, live coral, dead coral, and others. However, the size and structure of most underwater colonies vary among species or even within species. These colonies have a low stalk, which is considered the base, and a wide capitulum. Some species have a plain capitulum, and in some species, the capitulum is modified into fingerlike lobes, crest-like lobes that are present throughout the colony, crests shapes originate from the edges of the colony, and the center might be occupied with lobes or free of lobes. Because colony morphology varies within species, it is extremely difficult to identify the species in situ. As a result, species identification is limited to sclerite morphology and length.

The colony of *Lobophytum altum* has a distinct stalk; the wide capitulum contains crested lobes that form at the periphery of the colony, and hollow center devoid of lobes (Fig. 1: a). The colonies of *Lobophytum catalai*, *L. crassum*, and *L. sarcophytoides* have an encrusted capitulum that is large plate shaped with the edges rising upward and forming thick or thin crests on the edges; the basal portion of the colony is low and lacks a distinct stalk (Fig 1: b-f; Fig 2: e). *L. crassum* has encrusted, low, distinct stalk. Sometimes, the colonies of *L. crassum* are large, and the capitulum is broad, forming crest-like lobes that are distributed throughout the capitulum. Some colonies have crests that eventually spread from the colony's periphery to the centre. But the *L. sarcophytoides* colony is encrusted, has a low stalk with a capitulum that is bowl-shaped, and the peripheral region of the capitulum rose upwards and formed crests on the edges. In *L. crebriplicatum*, the colony is encrusting with a low stalk; the polyparium is the same width as the stalk, and thick lobes rise above the edges of the capitulum and form a hollow or bowl-shaped structure (Fig 1: g). in *Lobophytum hirsutum*, *L. pauciflorum*, and *L. pusillum*, there are finger-like lobes on the surface of the capitulum (Fig. 1: h; Fig.2: a-d). The formation of lobes, the width of the lobes, and the zooids arrangements at the summit of the lobe and on its sides vary from each other. *L. hirsutum* contains a low stalk and more erect or fingerlike lobes; *Lobophytum pauciflorum* is broadly encrusted, and the capitulum is rather flat with upright lobes and densely arranged lobes. In some colonies, the summits of the lobes are pointed or rounded, and in a few colonies, the erected lobes are disposed far from each other, and sometimes the lobes are present only on the peripheral region of the colony. Sometimes individual lobes are fused at their bases, forming crests like compound lobes. Contrarily, colonies of *Lobophytum pusillum* with a low stalk, a wide capitulum, and spherical or finger-like lobes are not found in all areas of the capitulum. The polyparium's centre is flat, has zooids that are easily seen, and lacks any lobes. Except for the center, the edges of the polyparium are formed as erected finger-like lobes. Small ridges or nearly flat capitulum are characteristics of *Lobophytum schoedei* and *L. variatum* (Fig 2: f-h). The *Lobphytum variatum* colony, on the other hand, is low-encrusting and spreads across the substrate. The colony is encrusting, has a short stalk, and a thin capitulum that resembles a plate or bowl with a few marginal lobes.

Sclerite morphometrics: Colonies of each species have various kinds of sclerites viz., poorly formed club shaped sclerites in the surface layer of the capitulum and base, spindle shaped sclerites in the interior of the lobe, crests or capitulum, and capstans, dumbbell shaped, cylinder shaped and spindles in the interior of the base. The detailed type of sclerites and their measurements are given in Table 1.

Surface layer of lobe or capitulum: The sclerites of the surface layer of *Lobophytum* are predominant with club-shaped sclerites rather than rod-shaped, shuttle-shaped, or fusiform-shaped. The structure of club-shaped sclerites varies from one species to another. In *L. altum*, club-shaped sclerites have warty heads and handles; in *L. catalai*, *L. crebriplicatum*, *L. hirsutum*, and *L. pauciflorum*, club-shaped sclerites have low developed heads; club shaped sclerites of *L. crassum* have tiny spines at the top of the club head that are directed upwards; clubs are weakly developed heads in *L. irregulari*, but clubs have softly developed heads, smaller rod shaped, few clubs have strong heads; and handle cone shaped prominences in *L. pusillum; L. sarcophytoides* has clubs with irregularly placed warts on the heads of the club, *L. schoedei* has clubs are the heads with a centre wart, and few have thick warty heads without central wart, and *L. variatum* contain smaller clubs have a middle wart and lower handle a girdle of wart and larger clubs often have warty heads (Fig 3: a-j).

Interior of lobe or capitulum: Sclerites of interior layer of *Lobophytum* contain spindle shaped, oval shaped, fusiform shaped, and in some species four rayed crosses. The structure of lobe interior sclerites are also vary from one species another. In *L. altum* contain spindles contain irregular shaped prominences and cylinder shaped sclerites with medium warts and covered with warts; *L. catalai* has cylinders contain two to four distinct sets of warts, the longer pointed spindles, prominences are irregularly distributed. The structure of capstans of *L. crassum*, two whorls of large spiny warts, and two terminal clusters of warts and spindles are covered with numerous whorls. In, *L. crebriplicatum*, pointed or blunt ended spindles with irregular distributed warts or distinct girdles present on their surface. But in *L. hirsutum* contain spindles have middle zoned bigger warts and smaller warts are dispersed or form girdles towards both ends of the spindles. Spindles with irregularly distributed prominences or warts present in *L. irregulari.* Whereas in *L. pauciflorum* contain pointed or blunt ended spindles with zones of warts. In, *L. pusillum*, spindles are with high warts, at centre of sclerite may be zoned. Sometimes often irregular in shaped which curved. The spindles of *L. sarcophytoides* are slender, pointed with small spined warts prominenses which may sometimes be zoned and some spindles have antler like warts. But in spindles of *L. schoedei* covered with covered with girdles of warts. Whereas in *L. variatum* contains shuttle shaped blunt ended spindles have four to six girdles of warts which are unevenly distributed on sclerites (Fig. 3: k-t).

Surface layer of the base or stalk: *L. altum* contains small, club-shaped and rod-shaped sclerites; these clubs have warty heads and handles of low cone prominence. *L. catalai*, *L. crebriplicatum*, and *L. irregulari* contain club-shaped sclerites with poorly developed heads and warty handles. *L. crassum* clubs have a cone shape with large warts on the surface. *L. hirsutum* contains clubs with a wide head and one to two girdles of warts on the handle. In *L. pauciflorum*, there are warty clubs and short, wider spindles. In *L. pusillum*, clubs have softly developed heads and handle cone-shaped prominences and rod shaped sclerites. In *L. sarcophytoides,* it has a big, warty head with a small, thin handle and one or two girdle-like prominences. *L. schoedei* has clubs, which are the heads with a centre wart, and few have thick, warty heads, while *L. variatum* clubs are dense and comprise clearly whorls of warts with one central wart on the handle (Fig. 4: a-j).

Interior of the base or stalk: The structural composition of stalk interior sclerites plays a significant role in the confirmation of species because it varies from one species to another. The stalk interior sclerites of *Lobophytum altum* contain capstans, barrels, dumbbells, and cylinders, with a middle waist and spindles also present. *L. catalai* contains capstans, oblong or cylinder-shaped, shuttle-shaped, and spindle-shaped sclerites; *L. crassum* has capstans, which are two girdles of spiny warts with clusters at the end and pointed spindles. In the stalk interior of *L. crebriplicatum*, numerous cylindrical forms, and pointed spindles. *L. hirsutum* contains oblong to cylindrical capstans and a few spindle-shaped sclerites. *L. irregulari* oval-shaped and pointed spindle-shaped sclerites are present. *L. pauciflorum* contains cylindrical and capstan-shaped sclerites with two to four girdles of compound warts and four rayed crosses. Whereas only pointed spindles with warty zones are present in the *L. sarcophytoides*, spindles that are distinctly broader and with a few irregularly distributed warts are structured in the girdles present in the *L. schoedei*. The sclerites structure varies in *L. variatum*, with cylinder-shaped, blunt-ended, fusiform shaped sclerites; numerous shuttles and prominences that are cones, simple warts, and compound warts (Fig: 4: k-t).

Andaman and Nicobar Islands are known as the most ecologically significant region in the Indo-Pacific region, with abundant coastal and marine biodiversity. Despite being one of the most important components of the reef ecosystem, comprehensive soft coral inventories are sporadic and scarce. The current study aims to provide colony morphological and sclerite comparative analysis of ten species of the genus *Lobophytum* from the Andaman and Nicobar Islands, which could be useful for easy identification.

Table 1: Comparative sclerite morphometry of soft corals, ten *Lobophytum* species (Sarcophytidae) from the Andaman and Nicobar Islands

Attributes		*Lobophytum altum* Tixier-Durivault, 1956	*Lobophytum catalai* Tixier-Durivault, 1957	*Lobophytum crassum* von Marenzeller, 1886	*Lobophytum crebriplicaltum* von Marenzeller, 1886	*Lobophytum hirsutum* Tixier-Durivault, 1956	*Lobophytum pauciflorum* (Ehrenberg, 1834)	*Lobophytum pusillum* Tixier-Durivault, 1970	*Lobophytum sarcophytoides* Moser, 1919	*Lobophytum schoedei* Moser, 1919	*Lobophytum variatum* Tixier-Durivault, 1957
Distance between two auto zooids	At the peripheral region or on the lobes (mm)	0.8 to 1.2	0.5 to 1.5	0.7-1.5	1.0 to 1.5	1.1-2.2	1.5 to 2.0	1.7 to 3.7	0.4 to 0.7	0.3 to 0.7	0.5 to 0.8
	At the base of lobe or centre of the capitulum (mm)	up to 2.5 mm	up to 3.0	1-4	3 to 4	2-3	Up to 7.0	2.5 to 4.7	Up to 1	0.5 to 1.5	Up to 1
No. of Siphonozooids present between two autozooids	At the peripheral region	1-3	1-2	1-2	1-2	1-3	3-4	Up to 6	1-2	1	1-2
	At the centre of the capitulum	Up to 5	Up to 8	2-6	Up to 7	2-5	Up to 8	Up to 10	2	1-2	3
Surface layer of the capitulum	Type of sclerites	Clubs	Rod and club shaped sclerites	Club and shuttles	Rod shaped or club shaped	Club shaped	Club, fusiform shaped and spindle-shaped	Shuttle or Volcano shaped and rod shaped	Club shaped	Rods and club shaped	Club shaped
	Length of sclerites (mm)	0.11 to 0.27	0.06 to 0.20	Clubs (0.10-0.17) few are up to 0.24 Shuttles (0.09-0.16)	0.16 to 0.33	0.12 to 0.28	0.10 to 0.25	0.08 to 0.26	0.06 to 0.23	0.08 to 0.22	0.07 to 0.19

Attributes		*Lobophytum altum* Tixier-Durivault, 1956	*Lobophytum catalai* Tixier-Durivault, 1957	*Lobophytum crassum* von Marenzeller, 1886	*Lobophytum crebriplicaltum* von Marenzeller, 1886	*Lobophytum hirsutum* Tixier-Durivault, 1956	*Lobophytum pauciflorum* (Ehrenberg, 1834)	*Lobophytum pusillum* Tixier-Durivault, 1970	*Lobophytum sarcophytoides* Moser, 1919	*Lobophytum schoedei* Moser, 1919	*Lobophytum variatum* Tixier-Durivault, 1957
Interior of the capitulum	Type of sclerites	Spindles, cylinder shaped and four rayed crosses	Oval shaped, capstans, cylinders and spindles	Oblong, subcylindrical or fusiform and spindle shape	Spindle shaped	Straight, curved pointed spindles.	Spindle-shaped	cylinder and spindle	Slender, and pointed spindles	Spindle shaped	Rods, cylinders, spindles, fusiform and shuttles
	Length (mm)	Up to 0.37	Up to 0.34	0.16-0.20 and spindles (Up to 0.36)	Up to 0.34	Up to 0.49	Up to 0.45	0.21 to 0.36	Up to 0.40	Up to 0.40	Up to 0.36
Surface layer of the stalk	Type of sclerites	club shaped and cylinder shaped	Small rods and club shaped	Clubs more or like surface layer of the capitulum	Club shaped	Club shaped	Clubs	Rod and club shaped	Club shaped	Club shaped sclerites	Club shaped
	Length (mm)	0.08 to 0.18	0.07 to 0.20	0.09-0.16	0.10 to 0.18	0.10 to 0.18	0.08 to 0.20	0.07 to 0.18	0.09 to 0.21	0.08 to 0.20	0.08 to 0.25
Interior of the stalk	Type of sclerites	Capstans, barrel shaped, dumbbell, cylinder shaped and spindles	Capstans, oblong or cylinders, shuttle and spindles	Capstans and spindles	Oblong, sub cylinders and pointed spindles	Oblong capstans to cylindrical shaped and spindle shaped	Capstans and cylindrical or fusiform-shaped sclerites	Dumbbells and capstans	Pointed spindles	Spindles	Cylinder, blunt ended fusiform shaped sclerites, shuttles
	Length (mm)	Capstans Up to 0.29 mm; spindles, up to 0.38	Capstans up to 0.28 mm shuttles measure up to 0.26 spindles up to 0.38	Capstans (0.17-0.20), and spindles (0.33)	Up to 0.39	0.15 to 0.24 Spindles up to 0.33	0.17 to 0.24	0.16 to 0.20	0.19 to 0.33	Up to 0.39	Up to 0.39

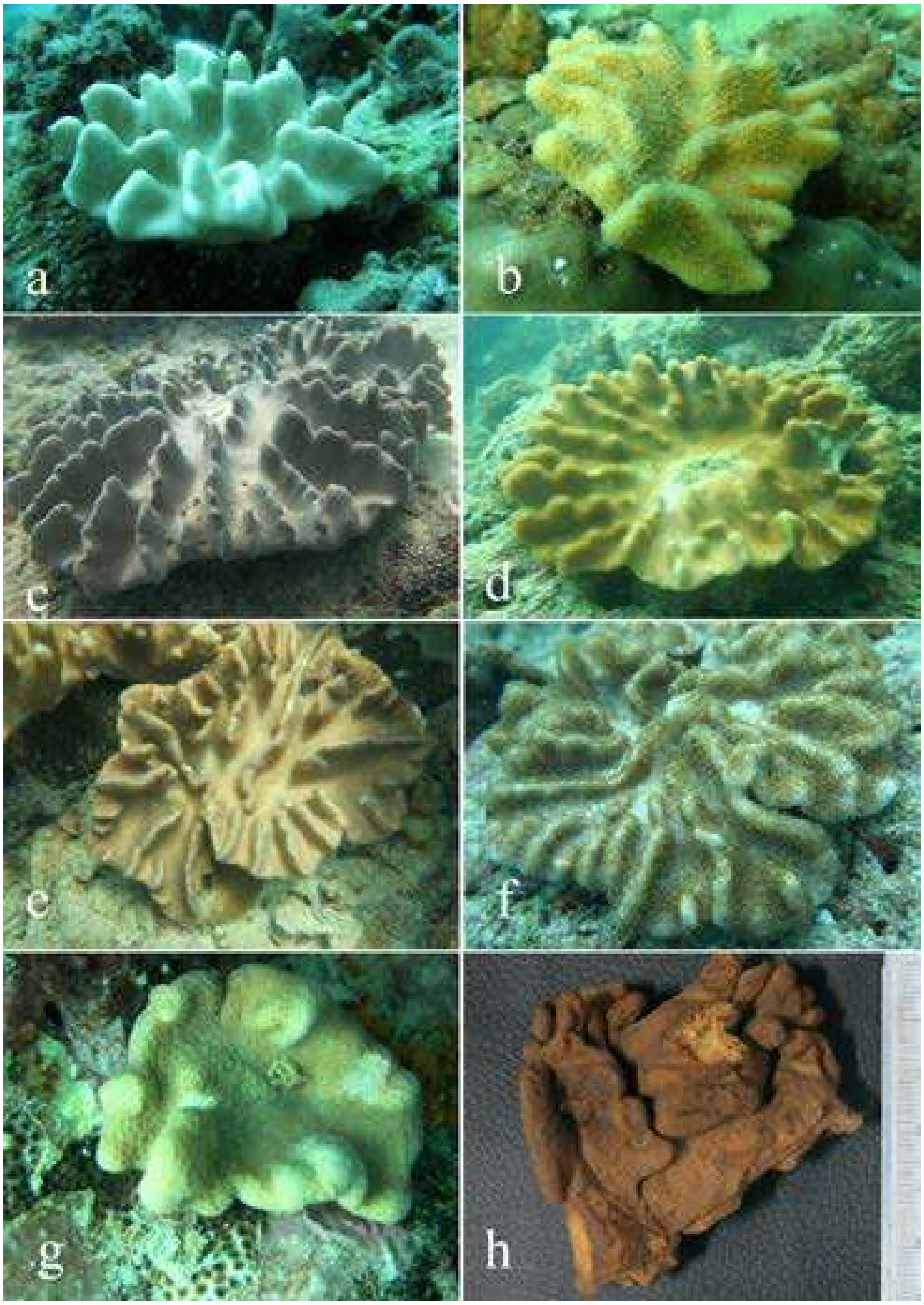

Figure 1: a-h examples of *Lobophytum* colonies; a. *Lobophytum altum* Tixier-Durivault, 1956 has bifurcated or low crest like lobes raised from edges of the colony, stalk is low; b. *Lobophytum catalai* Tixier-Durivault, 1957 contain thick crest like forms distributed throughout capitulum; c-f. *Lobophytum crassum* von Marenzeller, 1886 crest like lobes raised from colony edge and continuous towards the center, stalk or base is low almost as much as width of capitulum; g. *Lobophytum crebriplicaltum* von Marenzeller, 1886 thick crest raised at edges of the colony; h. *Lobophytum hirsutum* Tixer-Durivault, 1956 low stalk and more erect or fingerlike lobes

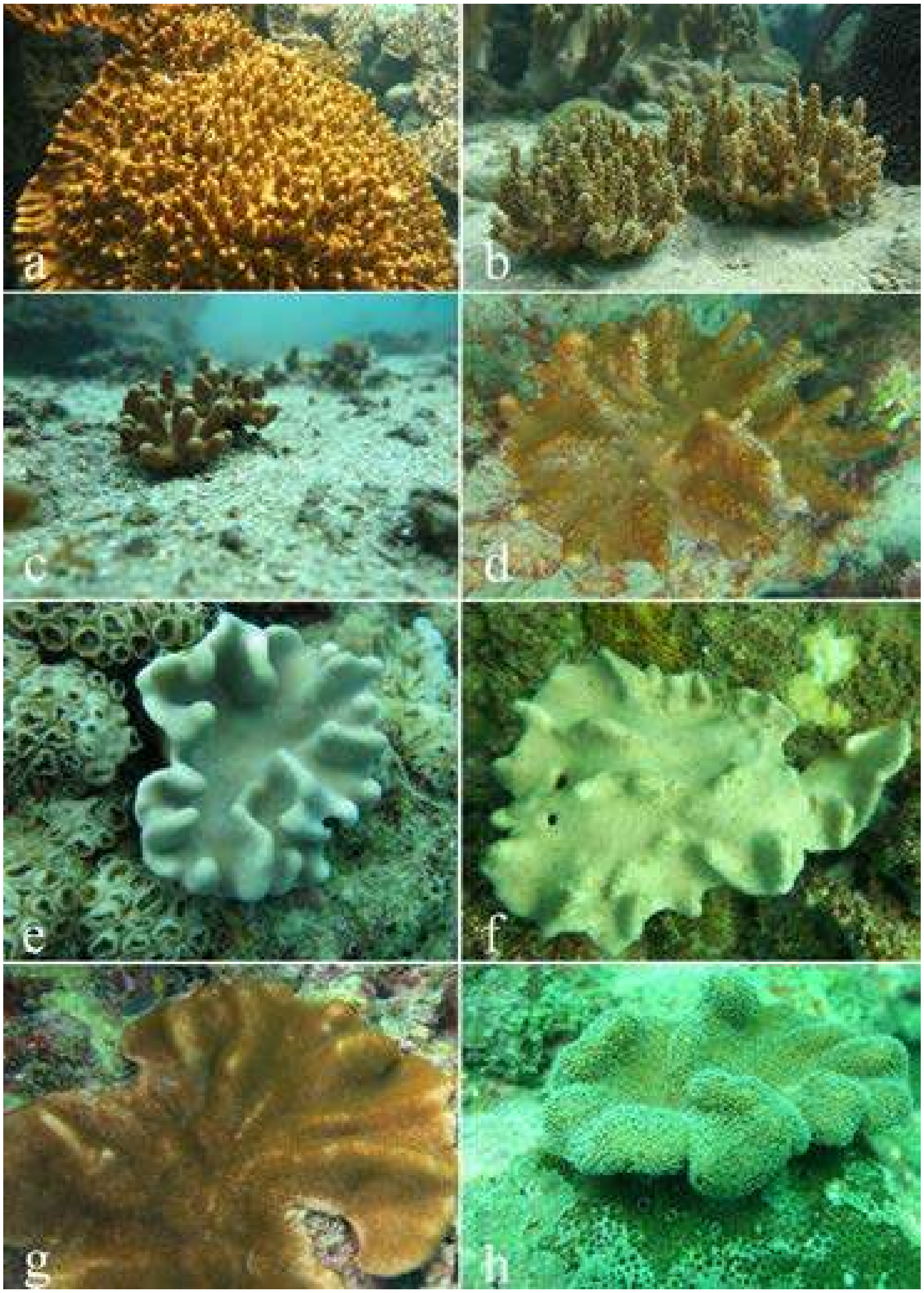

Figure 2: a-h examples of *Lobophytum* colonies; a-c, *Lobophytum pauciflorum* (Ehrenberg, 1834), *a-capitulum* has finger like lobes entire colony from edges to centre of the colony, low stalk; *b- finger* like lobes are erected highly and divided lobes at edges of the colony; *c- finger* like lobes with round upper portion raised from edges of the colony;d. *Lobophytum pusillum* Tixier-Durivault, 1970, capitulum has finger like lobes and crests from edges to center of the colony, autozooids visible in small tubercles exist throughout capitulum, and low stalk; e. *Lobophytum sarcophytoides* Moser, 1919 capitulum bowl-shaped, and the peripheral region of the capitulum rose upwards and formed crests on the edges; f. *Lobophytum schoedei* Moser, 1919 Small ridges or nearly flat capitulum; h. *Lobophytum variatum* Tixier-Durivault, 1957, broad capitulum with low crests and low stalk

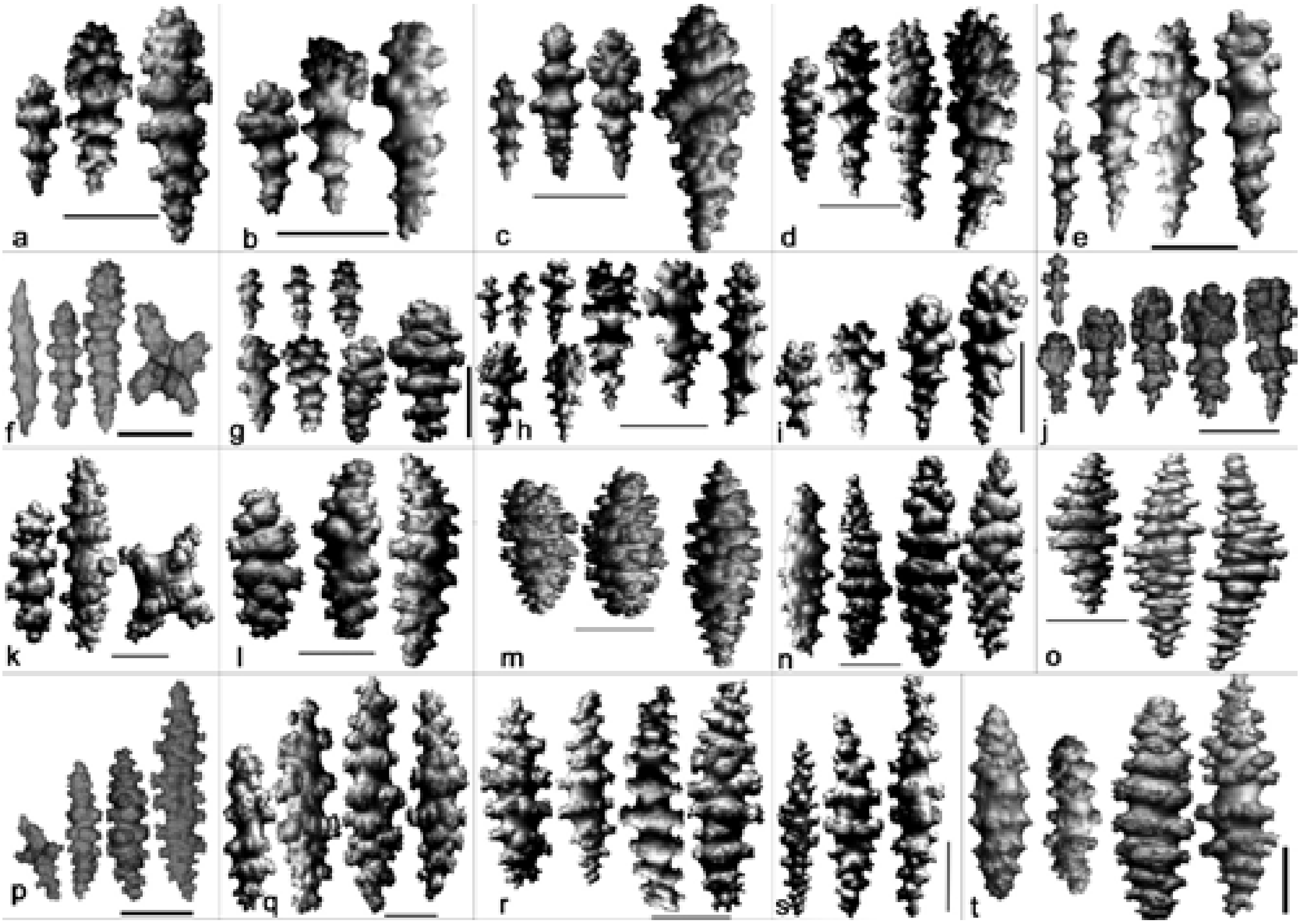

Fig. 3: a-j. Sclerites of surface layer of lobe of *Lobophytum* species, a. *L. altum;* b, *L. catalai;* c. *L.crassum*; d. *L.crebriplicaturm*; e. *L. hirsutum*; f. *L. pauciflorum*; g. *L. pusillum*; h. *L.sarcophytoides*; i. *L. schoedei*; j. *L.variatum*; k-t. Sclerites of interior layer of lobe of *Lobophytum* species, k. *L. altum;* l, *L. catalai;* m. *L.crassum*; n. *L.crebriplicaturm*; o. *L.hirsutum*; p. *L. pauciflorum*; q. *L. pusillum*; r. *L.sarcophytoides*; s. *L. schoedei*; t. *L.variatum*

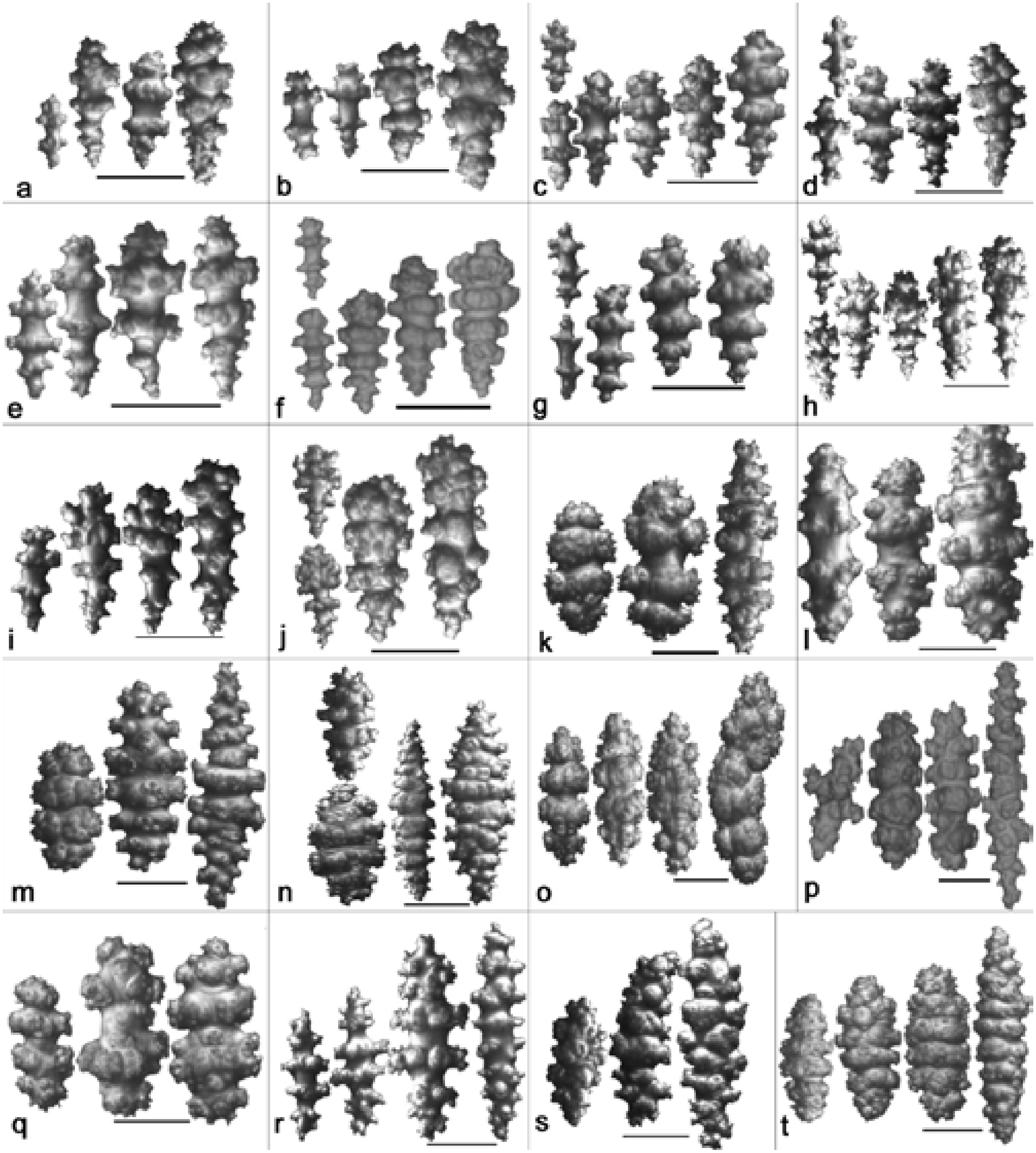

Fig. 4: a-j. Sclerites of surface layer of base of *Lobophytum* species, a. *L. altum;* b, *L. catalai;* c. *L.crassum*; d. *L.crebriplicaturm*; e. *L.hirsutum*; f. *L. pauciflorum*; g. *L. pusillum*; h. *L.sarcophytoides*; i. *L. schoedei*; j. *L.variatum*; k-t. Sclerites of interior layer of base of *Lobophytum* species, k. *L. altum;* l, *L. catalai;* m. *L.crassum*; n. *L.crebriplicaturm*; o. *L.hirsutum*; p. *L. pauciflorum*; q. *L. pusillum*; r. *L.sarcophytoides*; s. *L. schoedei*; t. *L.variatum*

Acknowledgements

The authors are grateful to the Director, Zoological Survey of India, Kolkata, for providing facilities. Authors are also thankful to the Department of Environment and Forests, Andaman and Nicobar Administration for providing the logistics support.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Scanning Electron Microscopic study on mouth parts of hill stream fishes, *Psilorhynchus ngathanu*, Shangningam *et al.,* 2013 and *Garra abhoyai*, Hora, 1921 from Chindwin Basin, Manipur, India. (Teleostei: Cyprinidae)

[1]Shagolsem Aruna Chanu, [2]I. Linthoingambi, [3]Kh. Rajmani Singh, [4]Ng. Catherine

Department of Zoology,
Dhanamanjuri University, Imphal, Manipur,795001
Email: [1]arunachanush20@gmail.com, [2]irengbamlinthoi78@gmail.com,
[3]rajmanikh@rediffmail.com [4]pipingangbam@gmail.com

Abstract

Scanning electron microscopy (SEM) on the associated structures of mouth of *Psilorhynchus ngathanu* and *Garra abhoyai* has been carried out. SEM structures of mouth parts of *P. ngathanu* reveal the presence of elongate and pointed tubercles on the rostral cap. Papillae studded with unculi and taste buds are seen along with numerous mucus. In *G. abhoyai* hexagonal epithelial cells with elevated cell boundaries and scantly mucous gland opening are observed. Taste buds present at the apex of epithelial cells with micro-ridges pattern have also been observed. Histology of rostral cap and parts of Gular disc of *Garra abhoyai* are also carried out. Fringed and papillated rostral cap on upper lip are observed. Clavate cell, sensory cell, pigment cell of central callous are seen.

Keywords: *Garra abhoyai*, *Psilorhynchus ngathanu*, mouth, lips, adhesive organ, SEM, Histology.

Introduction

The *Psilorhynchus ngathanu,* Shangningam *et al.*, 2013 and *Garra abhoyai,* Hora,1921 are true rheophilic fishes of the hill stream freshwater fishes. They are the cyprinid fish that include bottom dwelling fishes usually found in fast flowing streams where they cling to rocks using the highly modified mouth and its associated parts. The genus *Garra* (Hamilton, 1822) is widely distributed from southern China, across south east Asia, India and the middle east to northern and central Africa and the members of the genus *Psilorhynchus* McClelland, 1839 are small - size fishes with arched backs and flattened ventral surfaces that inhabits torrential rivers and streams of north-eastern and south-western India, Bangladesh, Myanmar, Nepal & and adjacent China .

The earlier study on histology of the adhesive apparatus of hill stream fishes has been described by Hora (1922) on *Garra annandalei* (Sunder Lal Hora). Worthy of mention is Hora's (1921) observations on the morpholaxis of the disc of *Garra rupeculus* (McClelland). More works on the adhesive organs of hill stream fishes are that of Saxena (1959, 1961). Hora, 1922 described *G. abhoyai* from the stream of Ukhrul district of Manipur, Chindwin basin. The species was characterised by having smoothly rounded snout tip, proboscis absent, pre-dorsal scales present but those towards head reduced. There are also very few structural reports of SEM and histological studies of the genus *Garra* (*G. annandalei*, Hora, 1921; *G. mullya*, Saxena and Chandy, 1959; *G. gotyla*, Das and Nag, 2006; *G. lamta*, Tripathi *et al.*, 2012). Recently, Linthoingambi *et al.*, 2013 has given an

*Author for correspondence : researchwild.ophidia@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

account on the histological analysis of adhesive organ of *G. abhoyai* but there has not been analysis of these characters of *G. abhoyai* through SEM till now.

Genus *Psilorhynchus* has three groups of species such as *P. balitora* species group, *P. nudithoracicus* species group and *P. homaloptera* species group (Conway 2011, Conway *et al.*2013). Shangningam *et al.*, 2013 described *P. ngathanu* from the stream of Dutah river, Chindwin basin, Manipur, India. The species belonged to *P. balitora* species group. As morphometric and meristic characters, the species of *P. ngathanu* was described as having head and eye large, mouth inferior, snout rounded, absence of scales from the midventral region between pectoral fins, the presence of two rows of spots on the dorsal-fin ray and two black bars on the caudal fin.

Thus, the aim of present study assigns with the scanning electron microscopic analysis of Mouth parts of *P. ngathanu* and SEM and histological analysis of adhesive organ of *Garra abhoyai*.

Materials and Methods

Live adult 11 specimens of *P. ngathanu* (fig.1.) and 15 specimens of *Garra abhayai* (fig.2.) were collected from the Maklang river, Kamjong district, Manipur, Chindwin basin and from the Sekmai river, Awang Leikinthabi region, Manipur, Chindwin basin respectively.

For Scanning Electron Microscopic study:

Specimens were maintained in laboratory at 25 ± 20°C. The fishes were cold anesthetized, tissues were cut from the mouth parts of *Psilorhynchus ngathanu* and *Garra abhoyai* as half of each. Halves of other sides were kept for later observation on. Then, it was rinsed in 70% ethanol and fixed in 3% Glutaraldehyde for 2 to 4 hours at 40°C. The tissues were washed in 2-3 changes of 15 minutes each at 40°C with 0.1M phosphate buffer and dehydrated in the graded series of ice-cold Acetone (30%, 50%, 70%, 90% and 100% approximate 20-30 min.) at 4°C. For drying, using TMS method, the tissues were immersed in Tetra Methyl Silane for 5 – 10 min. for two changes at 40°C. They were brought to room temperature (25-26°C) to dry.

Tissues were mounted on Aluminium stubs using a double-sided adhesive tape and sputter coating was carried out by carbon coating. Samples were examined in a SEM at the Sophisticated Analytical Instrument Centre, IASST, Guwahati, India. The results were recorded using Zeiss Sigma-Field emission scanning electron microscope.

For Histological study:

Tissues were fixed in Bouin's fluid for 24 hrs. After fixation, the tissues were dehydrated in a graded ethanol series as 30 min each that is 30%, 50%, 70%, 90%, 100% and then in pure xylene for clarification and then it was embedded in paraffin wax. Paraffin block was cut into slices by using Microtome. 0.6 micro paraffin sections of the adhesive organs were subjected to routine histological staining procedures. Prepared histological slides were observed under Olympus Magnus MLX microscope (100X) and the images were captured with Olympus Pen system camera (E-PL1).

Results:

Scanning Electron Microscopic (SEM) Observation:

Mouth parts of *Psilorhynchus ngathanu*:

Upper lip (UL) bears with numerous, horizontally arranged rows of heavily set, elongate and pointed Unculi (U). Rostral cap (RC) is fused with upper lip and separated by shallow groove. Numerous mucous pores (MP) are seen. Scattered tubercles(U) are present on the posterior margin of rostral cap. Lower Jaw (LJ) covered by thick squarish cushion that can be folded backwards. Blunt unculi arranged in the form of tiles are present over the lower lip surface. Lower jaw cushion is composed of two layers, one is anteriorly located in lower lips and another is posteriorly located in superficial layer. Unculiferous globular papillae present on surface of superficial portion are studded with multiple taste buds. Slightly papillated skinfold at posterolateral most corner of mouth connects the superficial layer with rostral cap. Taste buds are also present on the posterolateral skin folds (PLSF) (Fig.3).

Adhesive Organ (AO) of *Garra abhoyai*:

SEM reveals the detailed surface features of the adhesive organ of *Garra abhoyai* as:

Stub Shaped Papillae,

At low magnification, the disc exhibits the presence of Stub shaped Papillae (SP) bearing spines. Large portion of the disc comprises the elevated pulvinus.

At higher magnification, the stub shaped papillae are seen covered with hexagonal epithelial cells with numerous mucous openinf pores (figure-4, g). These cells have well-marked cell boundaries and are modified into spines.

Spines

The spines are broad at base and gently taper towards the tip. Some spines are short and have blunt ends whereas many spines are long and curved at the end. It is also noted that the spines tend to face the same direction, some spines are seen with no nucleus due to lack of development. This could be immature spines. Some papillae exhibit few hexagonal epithelial cells without spines. Some epithelial cells bear very short spines that may be in the process of development.

Lower lip (LP)

Papillae bearing pointed and longer spines are present. The pulvinus of adhesive disc is composed of irregular, rough epithelium that bears many mucous opening pores. At low magnification, it exhibits wide epithelial layers with small elevations throughout the entire area and at higher magnification, it shows the presence of concentrically irregular micro ridges with numerous mucous openings (MO and taste buds). This spread of mucus of pulvinus is facilitated by numerous canaliculi (microscopic canals) formed by epithermal micro ridges. Hence, this kind of cumulative action of spines and mucus enables the fish to make firm hold on the substratum. (Fig.4)

Histological observation of *Garra abhoyai:*

Rostral cap in upper lip consists of numerous stub shaped papillae bearing spines and grooves between them. These papillae are formed by the rapid divisions of epithelial cells of stratum germinativum (basal cell layer producing new cells) that are covered with spines having nuclei. The surface of epithelium is keratinized. Spines are formed by the outermost layer of the epithelial cells, lying immediately below the stratum corneum. The nuclei of spines are somewhat oval in outline. Immature spines are present towards the snout portion of rostral cap. Some papillae which are devoid of spine are present. Two types of papillae are observed as large papilla formed by polygonal cells (PC) on upper region and lanceolate shape cells (LC) at base. They are observed on the peripheral region of skin fold and small papillae with 4 to 6 polygonal cells having large nuclei observed near the junction of pulvinus. These papillae are covered with spines (modification of stratum corneum layer).

Clavate Cells (CC)

Most of the central space of the epithelium is occupied by a number of CC which are distinguished at regular intervals and form a distinct layer of their own having distinct cell wall and sometimes their nuclei may be as big as an ordinary epithelial cell and it also present more than one nucleus.

Sensory cells (SC) are present near the base of papillae and open in stratum corneum layer. Pigment cells are present in between the stratum compactum and stratum germinativum. (Fig.5 a-d).

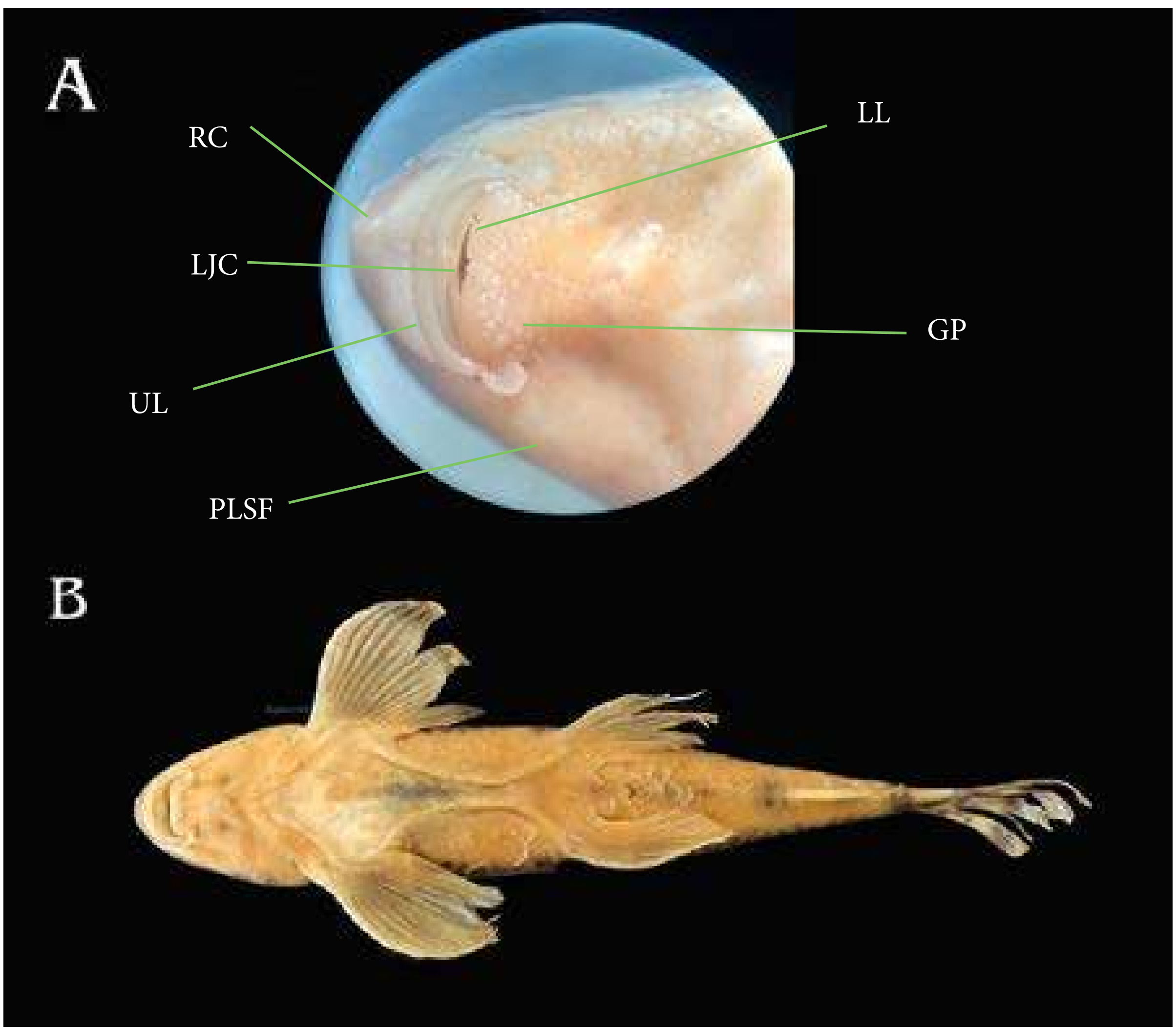
Discussion:

Earlier SEM studies reported that fish taste buds fall into three categories based on their external surface morphology (Reutter *et al.*, 1974; Ezeasor, D.N. 1982). In addition to the three types of taste buds previously described from various teleost fish, a fourth type comprising very small buds, was found in some cardinal fish (Fishelson, 2004). The taste buds in the mouth cavity of *Rita rita* (Hamilton,1822) are of three types which are elevated from the epithelium at different levels, which may be useful for ensuring full utilization of the gustatory ability of the fish, detection and analysing of taste substances, as well as for assessing the quality and palatability of food, during its retention in the mouth cavity (Yashpal *et al.*, 2006) In present study, only one type of taste bud is observed in *P. ngathanu.* Agrawal & Mittal (1992a) reported the presence of keratinized unculi on the ventral side of the upper lip and keratinized cone like structure with sharp cutting edge on the horny lower jaw sheath associated with the lower lip of an omnivorous bottom feeder, *Cirrhina mrigala*. Agrawal & Mittal (1992b) observed keratinized unculi on the ventral side of the upper lip and on the dorsal side of the lower lip facing the mouth opening. In addition, they observed keratinized cone like structure on the horny upper jaw sheath and on the horny lower jaw sheath associated with the lips of the herbivorous column feeder, *Labeo rohita*. The present study shows that in *P. ngathanu*, the presence of unculi in both upper lip and lower lip are observed by SEM studies.

Garra abhoyai:

The study on lips and associated structures began about 200 years ago, as described by Anson, 1929. He made an attempt to define lips and on Danforth's interpretation of homology, homologous lips were found at certain stages of development in some representatives of all classes of vertebrates. Lips were varied in structure to accord with their physiological functions, whether sensory, prehensile, or adhesive (Anson, 1929). Fishelson, (1984) correlated the variations in micro-ridge pattern with the locomotory activity of the fish. He suggested that in faster swimming fishes, micro-ridges were most developed and served to trap mucus on the epithelial surface. *G. abhoyai* has also well-developed micro-ridges. Secretions elaborated by the epithelial cells and the mucous cells in the mucogenic epithelia could be regarded as an adaptation to lubricate and protect the epithelia from abrasion (Pinky *et al.*, 2002). The role of mucus was likewise postulated previously to inhibit the invasion and proliferation of pathogenic micro-organisms and to prevent their colonisation in fish epidermis (Nigrelli, 1937; Nigrelli *et al.*, 1955; Hildemann, 1962; Liguori *et al.*,1963; Lewis,1970). For such kind functions numerous mucous opening pores in *Garra abhoyai* are also shown in squamous epithelial cells. A very prominent taste bud in large numbers is observed in *Garra lamta* (Tripathi, A., 2012) but only one type of taste bud is also observed in *G. abhoyai* on lower lip.

G. abhoyai and *P. ngathanu* occupy peculiar trophic niche and they scrape epilithic or epiphytic algae and other food items from submerged substrates. This specialized feeding type is possible due to the remarkably formed, ventrally placed sucker mouth (adhesive disc) just behind the arched lower lip for *Garra* species and for *Psilorhynchus* species lower jaw cushion in lower lip is present. In spite of this highly specialized feeding apparatus, diversity in both thickness of the different regions of lips and in shape of lips exists, and these fishes actually feed on a broad range of food. As such, Cyprinidae are the most specialized and successful fish family within the order Cypriniformes (Mittal, A.K, *et al.*, 2012).



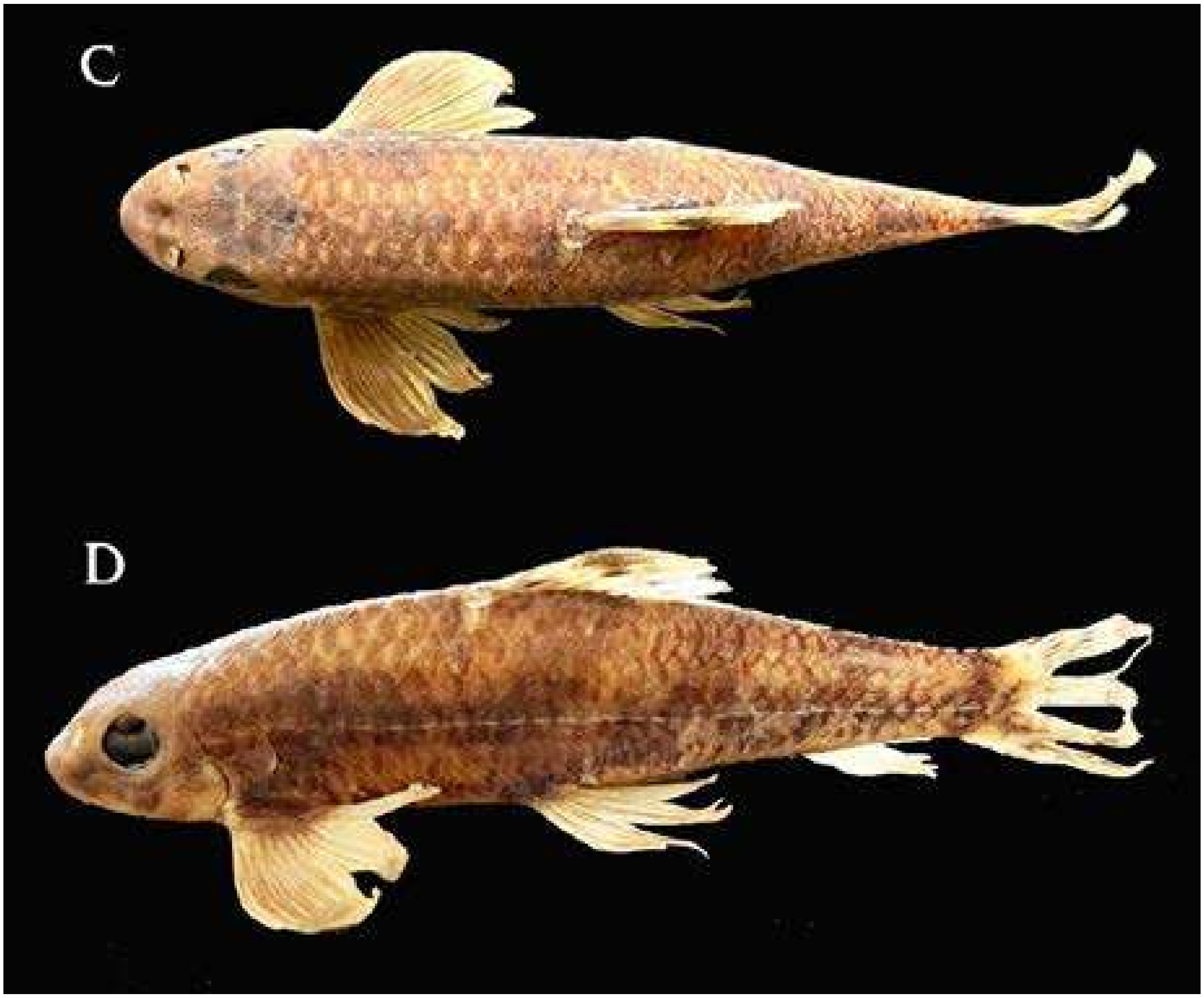


Fig 1. A – Mouth of *Psilorhynchus ngathanu* showing Rostral Cap (RC), Posterolateral skin folds (PLSF), Lower Jaw Cushion (LJC), Globular papillae (GP), Upper Lip (UL), Lower Lip (LL) using Light Electron Microscope.

B – Ventral view of *P. ngathanu*

C – Dorsal view of *P. ngathanu*

D – Lateral view of *P. ngathanu*

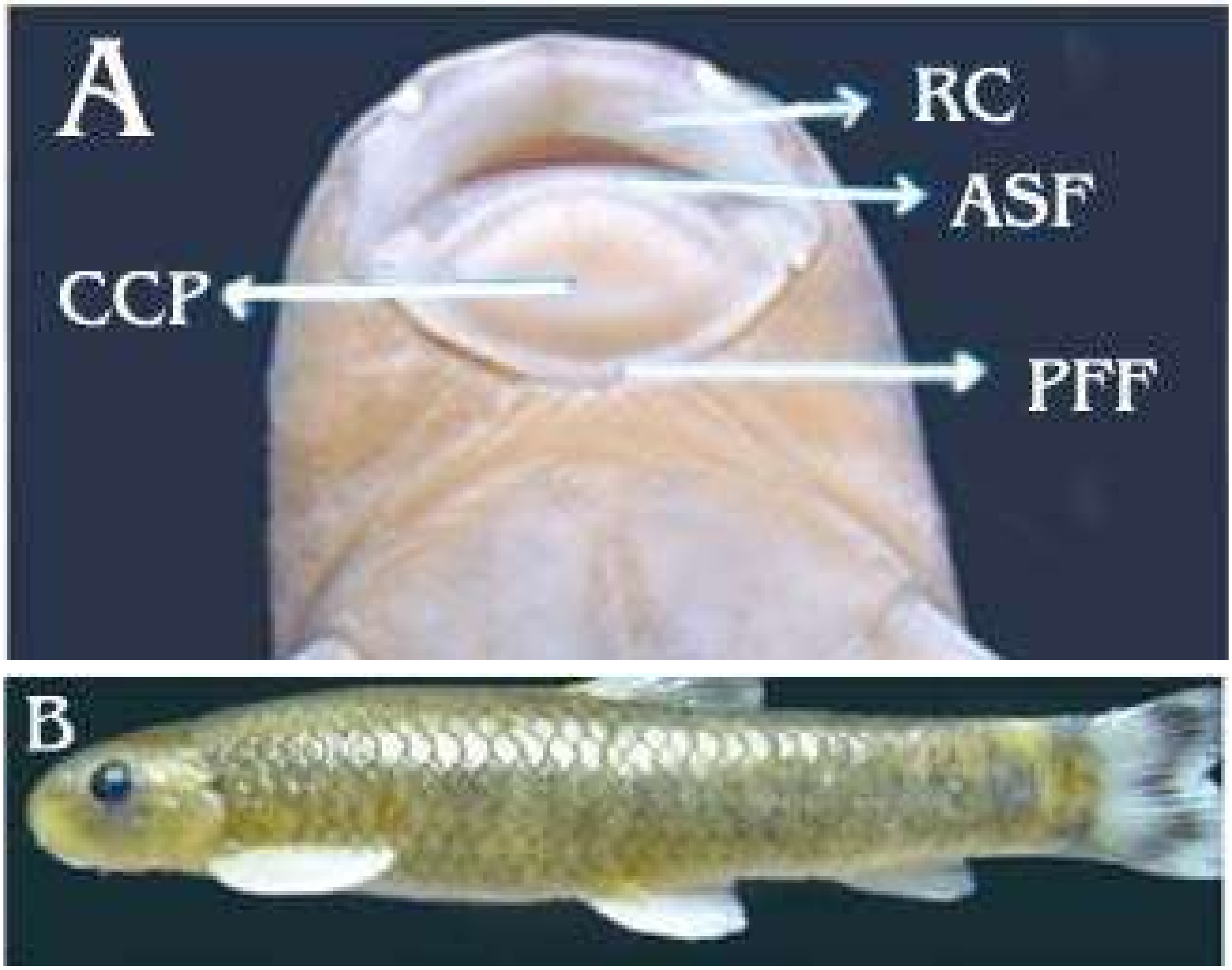
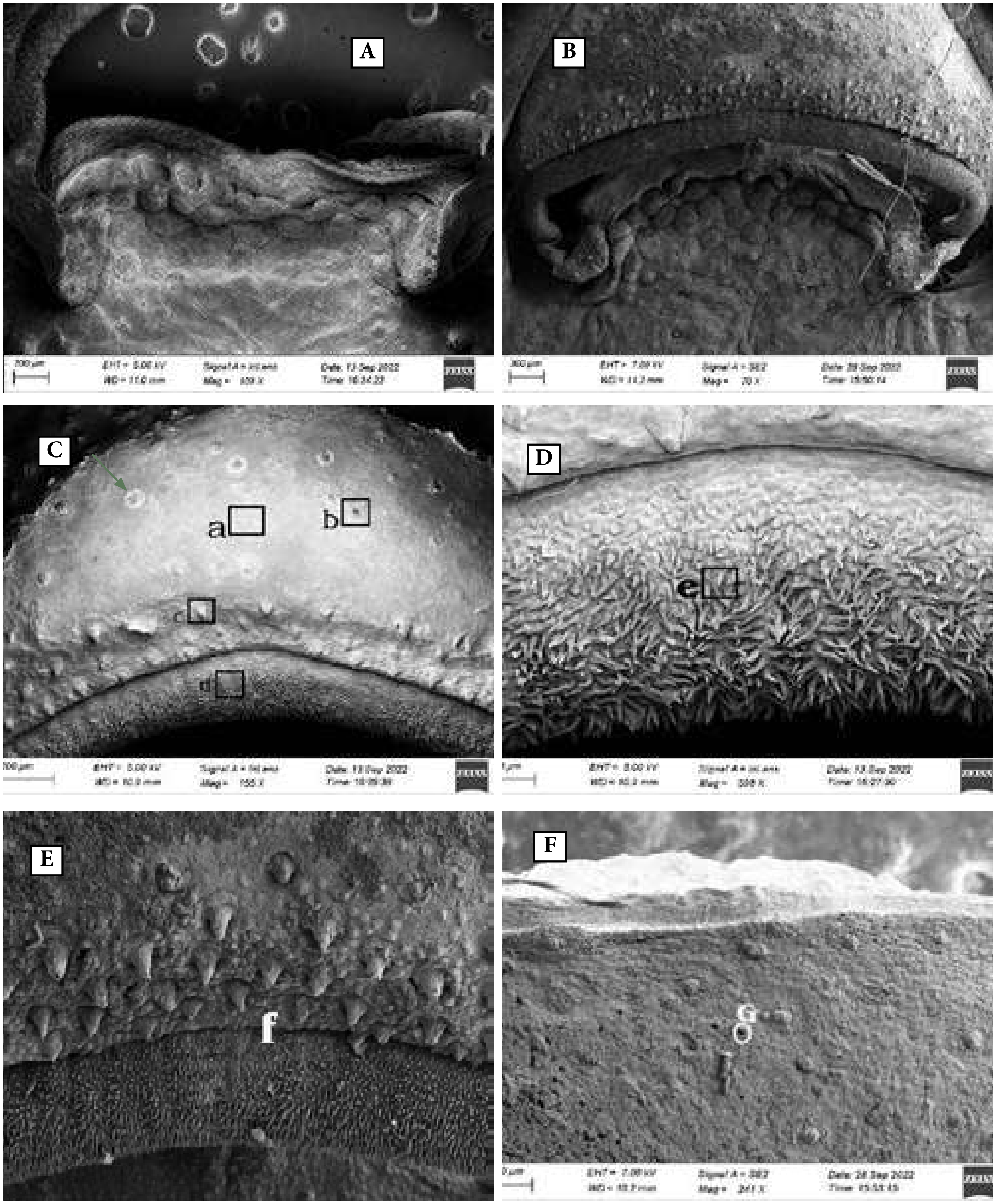


Fig 2. A. Adhessive Organ of Lower Lip of *Garra abhoyai* showing Rostral Cap (RC) and remove (ASF-Anterior Skin Fold (Torus), CCP-Central Callous Part (Pulvinus), PFF-Papillated Fee Fold(Labrum)

B. Lateral view of *G. abhoyai*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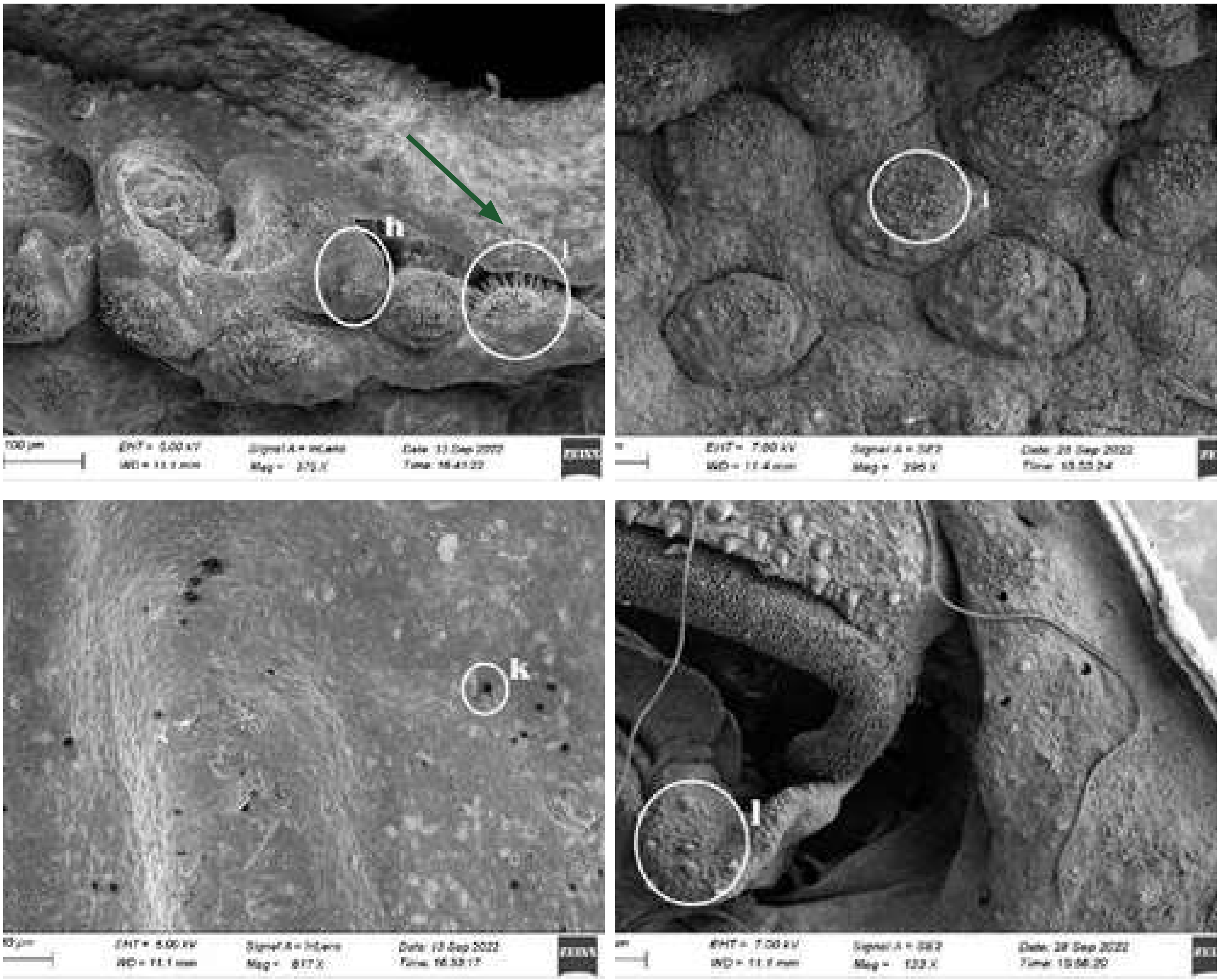


Fig. 3. Scanning Electron Microscopic pictures of Oromandibular structures of *Psilorhynchus ngathanu,* 57.86 mm SL.

A. Showing blunt unculi on lower jaw

B. Showing whole parts of the mouth of *Psilorhynchus ngathanu* i-rostral cap, ii-upper lip, iii- lower lip, iv- superficial layer densely papillated, v-skinfolded

C. a- Rostral Cap (RC) on the mouth, b. showing taste buds on RC with eroded tubercles, c. Pointed Tubercles (PT) on Rostral Cap, d. Upper Lip (UL) with heavily set elongated and pointed unculi, arrow shows eroded tubercles

D. e. magnifying image of elongated and Pointed Unculi (U) on UL,

F. Shallow groove (SG) between the RC & UL,

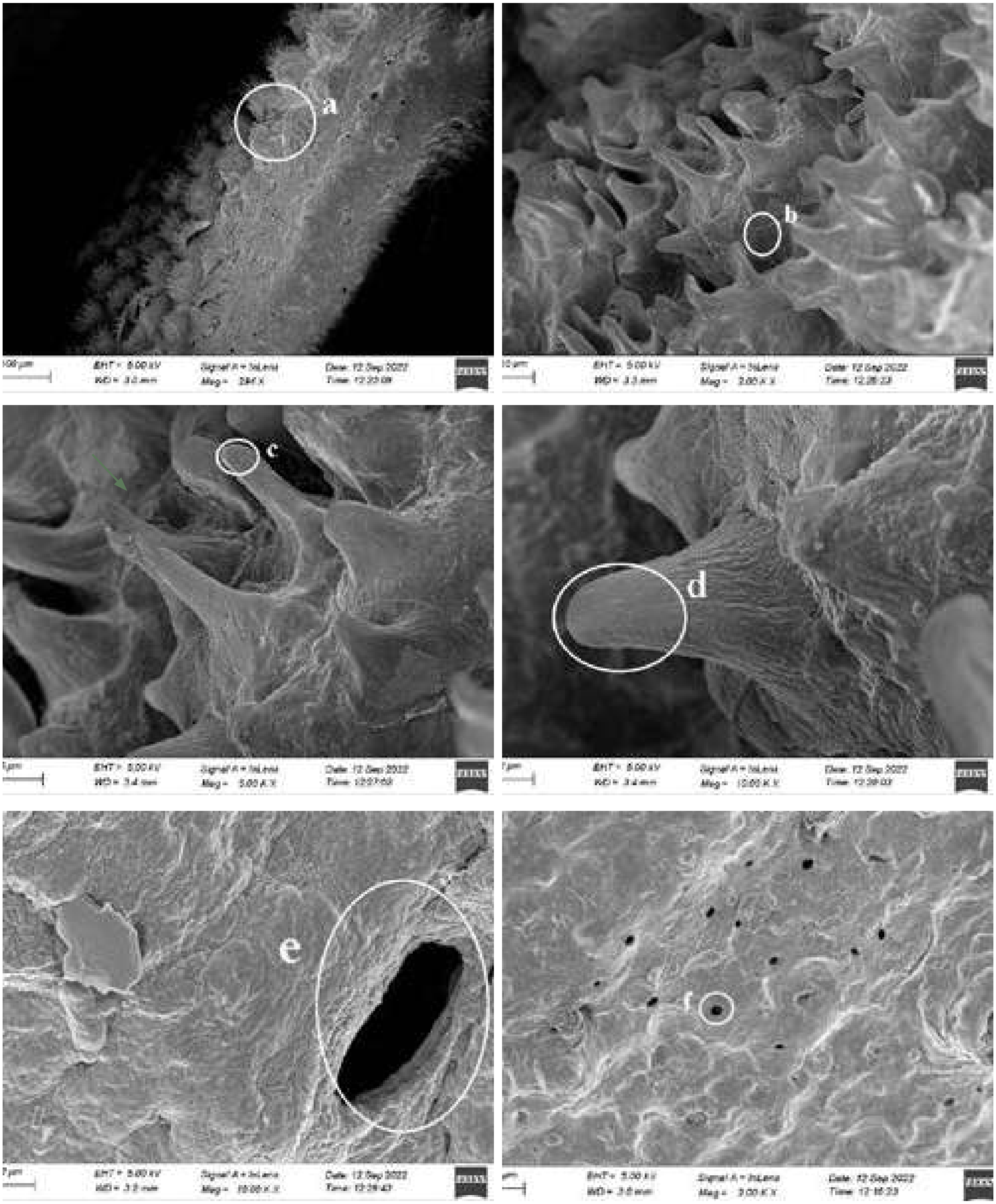
G. MO-Mucous opening pore on upper lip,

H & I- Unculiferous globular papillae on superficial layer of lower jaw cushion (LJC) on LL, and arrow shows the taste buds on lower lip

J. Superficial layer having densely unculiferous globular papillae covered with taste buds,

K. Mucus opening pore on lower lip,

L. Posterolateral skin folding (PLSF) with taste buds on corner of the mouth.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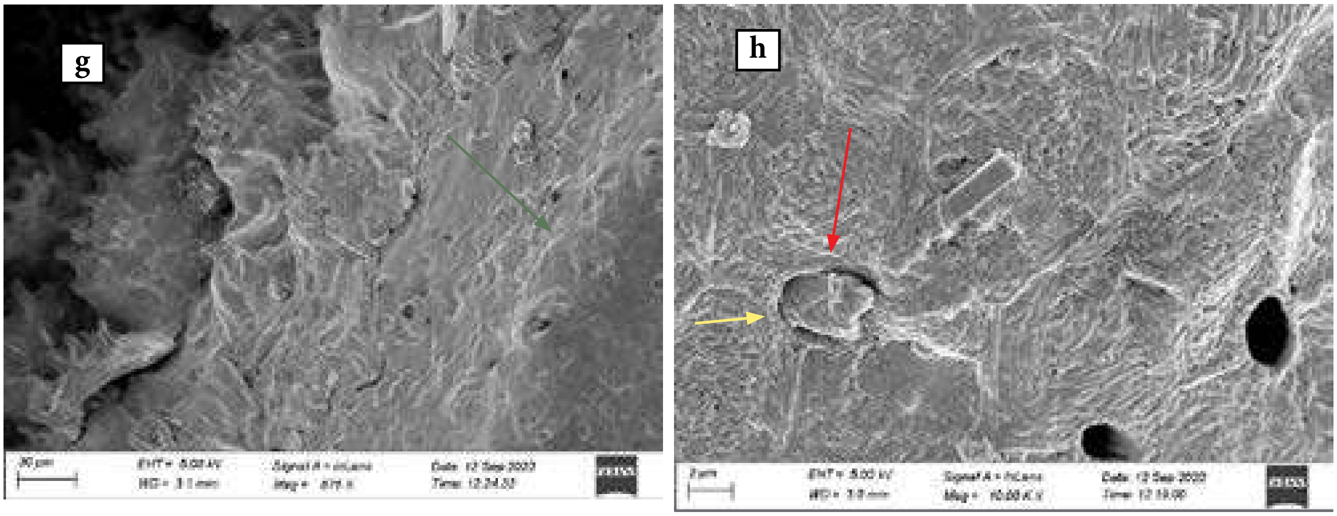

Fig. 4: S.E.M. micrograph of Adhesive organ of mouth parts of *Garra abhoyai*: a. at low magnification, showing Short Stub shaped Papillae (SP) bearing spines on lower lip (LL), b. groove between the papillae, c. at higher magnification, SP showing bearing elongated spines on lower lip (LL), d. blunt spines e. magnifying mucous opening pore on pulvinus, f. mucous opening pores on corner side of lower lip, g. arrow- showing squamous epithelium on the substratum, h- micro-ridges (arrow) with mucous opening pores on squamous epithelium.

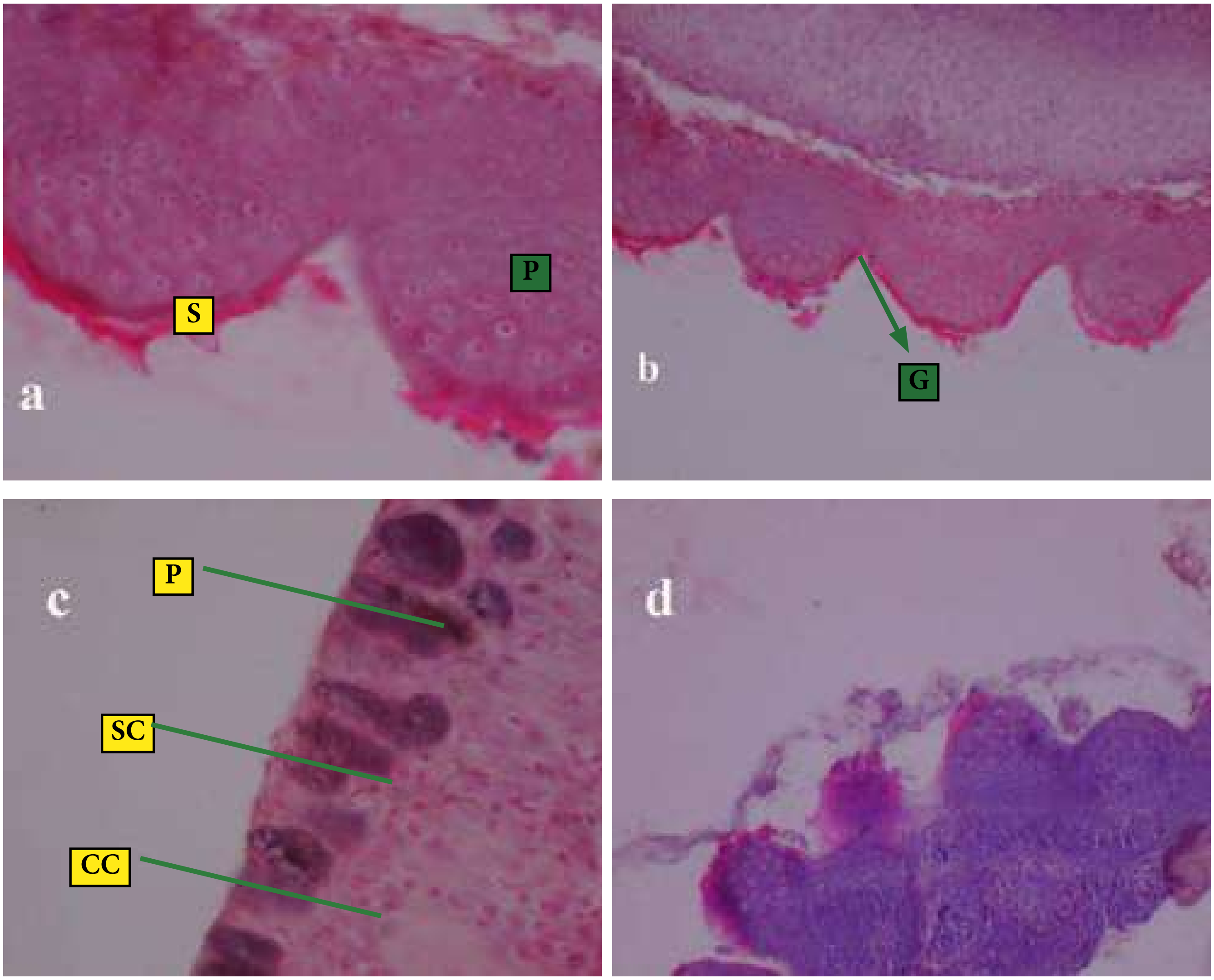

Fig. 5. Histological images of adhesive organ on mouth paths of *Garra Abhoyai* a. Papillae(P) with spine(S), b. groove (G) between papillae, c. PC - Pigment cells of pulvinus, SC- Sensory cells of pulvinus, CC- Cavate cell of pulvinus part, d. Papillae without spine present in papillated fold area (SC-Sensory cells).

Acknowledgments

We are showing the gratification to Dr. Bungdon Shangningam for her suggestive literatures and Dr. Nebeshwar for his constructive ideas and also intensely thank to fishery laboratory, Zoology Department, DM college of sciences, Dhanamanjury University, Imphal, Manipur for giving the facility of using any other kind of equipment that is related to our works.

Lastly, we are also very greatful to Sophisticated Analytical Instrument Centre, IASST, Guwahati for Scanning electron Microscopy (SEM).

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Characterization and Morphologically Identification of Scavenger Syrphid (Insecta: Diptera) pupae using Scanning Electron Microscopy (SEM) study

Bristi Roy*, Jayita Sengupta, Atanu Naskar, G. P. Mandal and Dhriti Banerjee[1]

Diptera Section, Zoological Survey of India
M-Block, New Alipore, Kolkata-700053
**Email of presenting author: roybristi19@gmail.com*

Abstract

The preimaginal stages of hoverflies have a range of feeding habitats benefiting the ecosystem in plenty ways: control aphid population on crop plants, scavenger, and predator in the ant nest, decomposer of organic matter, etc. Indeed, studies on Indian syrphid fauna have long been restricted only to the morpho-taxonomy of the adult stage. The present study has identified, characterize, and elucidate scavenger syrphid pupae collected from the different habitats of Gangetic Plains using a Scanning Electron Microscopic (SEM) study. The ultrastructural morphology of the pupal spiracle (shape, size, surface nature, and extensions from the surface) has been found to hold the diagnostic key to species.

Keywords: Hoverflies, immature stages, SEM, scavenger, spiracle.

Introduction

Hoverflies (Diptera: Syrphidae) are one of the large and most diverse group of the order Diptera with > 6000 species worldwide belonging to 200 genera (Doyle *et al.*, 2020). The diversity is largely attributed to the various forms and habitat preferences of their larvae. Besides pollination by adult flies, larvae of this family group have served as a potential biocontrol agent of soft-bodied insects (mainly aphids) (Ghorpadé, 1981). Larvae of the subfamily Eristalinae are saprophagous, which aids in scavenging decaying organic matter (Rotheray & Gilbert, 1999). Larvae of some syrphid flies (members of the subfamily Microdontinae) were also found predatory on immature stages of ants due to inhabitation of ant nests (Reemer, 2013), while larvae of *Eumerous*, *Merodon*, *Cheilosia*, etc., are phytophagous (Torretta *et al.*, 2021, Popov *et al.*, 2017), feeding on plant body parts. Also, larvae of genera- *Eristalis*, *Ornidia*, *Palpada*, *Eristalinus*, *Helophilus*, etc. have been reported to cause myiasis in vertebrate animals (Pérez-Bañón *et al.*, 2020). The majority of all those larval forms are terrestrial except larvae of the tribe Eristalini, which thrives on organic pollutant-rich aquatic or semisolid media such as municipal sewage, dirty ponds, marshes, bogs, manure lagoons, etc., and they are mostly air breathers, possess a characteristic long tail-like breathing siphon that extends to the surface water (allowing them to breathe air while submerged). This peculiar hallmark has endowed them the common name of "rat-tailed maggot". Being a consumer of the decaying matter these rat-tailed maggots fuel the rapid decomposition of organic wastes and nutrient recycling in the aquatic media they live in (Campoy *et al.*, 2017). These maggots seek a drier, more or less shady place for pupation and at that time their rapid migration from water bodies to adjacent drier areas can be observed. Pupation preferably occurs at a concealed place like crevices or soft burrowing grounds to circumvent predators. During the course of the metamorphosis of syrphid flies, only a few individuals from the preceding stage made it up to the pupal stage, and survival at this stage is critical for becoming an adult. In addition to this, these sessile pupae are easy to collect, handle, and process for identification, thus making them a good alternative for species-level diagnosis.

[1]Author for correspondence : diptera.zsi@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Despite having such an intriguing life history and economic importance, hoverflies are less explored at their immature stages, and studies on their developmental stages (egg, larva, pupa) have been carried out for only a few Palaearctic and Neotropical syrphids (Rotheray & Gilbert 1999, Pérez-Bañón *et al.*, 2003a, Pérez-Bañón *et al.*, 2003b, Pérez-Bañón *et al.*, 2013). India itself has 355 reported species of hoverflies under 69 genera (Sengupta *et al.*, 2016), but unfortunately, their developmental stages have not received much research attention so far. The present study is the very first initiative from the country to explore the immature stages of hoverflies by using Scanning Electron Microscopy (SEM) to characterize and elucidate scavenger syrphid pupae collected from various habitats of the Gangetic plains.

Material & Methods

Collection and Rearing of Pupa

For the present study different habitats of the Gangetic Plains, preferably areas of organic pollutant-rich open drainage systems were surveyed. Pupae were collected from the cracks, crevices, and holes on the drainage wall as well as the areas adjacent to the drainage, with the help of forceps, brushes, and strainers, and then stored and carried to the laboratory in separate containers (transparent disposable plastic glass) for further studies. The opening of each plastic glass containing pupa was covered with a piece of cotton cloth to ensure proper aeration and housed in large cartons. The pupae were exposed to normal room temperature (26.01 ± 0.31 °C), and room lights (light: dark cycle of 12 h light:12 h dark) till eclosion (Nicholas *et al.*, 2018).

Morphological Image

Newly emerged adults were narcotized by ethyl acetate in a killing jar, later pinned for identification, and empty puparia left behind were taken for further morphological observation and examination. Images of the habitus of adult flies and pupa were generated by using a 0.32x Acro lens of Leica M205A Microscope. Pupal spiracles were selected for a Scanning Electron Microscopic study as the ultrastructure of spiracle (length, shape, spiracle surface, arrangement of tubercles, basal part ornamentation) is critical for species-level identification (Pérez-Bañón *et al.*, 2013). Spiracles were dissected from the puparium and washed several times with distilled water, then passed through an ascending series of ethanol dehydration (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% for 15 mins and 100% for 15*15*15 mins) and to avoid any moisture, a 45-minute drying was carried out using 100 wt. yellow light bulb. Finally, the spiracles were mounted on a double-stick conductive tape on aluminium SEM specimen stubs and gold-coated in order to be observed under a Zeiss EVO 18 Special Edition Scanning Electron Microscope (Zeiss, Germany) operated at 10kV (Hore *et al.*, 2017). Morphological terminologies used to describe pupa follows Hartley (1961 & 1963).

Results

Identification of the adult emerged from the pupa

The adult syrphid flies raised from pupae were identified as *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787) (Figure 1: D, E, F) based on their morphological characteristics using the taxonomic keys of Brunetti (1923) and comparing with the reference national zoological collection (NZC) of Zoological Survey of India (ZSI).

Characterization of pupa

The pupa is pale to dark brown in color and looks like a dewdrop with a short tail (posterior respiratory process, functional at the larval stage). A pair of anterior spiracles (functional at the larval stage) present in front of the head and above them, a pair of thoracic horn-shaped pupal spiracles are present. The length of the pupal body without the posterior respiratory process measures 11.75-12.92 mm, and with posterior respiratory process measures 21.13-22.5mm, the width gradually reduces basally and maximum at the middle (4.52-4.72mm) (Figure 1: A, B, C).

Ultrastructure of pupal spiracle

The spiracle is sub-cylindrical in cross-section, slightly arched back, truncated and narrowed anteriorly, and flattened ventrally and posteriorly. More than 60% of the spiracle is covered dorsally and laterally with oval-shaped protrusions or tubercles bearing alveolar openings varying in numbers from 3-10. These tubercles arranged in indistinct lateral bands (~8), are more conspicuous posteriorly. Setae arranged in sub-circular bands covered almost the entire length (between intertubercular bands and, on the spiracle folds) of the spiracle except on the basal part. Ornamentation at the basal part consists of small irregular bulges with setae protruding from them (Figure 2- 4). Measurements were taken for each of the minute details of the spiracle at different parameters (Table 1).

Structural details	Parameter	Measurement
Spiracle	Length (mm), n = 10	1.94 ± 0.051
Spiracle	Width (µm), n = 10	316.42 ± 1.18
Oval protrusions from the surface (tubercle)	Length (µm), n = 6	27.46 ± 1.13
Surface setae	Length (µm), n = 6	64.31 ± 2.74
Alveolar openings	Diameter (µm), n = 10	21.39 ± 1.06

Table 1. Mean ± SE of the length, width, and diameter of the ultrastructural details of the pupal spiracle of *Eristalinus arvorum*.

SEM-generated images of spiracles from both, empty puparium after successful adult (*Eristalinus arvorum*) emergence and pupae from which adult flies didn't emerge, were observed, examined, and compared. The ultrastructure of spiracles derived from pupae from which adult flies didn't emerge was found indistinguishable and absolutely similar to the spiracles obtained from empty puparia in shape, size, surface extensions, and basal part ornamentations, and therefore are identified as *E. arvorum* pupa.

Discussion

Hoverfly research history from the country has shown vast coverage in terms of taxonomic identification, and economic benefits from the adult flies, but the valuable roles of their immature stages have long remained underappreciated, largely due to the lack of morpho-taxonomic knowledge of their preimaginal stages from the country as well as the Oriental region. Members of the tribe Eristalini not only aid in waste disposal but are also found to be forensically important as a causative agent of myiasis, especially the *Eristalis* and *Eristalinus* species (Korzets *et al.*, 1993, Salleh *et al.*, 2007, Heo *et al.*, 2019, Pérez-Bañón *et al.*, 2020), and due to insufficient literature on their larvae and pupae, identification of these species are limited to their adult morphological characters (Cao *et al.*, 2022). To bridge this gap area and enrich the morpho-taxonomic understanding of the preimaginal stages of hoverflies, the current study has identified and characterized pupa of scavenger syrphid fly *Eristalinus arvorum* (Fabricius, 1787) collected alongside the municipal drainage systems of Gangetic plains, with proper elucidation using a Scanning Electron Microscopic (SEM) study. The ultrastructural morphology of pupal spiracles such as their shape, size, surface nature, types of surface extensions, arrangement of tubercles, ornamentations, etc. is of crucial consideration for species-level identification. More studies and investigations should be conducted at regular intervals on the preimaginal stages of hoverflies, in order to have a better understanding of their developmental stages and to harness their natural potential for mankind.

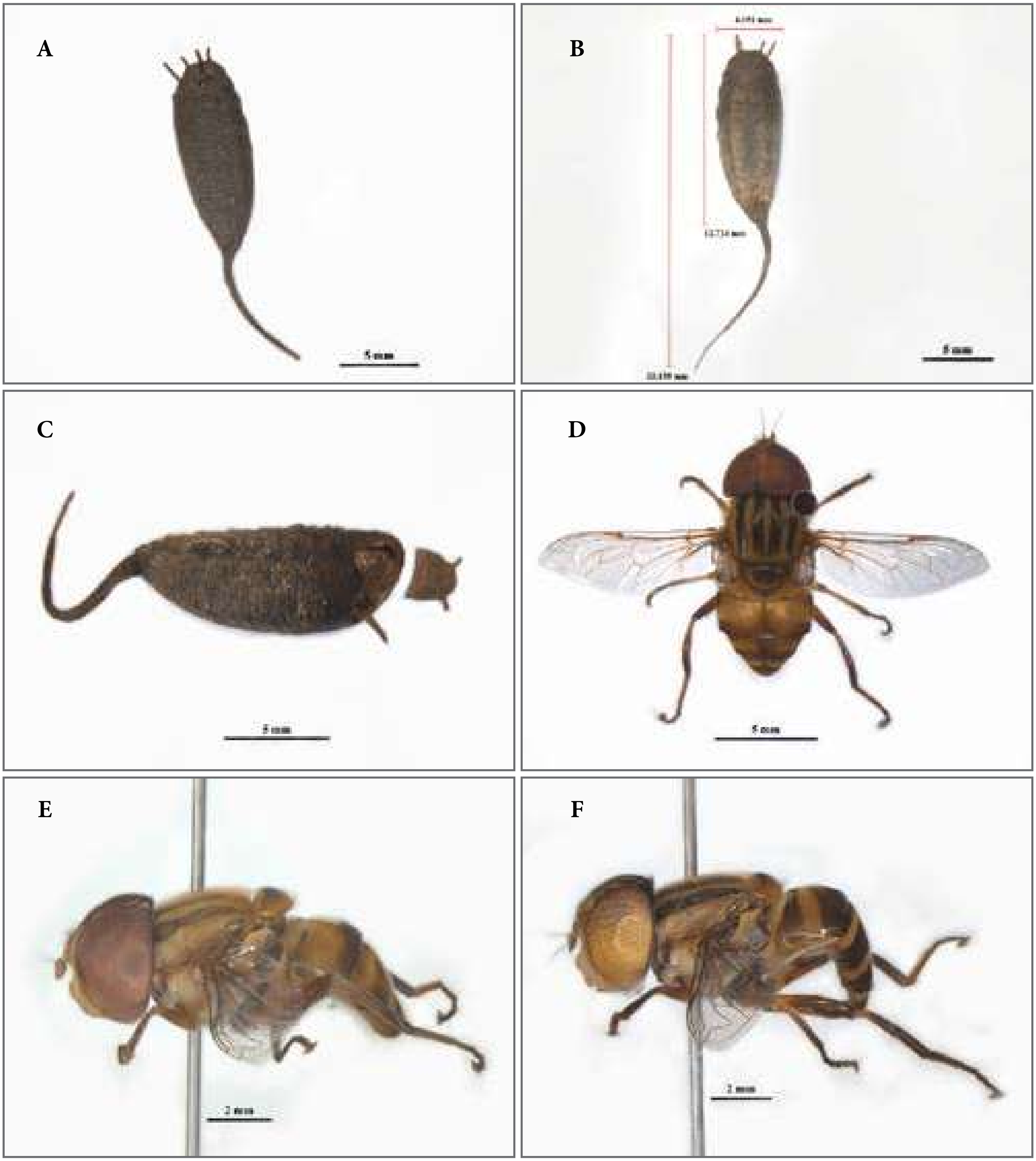

Figure 1. Pupa and newly emerged adult (*Eristalinus arvorum*): Pupa: Dosal view (A) | Ventral view with measurements (B) | Empty puparia after adult emergence (C) | Adult: Male habitus, dorsal view (D), lateral view (E) | Female habitus, lateral view (F)

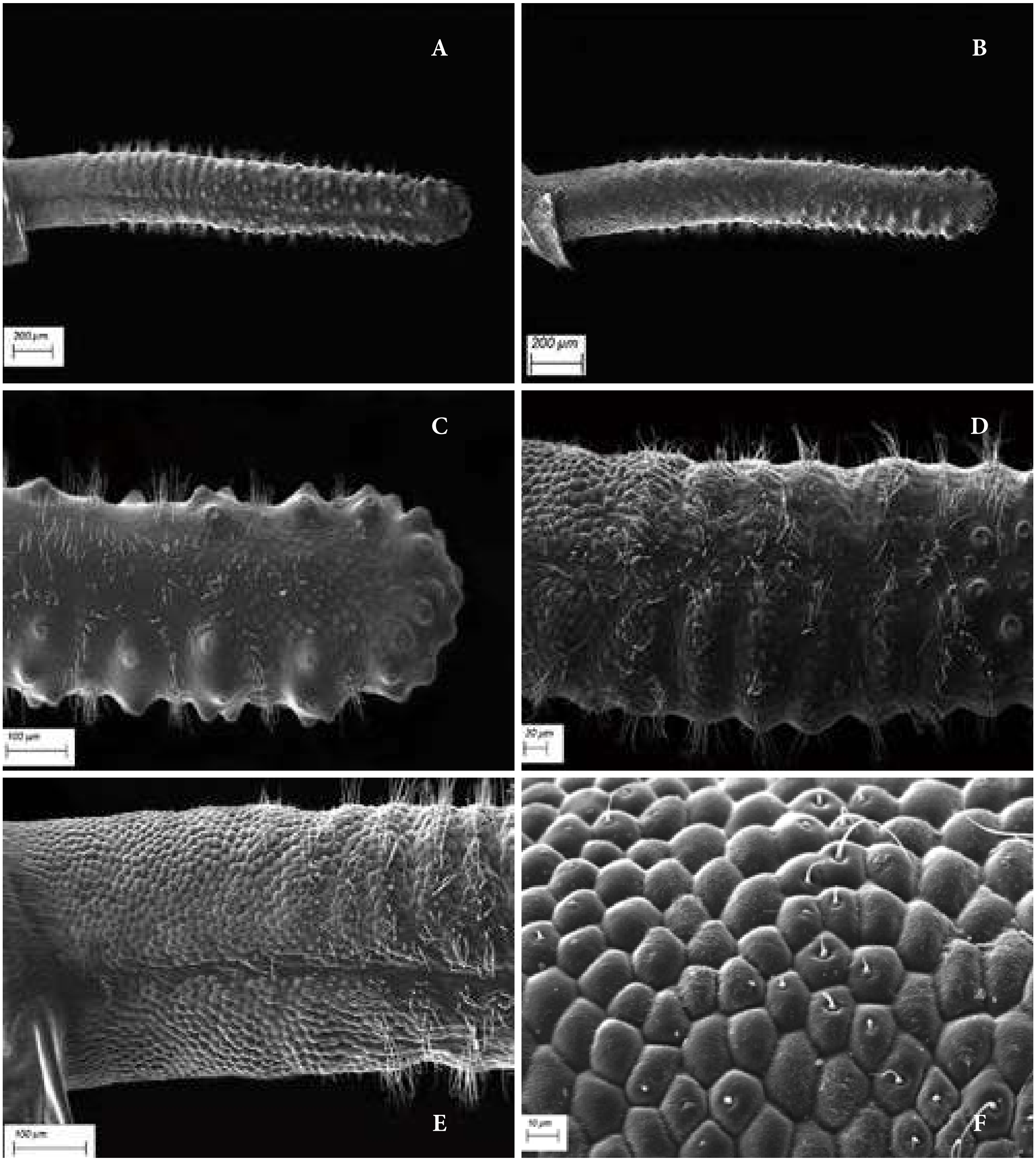

Figure 2. SEM micrographs of pupal spiracle (*Eristalinus arvorum*): Dorsal view (A) | Ventral view (B) | Anterior end (C) | Spiracle folds (D) | Basal part ornamentation (E), (F)

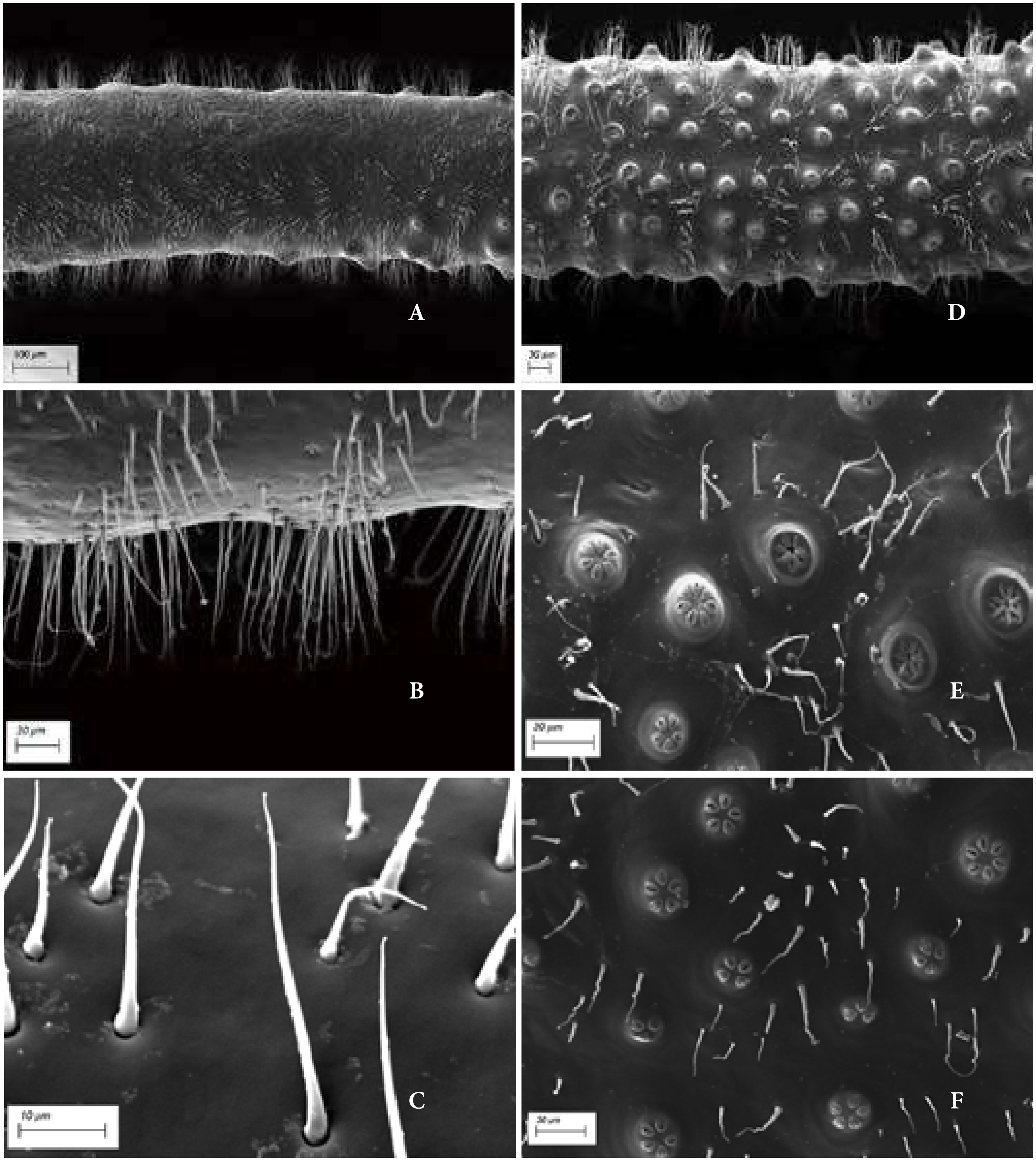

Figure 3. SEM micrographs of ultrastructural details of pupal spiracle (*Eristalinus arvorum*): Arrangement of surface setae (A), (B), (C) | Lateral bands of tubercle (D) | Spiracular openings varying in number, five, six, & seven with both open and close mouth, (E) | Spiracular openings varying in number, three, four, five, & six (F)

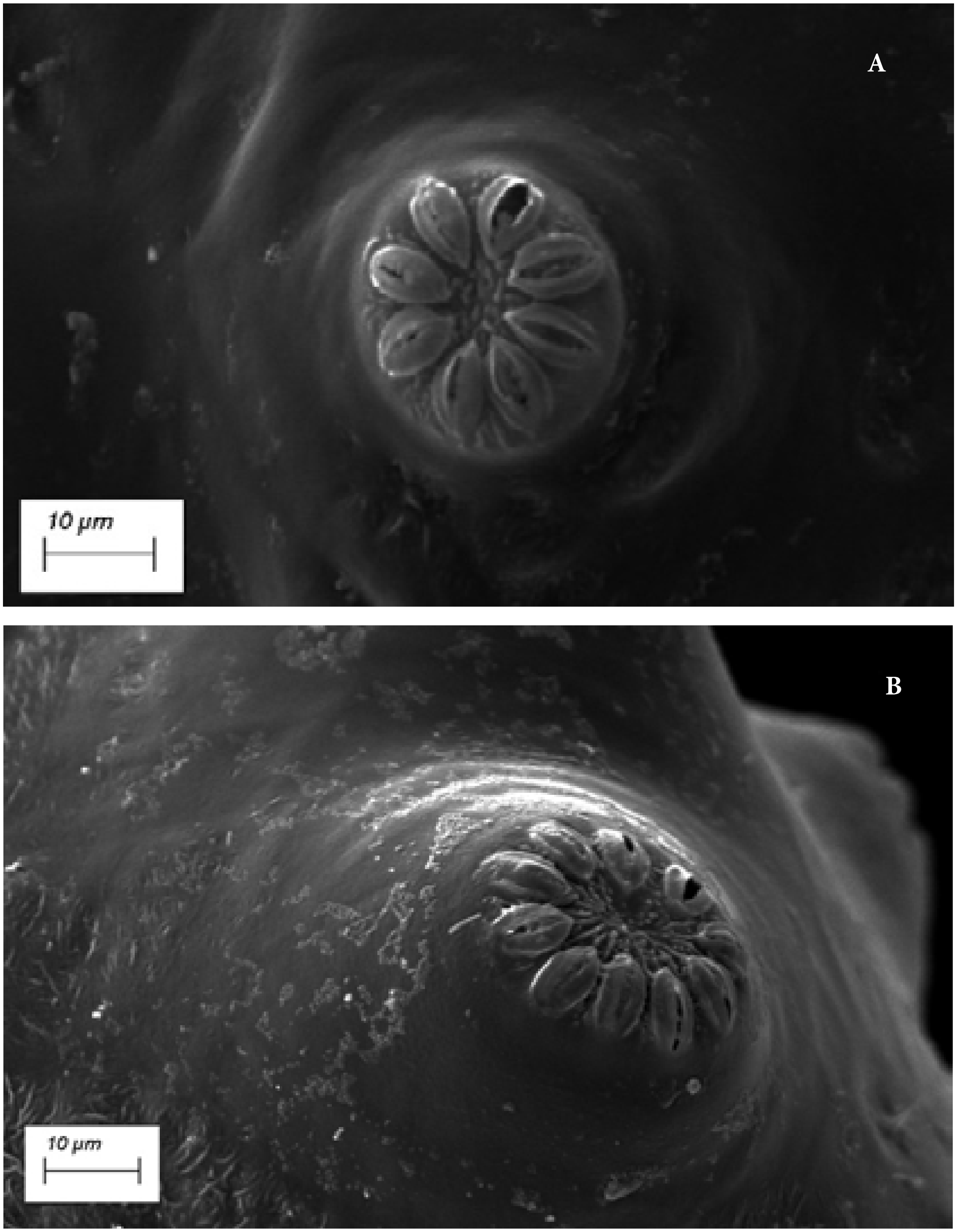

Figure 4. SEM micrographs of pupal spiracle (*Eristalinus arvorum*): Spiracular openings on tubercle; eight (A), ten (B)

Acknowledgments

We would like to thank the Director, Zoological Survey of India (Kolkata), the Ministry of Environment, Forests, and Climate Change, for providing us with the necessary facilities required to carry out the study. The financial assistance under the Junior Research Fellowship (ID-201610101398) provided by the University Grants Commission, Govt. of India, New Delhi is gratefully acknowledged. We further acknowledge and convey our sincere thanks to the Scanning Electron Microscopy (SEM) unit of ZSI, Kolkata, for their technical assistance, Sri. P. Parui, Retd. Assistant Zoologist, for helping with the identification, fellow members of Diptera Section for their constant encouragement, and a big thanks to my parents for helping during sample collection.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Larval and adult taxonomy of kodomillet shoot fly *Atherigona simplex* (Thomson) (Diptera: Muscidae)

Prabhu Ganiger*, Muddasar[2], Yamanappa R Madigar[3] and Aswini R[2]

** Entomologist and PI, PC unit, ICAR-AICRP on Small millets, UAS, GKVK, Bangalore*

[2] Senior Research Fellow, DST-Project on Systematics of Shoot flies of India, ICAR-AICRP on Small millets, UAS, Bangalore, Karnataka, India

[3] Department of Entomology, UAS, GKVK, Bangalore

Abstract

The present study provides a detailed taxonomic note on both adult and maggot stages of *Atherigona simplex*. The adult males are mainly identified with the genitalia characters *i.e.*, the hypopygial prominence with a characteristic deep notch at the middle; trifoliate process with median piece and lateral plates yellow on basal half and dark brown in apical half. The maggots are identified based on the characters of cephalopharyngeal skeleton, number of digitations in anterior spiracles and shape of the posterior spiracles. Here, the detailed morphology of first, second and third instar maggots is described and illustrated for the first time.

Keywords: kodomillet, *Atherigona simplex*, maggot, adult, taxonomy

Introduction

Muscidae is a large family of calyptrate Diptera distributed in all biogeographic regions, represented by six sub-families (Pont,1981), comprising of about 4500 described species in 180 genera (De Carvalho *et al.*, 2005). In India, about 263 species in 35 genera are known (Meenakshi, 2008). Subfamily Atherigoninae comprises 37 species of *Atherigona* (Ramachandra Rao, 1924, Malloch, 1925, Pont, 1972, Pont, 1981, Srivastav, 1985. Shoot flies of the genus *Atherigona* are known to cause 'dead-hearts' in a number of tropical grass species of Poaceae, mainly cereals and millets (Deeming, 1971; Pont, 1972). Fletcher (1914) reported the incidence of shoot fly for the first time in South India. Among major pests in small millets, shoot flies were found to be dominant ones causing 25-90% dead-heart (DH) damage (Jotwani, *et al.*, 1969; Selvaraj *et al.*, 1974). Around 50 to 55 different species of insect pests damage during cropping period, among these shoot flies of the genus *Atherigona* (Muscidae) were the most important in terms of causing higher yield loss, particularly in little and proso millets at 4 to 5 leaf stage (Nageshchandra, 1983). Two species, *Atherigona soccata* Rond. and *Atherigona approximata* Mall., are pests of two of the world's major cereals, sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*), respectively.

The muscid shoot-fly *Atherigona simplex* (Thomson) (Diptera: Muscidae) is a major pest in kodomillet, *Paspalum scrobiculatum*, grown in different parts of India. Farmers growing small millets are facing serious problem of shoot fly infestation in kodomillet during the early stage of the crop. There is a need for taxonomic identification of maggot and adult stages of kodomillet shoot fly, *Atherigona simplex*. The literature pertaining to morphological description of maggots is very scant and hence the present study was taken up to taxonomically characterize the species both in adult and maggot life stages.

*Author for correspondence : prabhuganiger@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Material and Methods

Slide preparation procedure: Maggots were collected from the infested (dead-heart symptom) plant parts and washed thoroughly in cold water. Maggots were killed by immersing in the hot water (just off the boil) for about two to three minutes. After allowing the water to cool to room temperature, the maggots were then subjected to serial dilution of 30%, 50% and 70% ethanol. Specimens to be mounted were slit using sharp scalpel and kept overnight in 10 % caustic potash (KOH) for digestion. On the next day, internal content and fat bodies of digested maggots were removed through the slits. After clearing, the specimens were processed in 70%, 80% and absolute alcohol (Ethanol). The processed maggots were then kept length wise on glass slide; cephalopharyngeal skeleton, anterior spiracles and posterior spiracles were mounted properly on the slide (Frias *et al.*, 2006); posterior spiracles were slightly folded laterally or mounted dorsoventrally for better view. The maggots were mounted using Euparol and covered with 18mm round cover slip and dried at room temperature for about four to five days and observed under compound microscope at 10X and 40X magnifications. Morphological terminology follows Borror *et al.*, 1981; Chu and Cutkomp, 1949; Peterson, 1957; Stehr, 1987 and 1991; McAlpine, *et al.*, 1981 and 1987. The specimen mounted slides were identified by using the literature of Grzywacz *et al.*, 2013; Ogwaro and Kokwaro, 1981; Couri and Araújo, 1992.

Laboratory rearing

Field collected dead-heart plants of kodomillet were brought to laboratory and kept in polythene bags for adult emergence. The adults collected were killed using ethyl acetate and then pinned for identification. They were labelled with details such as locality, host, date of collection *etc*. The processed specimens were identified based on literature of Pont (1973, 1981); Pont and Magpayo (1995). In the instance of sorghum and millet collections both males and females were identified (Clearwater and Othieno, 1977). Images of the habitus and other important characters were illustrated to facilitate their identification and the diagnostic characters were marked by arrowheads. The examined specimens were deposited at the Department of Entomology, University of Agricultural Sciences, Bangalore, Karnataka, India.

Male genitalia

For the study of male genitalia, the specimens were dissected after relaxing and, with the help of fine needle, the abdomen was detached and placed overnight in vials containing 10% KOH. The male genitalia were carefully separated from the abdominal segments into cavity block and washed thoroughly with distilled water and then placed in glycerin. Photographs of the genitalia were made using a Leica M205C microscope mounted with a Leica DFC 450 camera and by using auto-montage software. Genitalia of each specimen were stored separately in genital vials containing a drop of glycerol and pinned underneath the respective specimen for subsequent studies.

Systematic accounts

Family: Muscidae

Subfamily: Atherigoninae

Genus *Atherigona* Rondani, 1856

Generic diagnosis

Angular head, with very long sunken face and antennal flagellomere, almost reaching lower facial margin in lateral view; arista bare; basal lateral setae of scutellum at most one third as long as sub basal lateral setae, presutural acrostichal setae often in 2-3 rows at suture; Cross vein r-m always well in basal half of cell dm.

***Atherigona simplex* (Thomson, 1869)**

Coenosia simplex Thomson, 1869: 560; Wulp, 1881: 48.
Atherigona simplex (Thomson); Stein, 1910a:77.
Atherigona bituberculata Malloch, 1925: 119.
Atherigona (Atherigona) bituberculata, Malloch; Fan, 1965: 70.
Atherigona sp.; Joshi and Khan, 1968: 238.

Results

Adult

Description: Palpi mostly dark, rarely yellow at tip. Interfrontalia shining black. Male has the fore femur partly darkened, the wing usually with a dark smudge at the tip of the subcosta, and the fore tarsus without erect hairs. The fore tibia and tarsus are mainly brown, the tibia being yellow on basal third or less (Fig. 1. A-D).

Male Genitalia: The hypopygial prominence with a deep notch and base is 1.5 times wider than apex (Fig. 1E). Trifoliate process with long stalk and median basally slender with apex triangular with few prominent setae. The lateral plates and median piece are yellow on the basal half and dark brown on the apical half. Lateral plates with a weak inner lobe our margin basally with sharp edge (Fig. 1F).

Material examined: INDIA: Karnataka: 2♂: UAS, Bengaluru, reared on Kodomillet, 28. viii. 2021, PCG; 2♂: UAS, Bengaluru, reared on Kodomillet, 27. viii. 2021, PCG; 1♂: UAS, Bengaluru, reared on Kodomillet, 30. viii. 2021, PCG; 1♂: UAS, Bengaluru, reared on Kodomillet, 02. viii. 2021, PCG; 1♂: UAS, Bengaluru, reared on Kodomillet, 21. viii. 2021, PCG; 3 ♂, 8♀: Dharwad, UAS Campus, 10. viii. 2017 Yamanappa, R. M; 5♂, 7♀: Bengaluru, GKVK campus, 3. viii.2017, Yamanappa R. M; 6♂, 5♀: ARS Tiptur, 2.ix.2017, Yamanappa R. M.

Distribution: India: Assam, Bihar, West Bengal, Delhi, Tamil Nadu, Madhya Pradesh and Rajasthan.

Host plants: In present study specimens were reared on kodo millet, *Paspalum scrobiculatum.*

Remarks: Small dark brown coloured fly with black palpi and interfrontalia. Hypopygial prominence is small with two distinct lateral lobes. Stalk and basal half of the lateral plates and median piece of trifoliate process yellow.

Maggots

The detailed general morphology of shoot fly maggot (Fig 2A), cephalopharyngeal skeleton (2B) and posterior spiracle (C) identifying parts were labeled. .

First instar: with distinct mouth hook, suprabuccal teeth and dorsal process, Pharyngeal sclerite narrow and elongated. Dorsal cornua longer than ventral, both pointed apically and weakly pigmented. Dorsal bridge small, rounded at apex and weakly pigmented (Fig. 3A). Anterior spiracle with five digitations (Fig. 3D). Posterior spiracle with 2 spiracular openings surrounded by papillae (Fig. 3G).

Material examined: INDIA: Karnataka: 3 first instar slides; ZARS, GKVK, UAS, Bengaluru, reared from Kodomillet, 29.xii.2021, PCG.

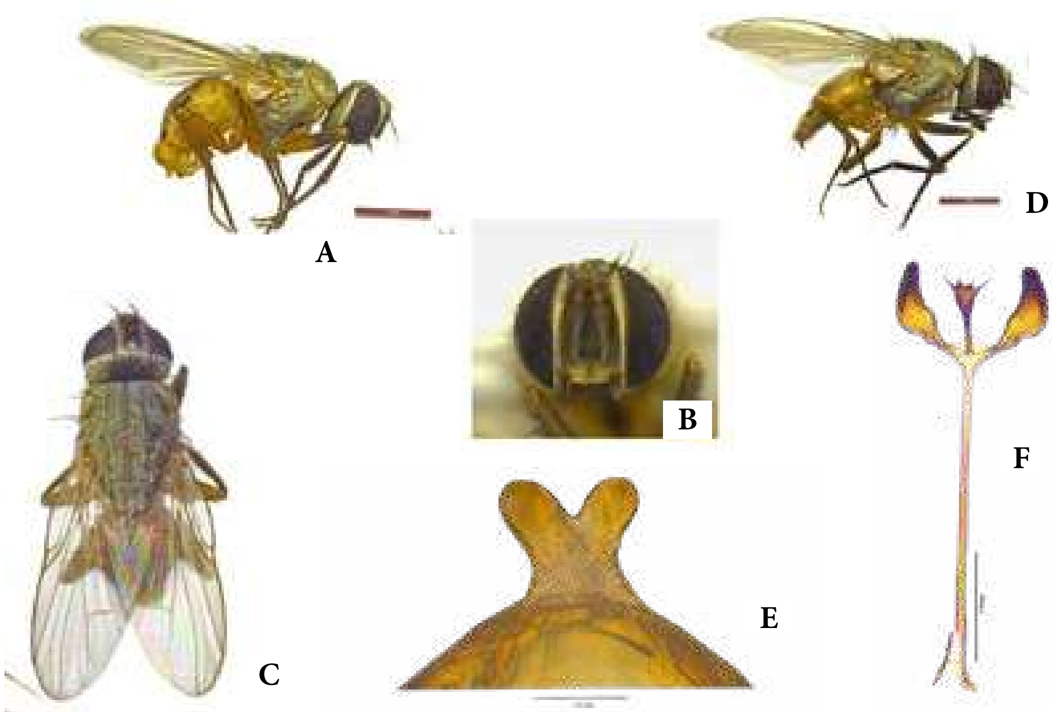

Fig 1. Adult *Atherigona simplex* (Thomson)

A. Lateral view (♂); B. Frontal view of head (♂); C. Dorsal view (♂); D. Lateral view (♀); E. Hypopygial prominence (♂); F. Trifoliate process dorsal view (♂)

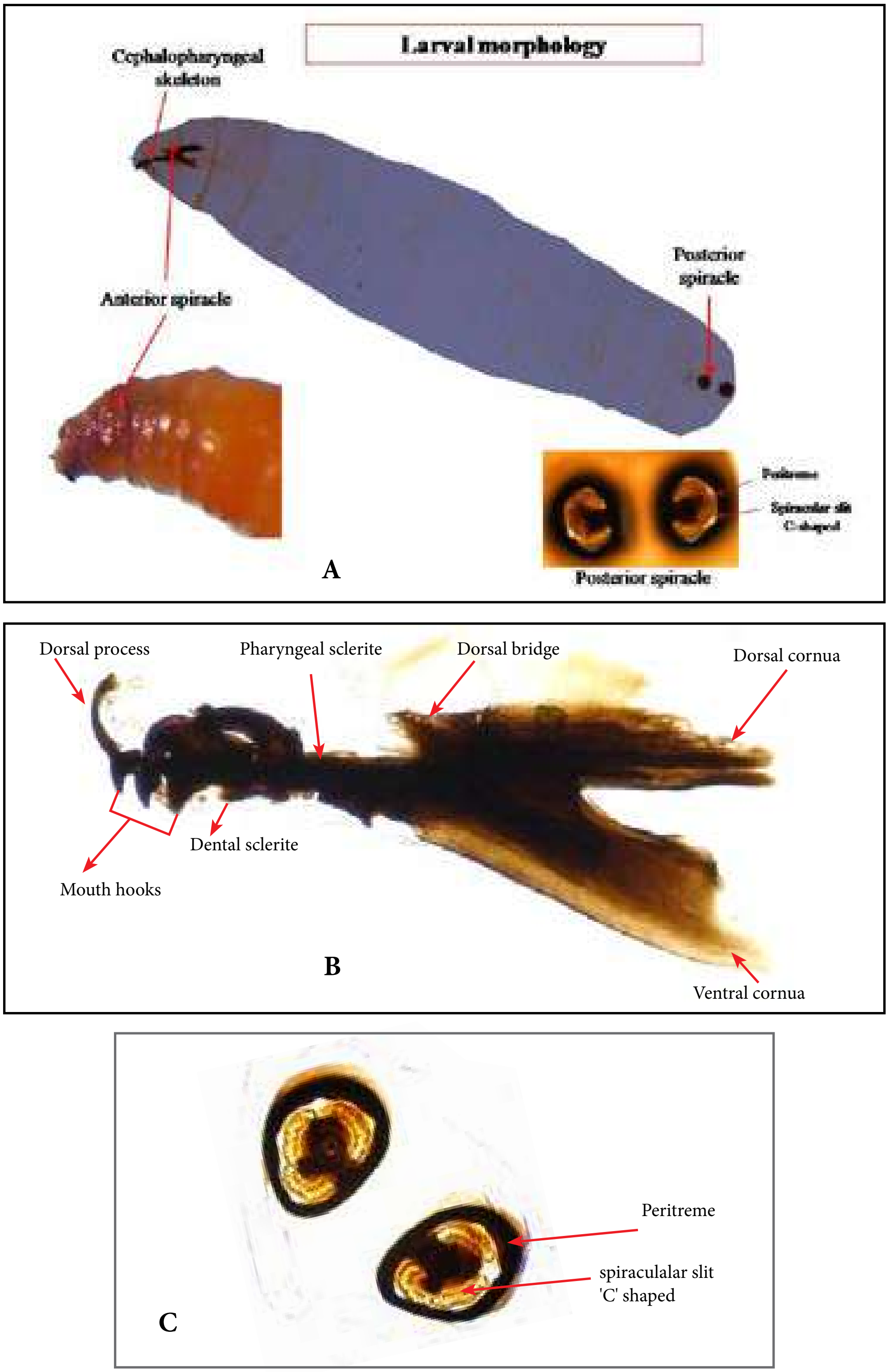

Fig 2. (A) General morphology of shoot fly maggot (B) morphology of cephalopharyngeal skeleton (C) morphology of posterior spiracle

Fig. 3. Cephalopharyngeal skeletons, anterior and posterior spiracles of different instars of shoot fly *Atherigona simplex* larvae. Cephalopharyngeal skeletons of (A) 1st instar, (B) 2nd instar and (C) 3rd instar, es-epistomal sclerite, at-accessory teeth; Anterior spiracles of (D) 1st instar, (E) 2nd instar, (F) and 3rd instar; Posterior spiracles of (G) 1st instar, (H) 2nd instar, and (I) 3rd instar.

Second instar: with three pair of mouth hooks and dorsal process, dorsal and ventral cornua are of equal length (Fig. 3B). Anterior spiracle with Primary and secondary arms with 9 digitations in each arm (Fig. 3E). Posterior spiracle with three C-shaped spiracular openings, peritreme slightly sclerotized (Fig.3H).

Material examined: INDIA: Karnataka: 2 second instar slides; Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences (UAS), Gandhi Krishi Vignana Kendra (GKVK), Bengaluru, collected from Kodomillet, 29.xii.2021, PCG. 2 second instar slides; ZARS, GKVK, UAS, Bengaluru, collected from Kodomillet, 23.xiii.2021, Prabhu C Ganiger (PCG).

Third instar: Cephalopharyngeal skeleton with a distinct mandible, Suprabuccal teeth and Dental sclerite. Dorsal and ventral cornua are of equal length (Fig.3C). Anterior Spiracle with Nine digitations (Fig. 3F). Posterior spiracle with three C- shaped Spiracular slits and heavily sclerotized peritreme (Fig. 3I).

Material examined: INDIA: Karnataka: 2 third instar slides, ZARS, GKVK, UAS, Bengaluru, collected from Kodomillet, 29.xii.2021, PCG. 3 third instar slides; ZARS, GKVK, UAS, Bengaluru, collected from Kodomillet, 23.xiii.2021, PCG.

The characters of cephalopharyngeal skeleton, number of digitations in anterior spiracles and shape of the posterior spiracles vary between the instars and the key distinguishing characters furnished in Table 1.

Table 1: Comparison of distinctive features of the 1st, 2nd and 3rd instar maggot of *A. simplex*

Character	1st instar	2nd instar	3rd instar
Cephalopharyngeal skeletal:			
Relative length of dorsal and ventral coronua	dorsal cornua longer than ventral cornua	equal length	equal length
Pharyngeal sclerite	narrow and elongated	moderately thick and stout	thick and stout
Dorsal sclerite	poorly formed	poorly formed	strongly developed
Digitations on anterior spiracle	five	nine	nine
Posterior spiracle:			
No. of slits (spiracular openings)	two	three, C-shaped	three, C-shaped
Papillae around spiracular slits	present	absent	absent
Peritreme	weakly sclerotised	slightly sclerotised	strongly sclerotised

Discussion

The species *Atherigona simplex* is reported on Kodo millet (*Paspalum scrobiculatum*) by several authors (Pont, 1972; Davies and Reddy, 1981; Pont, 1995). The species was often recorded as *Atherigona bituberculata* by Malloch (1925) and Ramachandra Rao (1924).

In India, Ramachandra Rao (1924) recorded the fly as Varagu or Kodom fly collected from *Eriochloa* sp.. Rawat and Sahu (1969) reported the pest on wheat from Madhya Pradesh and Rajasthan, referring it to as wheat stem fly, but Pont (1972) stated the identification to be doubtful. Davies and Reddy (1981) collected adult specimens emerged from the grasses *Echinocloa colonum and Eriochloa procera* from ICRISAT, Hyderabad.

The literature pertaining to taxonomic identification and description of the species is very scanty. A brief note on the morphological and genital characters of the species was given by Pont (1972, 1995). Further descriptions on the species in the recent years is lacking. This study provides a note on the species both with respect to external morphology and genitalia characters along with illustrations. The males can be distinguished with the trifoliate process being weakly sclerotized on the basal half, lateral plates and median piece yellow on the basal half and dark brown on the apical half; hypopygial prominenece with a characteristic deep notch at the middle. Grzywacz *et al.*, (2013), Ogwaro and Kokwaro (1981) and Couri and Araújo, (1992) gave the description of *Atherigona reversura, Atherigona soccata and Atherigona orientalis* respectively.

The research needs to be carried out on different species of shoot fly maggot identification. Here, efforts were made to describe, all the instars of *A. simplex* for the first time. The characters of cephalopharyngeal skeleton, number of digitations in anterior spiracles and shape of the posterior spiracles are described and illustrated. Repeated collection of dead-hearts from the field and checking for their adult emergence, confirmed the identity of the species.

Acknowledgments

The financial support for this work was provided by DST - Science and Engineering Research Board (SERB): sanction order No. "CRG/2020/005016" dated " 30th December, 2020. The authors are grateful to the project co-coordinating unit, ICAR-AICRP on Small Millets, GKVK, Bangalore, for the help rendered in field. The authors are thankful to Dr. Yeshawanth H M, Assistant Professor, Department of Entomology, University of Agricultural Sciences, Bangalore India helped in photographs of adult specimens.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Morpho-taxonomy and seasonal prevalence of *Culicoides* Latreille, 1809 (Diptera: Ceratopogonidae) in Sonamukhi protected forest, Bankura, West Bengal

Emon Mukhopadhyay, Supradipta Dutta, Moubanti Das, Suman Kumar Saha, Sudip Mondal and Dhriti Banerjee*

Diptera Section, Zoological Survey of India, M-Block, New Alipore, Kolkata 700053

Abstract

Culicoides (Diptera: Ceratopogonidae), popularly known as 'biting midges' play a significant role in transmission of pathogens to vertebrate animals- particularly livestock animals, humans, and birds causing severe diseases like Bluetongue (BT), Epizootic haemorrhagic disease (EHD), African horse sickness (AHS), Equine encephalitis (EE), etc. The present research focuses on morpho-taxonomy, ecological diversity, seasonal prevalence, and species abundance of *Culicoides* in different cattle farms and pastoral regions of Sonamukhi protected area, Bankura, West Bengal for three seasons (pre-monsoon, monsoon, and post-monsoon) from 2013 to 2015 in sixteen sampling sites. Taxonomic studies show four species under three subgenera - *Avaritia*: *Culicoides actoni, C. imicola; Remmia*: *C. oxystoma*; *Hoffmania*: *C. peregrinus* of genus *Culicoides* for the first time from Sonamukhi area. Ecological analyses show the highest species diversity (H =0.881) and species dominance maximum (D= 0.5179) in the post-monsoon, and species richness-maximum in monsoon (D_{mg}=0.6). Species relative abundance (p_i=0.664), rank abundance curve and seasonal prevalence pattern shows-*C. oxystoma* as the most dominant species. This study provides a brief idea of the taxonomy, ecology, and seasonal prevalence of *Culicoides* species in the Sonamukhi Protected area, Bankura. The moderate rainfall and moist weather play an essential role in the development of this vector fly. Despite the area showing extreme weather conditions, the pre- and post-monsoon seasons are the ideal time and the species abundance to reach its highest seasonal peak. This research is a preliminary step which delivers insights into the taxonomy, ecological role, species diversity, seasonal abundance, and factors affecting the growth and survival of *Culicoides,* for its scientific direction in vector control strategies as well as conservation and management of livestock via proper monitoring and surveillance programs.

Keywords: *Culicoides*, vector, ecology, prevalence, post-monsoon

Introduction

Genus *Culicoides* or biting midges belong to the family Ceratopogonidae which comprises 1347 species globally (Borkent, 2020). They are hematophagous, attacking mammals (mostly livestock) and birds, found in most continents (Mellor *et al.*, 2000). 30 *Culicoides* species in the world, including 13 species from India, are reported vectors of disease pathogens like Bluetongue virus (BTV), Epizootic hemorrhagic disease virus (EHDV), African horse sickness (AHSV), Akabane, Aino, Equine encephalitis virus (EEV), Schmallenberg virus, etc. (Wirth *et al.*, 1989; Mellor *et al.*, 2000; Mullen, 2009; Lassen *et al.*, 2012; Harrup *et al.*, 2015; Mukhopadhyay *et al.*, 2016). They live in the moist environment near cattle farms; females feed on blood, while males on plant juices (Birley and Boorman, 1982; Mellor *et al.*, 2000; Meiswinkel *et al.*, 2004).

*Author for correspondence : diptera.zsi@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Earth encompasses different biomes and abiotic factors determine its native flora and fauna. The physiography of West Bengal provides huge scope to study ecology, distribution, vector biology, and seasonal dynamics of various harmful insects. Our study was based on Sonamukhi protected forest area of dry deciduous vegetation, average rainfall of 1740mm, temperature range of 6ºC to 41ºC, laterite soil with drought, heat waves, floods, soil erosion, and deforestation (State Forest Report, West Bengal, 2006-07). The present research focuses on the discovery of *Culicoides* fauna from different cattle farms, their ecology and seasonal prevalence in this tropical dry deciduous ecosystem.

Materials and methods

Insect samples were collected from sixteen livestock farms in Sonamukhi forest area, Bankura for three seasons of pre-monsoon, monsoon, and post-monsoon from 2013 to 2015 by sweep net in the early morning, afternoon, and before sunset. Collections were preserved in 70% ethanol and identified by mounting different parts of the specimen in a phenol-balsam mixture on glass slides. Ecological data analyses on species' relative abundance were calculated to check the seasonal peak and highest abundance of the species, species diversity, and dominance were evaluated by using Shannon's diversity index (H) and Simpson's index of dominance (D) respectively, species richness per total sampling area was calculated by using Margalef's index of richness (D_{mg}).

Abbreviations: Cell r_2-second radial cell, cell r_5- fifth radial cell, cell m_2- second medial cell, cell m_4- fourth medial cell, R-M cross vein- Radio-medial cross vein, vein M_2- second medial vein, PRM-pre-monsoon, MON-monsoon, PST-post-monsoon, RA- relative abundance.

Systematic account

Superfamily **Chironomoidea**
Family **Ceratopogonidae**
Subfamily **Ceratopogoninae**
Tribe **Culicoidini**
Genus ***Culicoides***
Subgenus ***Avaritia***
Culicoides actoni Smith, 1929
Culicoides imicola Kieffer,1913
Subgenus ***Remmia***
Culicoides oxystoma Kieffer, 1910
Subgenus ***Hoffmania***
Culicoides peregrinus Kieffer, 1910

Results and Discussion

A. Taxonomy

Genus ***Culicoides*** Latreille, 1809
1809. *Culicoides* Latreille, *Paris and Strasbourg* 4: 399 pp.
Type species: *Culicoides punctatus* Latreille 1809 (= *Ceratopogon punctatus* Meigen 1804)

Pictorial key to subgenera shown in **Figure 1**

Subgenus ***Avaritia*** Fox, 1955
1955. *Avaritia* Fox, *Journal of Agriculture of the University of Puerto Rico* 39:214-285.
Type species: *Ceratopogon obsoletus* Meigen 1818

Key to species

1. One pale spot in cell m_1 at wing margin .... *C. actoni.*
   More than one pale spot in cell m_1 .... 2.
2. Cell m_1 with pale area continued to wing margin expanded posteriorly nearly to vein M_2 .... *C. imicola.*

Culicoides actoni Smith, 1929

1929. *Culicoides actoni* Smith, *Indian J. Med. Res.* 17:255-257.

1962. *Culicoides imperceptus* Das Gupta, *Science and Culture* 28:537-539.

Material examined. 7♂♂ and 5♀♀ Sonamukhi forest area, Bankura district, 23°10'29.24"N, 87°25'26.76"E, 24.ix.2013, coll. D. Banerjee & party. 4♂♂ and 1♀ Bandarhati, Bankura district, 23°13'16.9"N, 86°51'59.2"E, 19.ix.2013, coll. D. Banerjee & party. 2♀♀ Dihipara, Bankura district, 23°24'16.98"N, 87°24'57.47"E, 22.ix.2013, coll. D. Banerjee & party. 3♂♂ and 3♀♀ Pachal, Bankura district, 23°13'35.71"N, 87°17'16.59"E,15.ix.2013, coll. D. Banerjee & party. 1♂ and 5♀♀, Nachanhati, Bankura district, 23°20'52.08"N, 87°25'10.24"E, 12.i.2014, coll. D. Banerjee & party. 1♂, Rampur, Bankura district, 23°14'29.33"N, 87° 4'11.29"E, 2.i.2014, coll. D. Banerjee & party. 1♂ and 1♀,Radhamohanpur, Bankura district, 23°0'15.26"N, 86°50'54.19"E, 27.i.2014, coll. D. Banerjee & party. 2♂♂ and 3♀♀, Palsora, Bankura district, 23°27'49.6"N, 86°62'35.3"E, 24.vi.2014, coll. D. Banerjee & party. 4♂♂ and 5♀♀, Churamanipur, Bankura district, 23° 4'40.42"N, 87°17'34.49"E,11.xi.2014, coll. D. Banerjee & party. 3♂♂ and 5♀♀,Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 22.xi.2014, coll. D. Banerjee & party. 1 ♂, Krishtobati, Bankura district, 23°22'47.9"N, 86°'59.8"E, 15.xi.2014, coll. D. Banerjee & party. 1♂ and 4♀♀, Kalyanpur, Bankura district, 23°16'6.71"N, 87°23'36.51"E, 4.xi.2014, coll. D. Banerjee & party.

Diagnosis. Pictorial diagnosis shown in **Figure 2**

Present distribution: India: West Bengal: Bankura: Bandarhati, Bondalhati, Churamanipur, Dihipara, Kalyanpur, Krishtobati, Muslo, Nachanhati, Pachal, Palsora, Radhamohanpur, Rampur, Sonamukhi forest area.

Culicoides imicola Kieffer, 1913

1313. *Culicoides imicola* Kieffer, *Resultats scientifiques. Diptera* (5): 1-43.

1959. *Culicoides minutus* Sen and Das Gupta, *Annals of the Entomological Society of America* 52:617-630.

1962a. *Culicoides pseudoturgidus* Das Gupta, *Science and Culture* 28:537-539.

Material examined. 9♀♀, Sonamukhi forest area, Bankura district, 23°10'29.24"N, 87°25'26.76"E, 24.ix.2013, coll. D. Banerjee & party. 5♀♀, Hamirhati, Bankura district, 23°17'55.21"N, 87°21'46.60"E, 2.ix.2013, coll. D. Banerjee & party. 2♀♀, Dihipara, Bankura district, 23°24'16.98"N, 87°24'57.47"E, 22.ix.2013, coll. D. Banerjee & party. 3♀♀, Pachal, Bankura district, 23°13'35.71"N, 87°17'16.59"E, 15.ix.2013, coll. D. Banerjee & party. 2♀♀, Nachanhati, Bankura district, 23°20'52.08"N, 87°25'10.24"E, 12.i.2014, coll. D. Banerjee & party.7♀♀, Rampur, Bankura district, 23°14'29.33"N, 87°4'11.29"E, 2.i.2014, coll. D. Banerjee & party.1♀, Radhamohanpur, Bankura district, 23°0'15.26"N, 86°50'54.19"E, 27.i.2014, coll. D. Banerjee & party. 6♀♀, Balarampur, Bankura district, 23°15'49.67"N, 87°4'49.91"E, 20.vi.2014, coll. D. Banerjee & party. 1♀, Krishtobati, Bankura district, 23°22'47.9"N, 86°'59.8"E,15.vi.2014, coll. D. Banerjee & party. 2♀♀, Churamanipur, Bankura district, 23°4'40.42"N, 87°17'34.49"E, 11.xi.2014, coll. D. Banerjee & party. 9♀♀, Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 22.xi.2014, coll. D. Banerjee & party. 11♀♀, Bandarhati, Bankura district, 23°13'16.9"N, 86°51'59.2"E, 3.xi.2014, coll. D. Banerjee & party.

Diagnosis. Pictorial diagnosis shown in **Figure 3.**

Present distribution: India: West Bengal: Bankura: Balarampur, Bandarhati, Bondalhati, Churamanipur, Dihipara, Hamirhati, Krishtobati, Muslo, Nachanhati, Pachal, Radhamohanpur, Rampur, Sonamukhi forest area.

Subgenus ***Remmia*** Glukhova, 1977

1977. *Remmia* Glukhova, *Parazitologicheskii Sbornik* 27:112-118.

Type species: *Ceratopogon schultzei* Enderlein, 1908

Culicoides oxystoma Kieffer, 1910

1910. *Culicoides oxystoma* Kieffer, *Mem Ind. Mus.* 2:181-242.

1913. *Culicoides kiefferi* Patton, *Indian J. Med. Res.* 1:336-338, pl. 18.

1921. *Culicoides pattoni* Kieffer, *Bull. Soc. Entomol. Fr.* 1921:7.

1956. *Culicoides alatus* Dasgupta and Ghosh, *Bull. Calcutta Sch. Trop. Med.* 4:162-163.

Material examined. 25♂♂ and 70♀♀, Sonamukhi forest area, Bankura district, 23°10'29.24"N, 87°25'26.76"E, 24.ix.2013, coll. D. Banerjee & party. 35♂♂ and 32♀♀, Hamirhati, Bankura district, 23°17'55.21"N, 87°21'46.60"E, 2.ix.2013, coll. D. Banerjee & party. 3♂♂ and 40♀♀, Bandarhati, Bankura district, 23°13'16.9"N, 86°51'59.2"E, 19.ix.2013, coll. D. Banerjee & party. 19♂♂ and 70♀♀, Dihipara, Bankura district, 23°24'16.98"N, 87°24'57.47"E, 22.ix.2013, coll. D. Banerjee & party. 40♂♂ and 16♀♀, Pachal, Bankura district, 23°13'35.71"N, 87°17'16.59"E, 15.ix.2013, coll. D. Banerjee & party. 17♂♂ and 71♀♀, Churamanipur, Bankura district, 23°4'40.42"N, 87°17'34.49"E, 6.i.2014, coll. D. Banerjee & party. 11♂♂ and 21♀♀, Nachanhati, Bankura district, 23°20'52.08"N, 87°25'10.24"E, 12.i.2014, coll. D. Banerjee & party. 9♂♂ and 18♀♀, Rampur, Bankura district, 23°14'29.33"N, 87°4'11.29"E, 2.i.2014, coll. D. Banerjee & party. 11♂♂ and 20♀♀, Radhamohanpur, Bankura district, 23°0'15.26"N, 86°50'54.19"E, 27.i.2014, coll. D. Banerjee & party. 19♂♂ and 14♀♀, Balarampur, Bankura district, 23°15'49.67"N, 87°4'49.91"E, 20.vi.2014, coll. D. Banerjee & party. 20♂♂ and 9♀♀, Krishtobati, Bankura district, 23°22'47.9"N,86°'59.8"E, 15.vi.2014, coll. D. Banerjee & party. 6♂♂ and 30♀♀, Palsora, Bankura district, 23°27'49.6"N, 86°62'35.3"E, 24.vi.2014, coll. D. Banerjee & party. 12♂♂ and 29♀♀, Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 22.xi.2014, coll. D. Banerjee & party. 11♂♂ and 30♀♀, Kalyanpur, Bankura district, 23°16'6.71"N, 87°23'36.51"E, 4.xi.2014, coll. D. Banerjee & party.

Diagnosis. Pictorial diagnosis shown in **Figure 4.**

Present distribution: India: West Bengal: Bankura: Balarampur, Bandarhati, Bondalhati, Churamanipur, Dihipara, Hamirhati, Kalyanpur, Krishtobati, Muslo, Nachanhati, Pachal, Palsora, Radhamohanpur, Rampur, Sonamukhi forest area.

Subgenus ***Hoffmania*** Fox 1948

1948. *Hoffmania* Fox, *Proceedings of the Biological Society of Washington* 61:21-28.

Type species: *Culicoides inamollae* Fox and Hoffman 1944 (= *Culicoides insignis* Lutz 1913).

Culicoides peregrinus Kieffer, 1910

1910. *Culicoides peregrinus* Kieffer, *Memoirs of the Indian Museum* 2:181-242.

1932. *Culicoides assamensis* Smith and Swaminath, *Memoirs of Indian Medical Research* 25:182-186.

Material examined. 15♂♂ and 7♀♀, Sonamukhi forest area, Bankura district, 23°10'29.24"N, 87°25'26.76"E, 24.ix.2013, coll. D. Banerjee & party. 5♂♂ and 15♀♀, Hamirhati, Bankura district, 23°17'55.21"N, 87°21'46.60"E, 2.ix.2013, coll. D. Banerjee & party. 5♂♂ and 4♀♀, Bandarhati, Bankura district, 23°13'16.9"N, 86°51'59.2"E, 19.ix.2013, coll. D. Banerjee & party. 13♂♂ and 7♀♀, Dihipara, Bankura district, 23°24'16.98"N, 87°24'57.47"E, 22.ix.2013, coll. D. Banerjee & party. 9♂♂ and 21♀♀, Pachal, Bankura district, 23°13'35.71"N, 87°17'16.59"E,15.ix.2013, coll. D. Banerjee & party. 4♂♂ and 19♀♀, Churamanipur, Bankura district, 23°4'40.42"N, 87°17'34.49"E, 6.i.2014, coll. D. Banerjee & party. 9♂♂ and 15♀♀, Nachanhati, Bankura district, 23°20'52.08"N, 87°25'10.24"E, 12.i.2014, coll. D. Banerjee & party. 1♀, Rampur, Bankura district, 23°14'29.33"N, 87° 4'11.29"E,2.i.2014, coll. D. Banerjee & party. 1♂ and 3♀♀, Radhamohanpur, Bankura district, 23°0'15.26"N, 86°50'54.19"E, 27.i.2014, coll. D. Banerjee & party. 5♂♂ and 12♀♀, Balarampur, Bankura district, 23°15'49.67"N, 87°4'49.91"E, 20.vi.2014, coll. D. Banerjee & party. 6♂♂ and 15♀♀, Krishtobati, Bankura district, 23°22'47.9"N, 86°'59.8"E, 15.vi.2014, coll. D. Banerjee & party. 12♂♂ and 17♀♀, Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 17.ix.2015, coll. D. Banerjee & party.

Diagnosis. Pictorial diagnosis shown in **Figure 5**

Present distribution: India: West Bengal: Bankura: Balarampur, Bandarhati, Bondalhati, Churamanipur, Dihipara, Hamirhati, Kalyanpur, Krishtobati, Nachanhati, Pachal, Radhamohanpur, Rampur, Sonamukhi forest area.

The present research reports four species under three subgenera of genus *Culicoides -Avaritia*: *C. actoni, C. imicola; Remmia*: *C. oxystoma*; *Hoffmania*: *C. peregrinus* for the first time from Sonamukhi protected forest area.

C. imicola and *C. oxystoma* are distributed across the Afrotropical, Saharo-Arabian and Oriental regions while, *C. actoni* and *C. peregrinus* are found in the Australian, Oceanian, and Oriental region (Borkent, 2020). All these species are reported as vectors from India (Mukhopadhyay *et al.*, 2016; Maheshwari *et al.* 2012).

B. Seasonal prevalence

Ecological data analyses on species diversity, dominance and species richness are shown in the **Figure 6.**

The Shannon Index (H) shows the diversity of *Culicoides* species in the livestock community- post monsoon > pre monsoon > monsoon, collective species dominance pattern

(D) was post-monsoon > pre-monsoon >monsoon, species richness (D_{mg}) was highest in the monsoon > post monsoon > pre monsoon for all the sites. Relative abundance values (RA), seasonal prevalence, and species rank abundance calculated from each sample site based on the four species show prevalence -*Culicoides oxystoma*> *C.peregrinus*>*C. actoni*>*C.imicola* shown in **Figures 7-9.**

The highest species diversity is obtained in the post monsoon because humid conditions with moderate temperature favor vector flies but they do not survive on severe climatic situations or very high rainfall. Similarly, post –monsoon is the dominant period in regulating species diversity. But, the species richness value (D_{mg}) was highest in the monsoon, because species richness of an area depends on the collection per sampling site and not on the number of samples. Relative abundance pattern of four species reveal that the most prevalent species was *C. oxystoma* with highest seasonal prevalence in the post monsoon.

Our research delivers a brief example on the veterinary significance, taxonomy, ecology, and seasonal prevalence of *C. actoni, C. imicola, C. oxystoma, and C. peregrinus* in the tropical dry deciduous forests of Sonamukhi protected area, Bankura. From the seasonal effect studies, it is established that moist weather plays an essential role in the development of this vector fly. Despite the area showing extreme weather conditions, the pre- and post-monsoon seasons are the ideal time and the species abundance to reach its highest seasonal peak. Other factors like rural conditions with many cattle farms having poor sanitization, illiteracy on livestock management, and much more which still needs to be revealed. Therefore, following can be added as a wish list for future years: (i) a complete study on the habitats, breeding sites, and life cycle of genus *Culicoides* in the drought prone Sonamukhi and other parts of Bankura, and West Bengal, (ii) to authorize reports of diseases vectored by biting midges, and (iii) undergo proper investigations to conserve the livestock in various rural and urban areas of West Bengal.

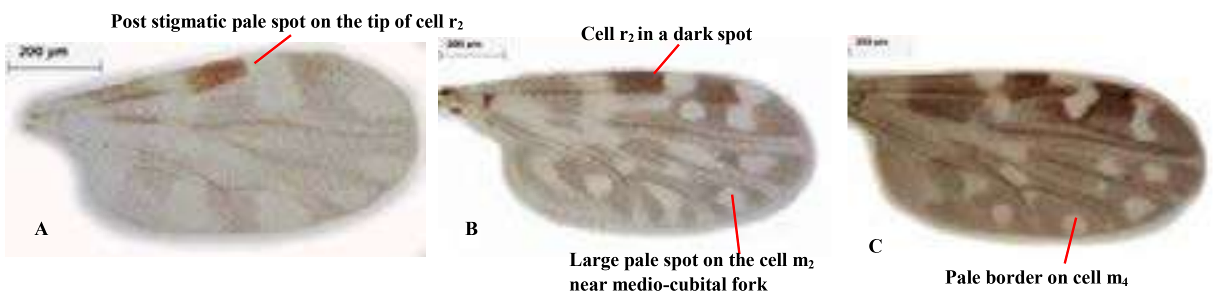


Figure 1. Pictorial key to subgenera (A. *Avaritia*, B-*Remmia*, C-*Hoffmania*) of genus *Culicoides*

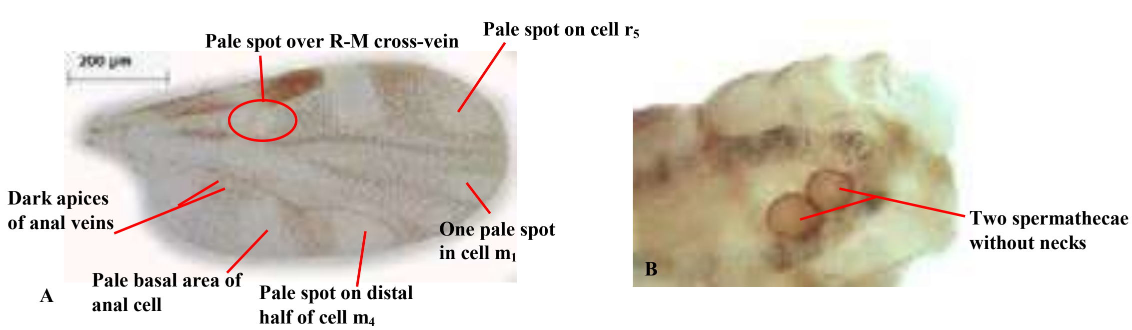


Figure 2. Pictorial diagnosis (A. Wing, B. Female genitalia) of *Culicoides actoni* Smith, 1929

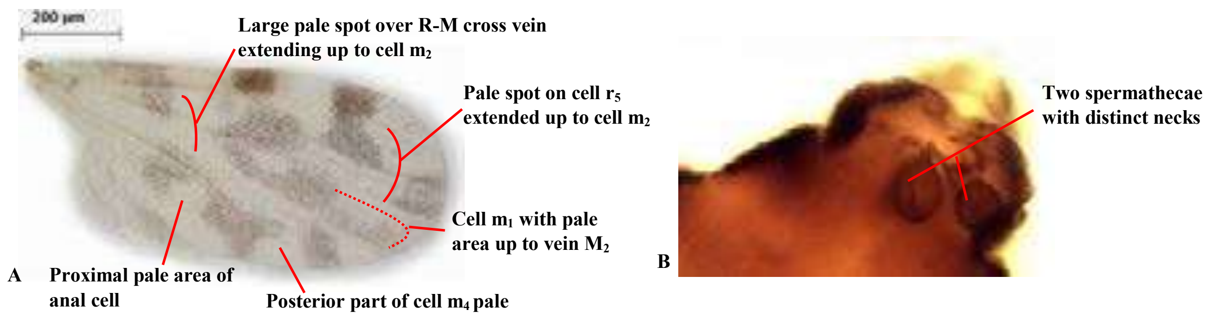


Figure 3. Pictorial diagnosis (A. Wing, B. Female genitalia) of *Culicoides imicola* Kieffer, 1913

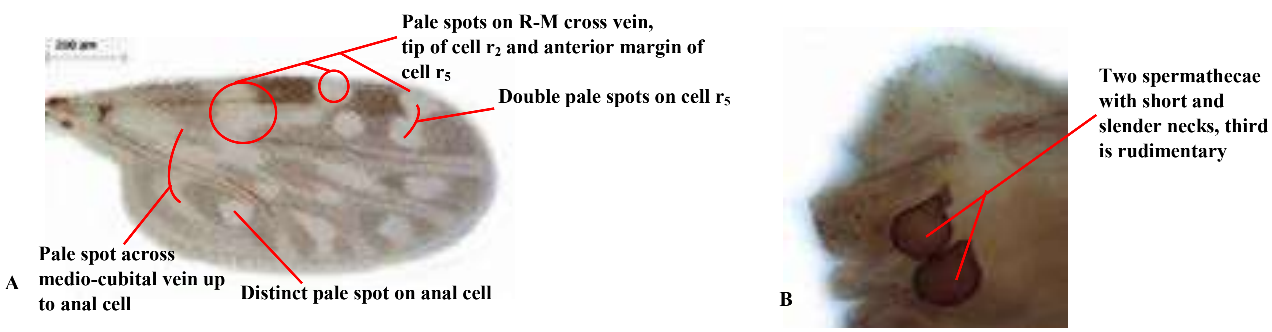


Figure 4. Pictorial diagnosis (A. Wing, B. Female genitalia) of *Culicoides oxystoma* Kieffer, 1910

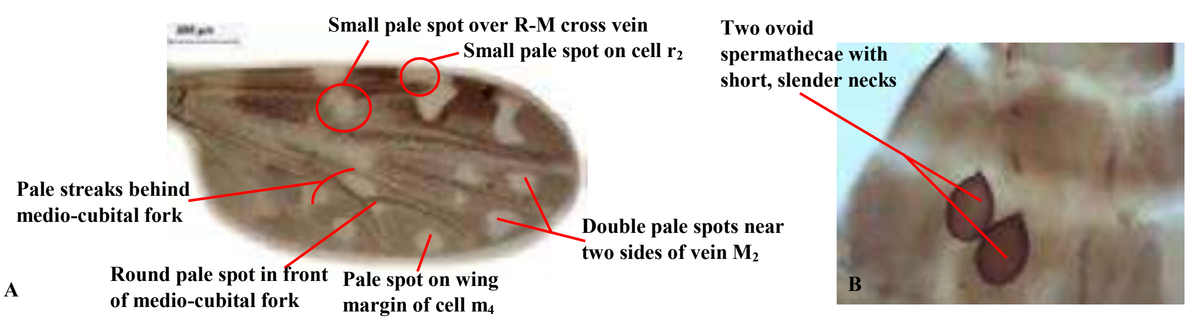
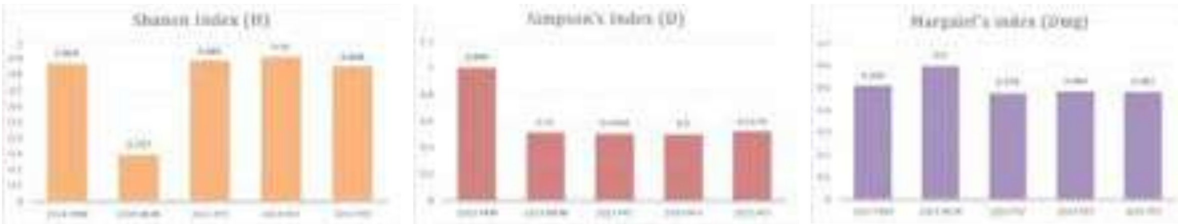


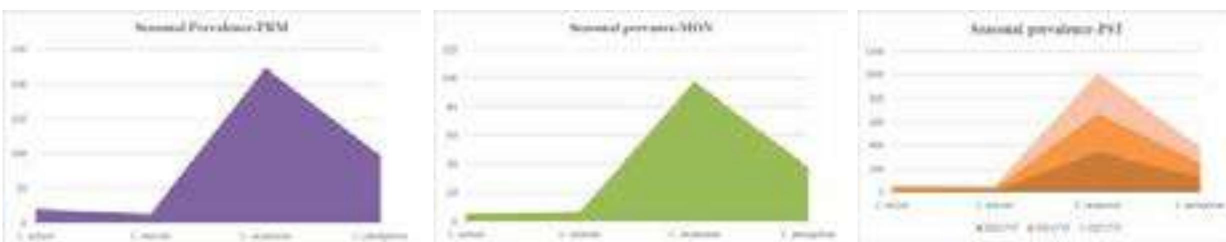
Figure 5. Pictorial diagnosis (A. Wing, B. Female genitalia) of *Culicoides peregrinus* Kieffer, 1910



A B C

Figure 6. Ecological indices (A. Diversity, B. Dominance, C. Richness) of *Culicoides* species in different seasons.

Figure 7. Species relative abundance values showing prevalence of *Culicoides* species in different seasons.



A B C

Figure 8. Seasonal prevalence (A. Pre-monsoon, B. Monsoon, C. Post-monsoon) of *Culicoides* species in different seasons.

A B

C D E

Figure 9. Species rank abundance curve (A. Pre-monsoon, B. Monsoon, C, D, E. Post-monsoon) of *Culicoides* species in different seasons.

Acknowledgement

We are gratified to the Bankura Forest Department for permitting us to survey the district. Further, we convey our heartfelt thanks to all the affiliates of the Diptera section who had contributed with their knowledge and technical support.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Comparative Cranial Osteology of *Hydrophis schistosus* Daudin, 1803 and *Hydrophis platurus* (Linnaeus, 1766) (Elapidae: Hydrophiinae)

Sonia Mondal*[1], Souradeepa Kundu[2], Pratyush P. Mohapatra[3] and C. Raghunathan[4]

[1-4]*Zoological Survey of India*
Kolkata

Abstract

The viviparous sea snakes of the subfamily Hydrophiinae are morphologically and ecologically diverse and distributed throughout the Indo-Pacific. Earlier works on the cranial morphology of the Hydrophiinae were mostly on the description of teeth-bearing bones and schematic diagrams of skulls. The present study aims to provide a detailed description of the cranium and mandibular structure of two commonly distributed sea snake species in India, namely *Hydrophis schistosus* and *H. platurus.* This study analyzes the variations in the cranial morphology between these two species using thirty-two allometric characters. This study also reveals that various components of the skull vary in shape as compared to their terrestrial Elapid cousins. On comparison among these two species, it was found that there are considerable morphological variations in the length of major bones like ectopterygoid, frontal, mandible, maxilla, nasal, parietal, premaxilla, pterygoid and quadrate. In addition, structural variation in the frontal, parietal, premaxillary, and basisphenoid bones along with variation in all the teeth-bearing structures including maxilla, palatine, pterygoid and dentine have also been noticed. Further, the basisphenoid process which is present in *H. schistosus* and absent in *H. platurus* which may have a functional role associated with the dietary specialization in the former species to capture the catfishes that constitute their major prey.

Keywords: Basisphenoid process, Cranial morphology, Hydrophiinae, Piscivorous, *Hydrophis,*

Introduction

The skull or the cranium in vertebrates is the protective casing of the brain and is the most complex skeletal structure involving several highly integrated structural and functional units (Hanken and Hall, 1993). The skull and the associated bones are also involved in feeding, protection of the central nervous system and accommodation of sense organs, along with locomotion, social interaction, mate competition, courtship and optionally defence mechanism (Smith, 1993; Cundall 2000; Cundall and Greene 2000; Shine *et al.*, 2000; Herrel *et al.*, 2007). The cranium of a snake is composed of a number of mobile and articulated elements involved in cranial kinetics (Smith, 1993; Herrel *et al.*, 2007). Taxonomic comparison in snakes involves a great deal of the skull (Kramer, 1980; Gloyd and Conant, 1990). Owen (1866) was possibly the first to describe osteology and myology of species such as *Crotalus horridus*, *Python tigris*, *Boa constrictor*, *Naja tripudians* and *Deirodon scaber*. Later, works by Huxley (1871), Gegenbaur (1878), Hoffman (1890), Sedwick (1905), Wiedershiem and Parker (1907), Williston (1925), Kingsley (1917), Goodrich (1930), Versluys (1937) and the classical book on "Osteology of Reptiles" by Romer (1956) have dealt with serpent skeletal systems.

The viviparous sea snakes of the subfamily Hydrophiinae distributed throughout the Indo- Pacific, originated 8-17 million years ago, and about 60% of species richness in this

*Author for correspondence : researchwild.ophidia@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

group is accounted for by the exceptionally rapid speciation of the *Hydrophis* clade dated around 1.5-7.5 million years old (Dunson, 1982; Mozzotti and Dunson, 1984). In the Indian Ocean, most of the sea snakes have been colonized within the last 3 million years and have allopatrically speciated from source lineages in the West Pacific (Ukuwela *et al.*, 2017). Earlier work on the cranial morphology of the species under this subfamily was restricted to a few points mentioned about maxilla bone by Gunther (1864) and a short description of some of the cranial bones was mentioned by Smith (1926) along with schematic diagram of the skull without detailed description. Kharin (2007) provided some information on the osteology of *Hydrophis platurus* collected from Russia. In the review of the genus *Hydrophis*, Kharin (2004) mentioned a few osteological characters of the genus. In recent times, only a few works have been done on osteological aspects of sea snakes involving a few Australian and South-east Asian species (Borczyk *et al.*, 2021; Sherratt *et al.*, 2019). There is a lack of literature on the osteological aspects of sea snakes from the Indian subcontinent. To address the gap, here we provide a detailed description and comparative analysis of various components of the cranium and the lower jaw bones in two widespread species, *Hydrophis schistosus* Daudin, 1803 and *H. platurus* (Linnaeus, 1766) in India. The hook-nosed sea snake (*Hydrophis schistosus*) and the yellow-bellied sea snake (*Hydrophis platurus*) are viviparous, of which the former is specialized to feed on spiny catfishes and puffer fishes (Voris and Voris, 1983), whereas the latter is more of a generalist and surface feeder which preys on small pelagic fishes (Klauber, 1935; Kropach, 1975).

Materials and Methods

We examined one adult specimen each of *Hydrophis schitosus* (Registration No. ZSI-K-23476) and *H. platurus* (Unregistered: collected by SKD & PPM from Puri coast, Odisha), housed in the collection of the Zoological Survey of India, Kolkata. These formaldehyde-preserved specimens were utilized in the preparation of skeletal material. The head portion was skinned and kept in boiling water for varying lengths of time, the time determined by the type of skeletal muscle attachment, then the muscles were removed manually using forceps under a stereoscopic microscope (LEICA EZ4). The skeletal material prepared in the aforesaid manner was then photographed using Nikon D7000 digital camera and thereafter the skull was disarticulated to describe various components of the skull bones. For each skull, 30 characters were observed (Bullock and Tanner, 1966), 32 measurements were taken (Borczyk *et al.*, 2021). Based on the overall skull shape and proportions of the skull elements involved in feeding these distances were chosen (Borczyk *et al.*, 2021). All measurements were taken with a digital Mututoyo Absolute calliper (to the nearest 0.1mm) directly from the skull.

Abbreviations: CQL: Quadrate crest length; QL: Quadrate length; ECT: Ectopterygoid length; FL: Frontal length; FW1: Frontal width taken at fronto-parietal contact; FWA: Frontal width at anterior point; FWM: Frontal width at mid-point; FWP: Frontal width at posterior point; FMDB: Mandibular fossa length; MXL: Maxilla length; NL: Nasal length; NW: Nasal width; NCL: Nasal component length taken at naso-frontal articulation to the most rostral tip of premaxilla; PAR: Parietal length; PW1: Parietal width at postorbital process; PWM: Parietal width at midpoint; PWP: Parietal width at posterior point; PFH: Prefrontal height; PFL: Prefrontal length; PML: Premaxilla length; PMW: Premaxilla width; PLL: Palatine length; PRETR: Retroarticular process length; PTL: Pterygoid length; PTTL: Length of tooth row on pterygoid; MDL: Mandible length taken from its rostral tip to the caudal tip; MD2L: Mandible length taken from the rostral tip of the mandible to the mandible joint; DENT: Dentary length; LCM: Length of compound bone of maxilla; STP: Supratemporal length; SL: Skull length; SW: Skull width; SH: Skull height; A: Angular; AR: Articular; BO: Basioccipital; BS: Basisphenoid; D: Dentary; DF: Dental foramen; EC: Ectopterygoid; EO: Exoccipital; FR: Frontal; M: Maxilla; NAS: Nasal; PAL: Palatine; PARA: Parasphenoid; PFR: Prefrontal; PM: Premaxilla; PO: Postorbital; PR: Prootic; PRA: Prearticular; PT: Pterygoid; QU: Quadrate; SA: Surangular; SM: Septomaxilla; SOC: Supraoccipital; SP: Splenial; SUP: Supratemporal; MT: Maxillary teeth; PT: Palatine teeth; PTT: Pterygoid teeth; DT: Dentine teeth.

Results and Discussion

The two species considered in this study (*H. schistosus* and *H. platurus*) show similar components of the cranium, however, they show variations in shape and size in some of the major components of the skull (Figure 1). A comparative measurement of various components of the cranium in these two species is provided in Table 1.

The premaxilla is a single median bone that terminates the snout. Its anterior surface is an inverted Y-shaped ridge, the prongs of which extend in a dorso-lateral direction; it is wider than its length in both the species but is much larger in *H. platurus* than *H. schistosus*. The postero-dorsal process extends dorsally to connect with the anterior part of the nasal in *H. platurus*, whereas the postero-dorsal process is very short and not in contact with the nasal in *H. schistosus*. The elongate, horizontal, plate-like structure called septomaxillae form the floor of the internal nares. The wing-like structure of the septomaxilla is much wider in *H. schistosus* than *H. platurus*. In the case of *H. schistosus* the edge is much rounded in comparison to the short rectangular edge in *H. platurus*. From a dorsal view, the articulated nasals appear as a pear-shaped structure between the septomaxilla and the frontals and are loosely connected to them by connective tissues. The nasal is not connected to the premaxilla; anteriorly it is connected with the posterior process of the septomaxilla and the posterior end which is oval shaped is articulated in between the two frontals. The nasal is much longer in *H. platurus* than *H. schistosus*. Although it is pear-shaped in both species, in the case of *H. schistosus* each nasal bone is dorsally distinctively separated by a suture, whereas in *H. platurus* this suture is less distinct. The frontals are highly developed and form a complete enclosure for the anterior portion of the skull. Anteriorly the frontal contacts with nasals and septomaxillae, and posteriorly with the parietal. Frontal is longer than wide in both species. It is longer and wider in *H. platurus* in comparison with *H. schistosus*. In the latter, the anterior width and the posterior width are equal having a wider middle region, whereas in the former have a wider middle region and posterior region and a much narrower anterior end. From a lateral view, each prefrontal is an irregular cone-shaped structure with a laterally compressed anterior process (forming the apex of the cone) extending laterally to the posterior portion of the nasal, septomaxilla. The prefrontal height is higher in *H. schistosus* than *H. platurus*. The prefrontal is constricted in the middle region with an elongated posterolateral process in *H. schistosa* as compared to *H. platurus*, the prefrontal is not constricted in the middle and has a wider middle and postero-lateral process. The largest element of the cranium is the parietal and forms the greater part of the braincase, but like frontals, it extends far down on either side of the brain reaching ventrally to the basisphenoid and forming the posterior of each orbit. The parietal is much longer in *H. platurus* and is wider at the point of the postorbital process. The width of the parietal in the middle is narrow in both species, however, the width of the parietal at the posterior region, where it is connected with the supraoccipital is much wider in *H. schistosus* than in *H. platurus*. Each maxilla is a short curved bar that conforms to the shape of the head on the medial border; about mid-way, there is a small horizontal dorso-posteriorly pointing process that articulates with the ventral surface of the prefrontal and does not extend beyond palatine. The maxilla is proportionately longer (MXL/SL) in *H. platurus* than *H. schistosus.* In both species, the venom-delivering poison fang is situated at tip of the maxilla bone followed by a diastema. The number of maxillary teeth after the fang is 3 in *H. schistosus* and 5-6 in *H. platurus*. The pterygoid and palatine are structurally similar in both species but differ in length and number of teeth on those two tooth-bearing structures. The length of the pterygoid is longer in *H. schistosus* than *H. platurus* having 13 and 23 teeth respectively. The percentage of PTTL to the length of the pterygoid is 71% in *H. schistosus*, whereas it is 83.5% in *H. platurus*. The palatine bone attached to the pterygoid also bears teeth which are different in both species, in *H. schistosus* the count is four, and in case of *H. platurus* it is 5-7. The ectopterygoid is a small club- shaped, flat bone in between the maxillae and the pterygoid, overlying on each side at its ends and connects with the pterygoid at the 10^{th} teeth in *H. schistosus* and at 12^{th} in *H. platurus*. The structure of ectopterygoid is similar in both species but is longer in *H. schistosus* than *H. platurus*. The quadrate in both species is rectangular in shape; proximally connected with the postero-lateral border of the supratemporal and distally with the condylar surface of the mandible. The quadrate bone is longer in *H. schistosus* than *H. platurus*, and has a longer crest length in the former. In the case of *H. schistosus,* the anterior end of the quadrate attached to the supratemporal is wider and gradually tapering as it extends down towards its posterior end where it articulates with the mandible, as compared to *H. platurus* which is of equal width along the length of the bone from anterior to the posterior end. The basisphenoid is present without a suture anteriorly to the elongated parasphenoid, forming a single bone. The basisphenoidal portion of the bone is a flat hexagonal plate, bounded dorsally at its margins by prootic and parietal walls and posteriorly by the basioccipital. The basisphenoid is a flat structure with a feeble keel medially in case of *H. platurus*, this structure has a distinct, wide shaft-like process medially in *H. schistosus* which we termed as “basisphenoid process” extending between 2^{nd} -6^{th} pterygoid teeth. The mandible is composed of two bones: the longer posterior part of each jaw is composed of angular, prearticular, articular, surangular and splenial aspects and is without teeth, the dentary forms the anterolateral portion of the jaw.

The Mandible or the lower jaw is 1.7 times longer than the skull length in *H. schistosus* and is 1.3 times in *H. platurus*. In *H. platurus* the compound bone of the maxilla at its anterior-most end is upwardly directed at the juncture to the dentine but is straight in *H. schistosus.* Further, the postero-lateral end of the dentine at the exterior side is longer and gradually slanting in *H. platurus* in comparison to *H. schistosus.* The ratio of dentine bone vs. mandibular length in *H. schistosus* is 0.47 as compared to *H. platurus,* which is 0.51. The dentine in *H. schistosus* has a knob-like process at its anterior free end which is absent in *H. platurus* and is much wider. The number of teeth present on the dentine is almost equal in both species with 15 rows of teeth in *H. schistosus* and 15-17 rows in *H. platurus*. The mandibular fossa is longer in *H. schistosus,* whereas in *H. platurus* the retroarticular process is longer.

Our results show that the overall length of the skull of *H. schistosus* is slightly longer than the *H. platurus*, whereas the skull height and skull width is 1.3 times and 1.2 times respectively than the *H. platurus*. The presence of a strong, wide basisphenoid process in *H. schistosus* and its absence in *H. platurus* indicates that this structure is associated with crushing the hard skull of the spiny catfish which is the predominant prey species in *H. schistosus*.

Table 1. Comparative skull measurement of *Hydrophis schistosus* and *Hydrophis platurus*

Characters	Measurements (mm)	
	Hydrophis schistosus	***Hydrophis platurus***
CQL	6.16	5.08
QL	15.03	10.37
ECT	12.31	7.87
FL	5.94	7.53
FW1	1.30	3.19
FWA	2.84	3.23
FWM	3.33	7.31
FWP	2.84	6.13
FMDB	7.24	5.51
MXL	10.88	13.36
NL	4.88	7.23
NW	1.36	1.81
NCL	9.08	8.95
PAR	9.64	11.38
PW1	6.86	10.08
PWM	3.63	4.89
PWP	5.17	1.99
PFH	6.58	5.26
PFL	3.48	4.36
PML	1.12	2.59
PMW	4.2	5.16
PLL	8.62	9.28
PRETR	3.46	4.76
PTL	27.84	24.46
PTTL	19.80	20.43
MDL	42.32	38.15
MD2L	36.85	32.59
DENT	20.14	19.78
LCM	32.67	26.64
STP	7.41	7.42
SL	30.93	29.00
SW	9.58	7.12
SH	19.17	15.74

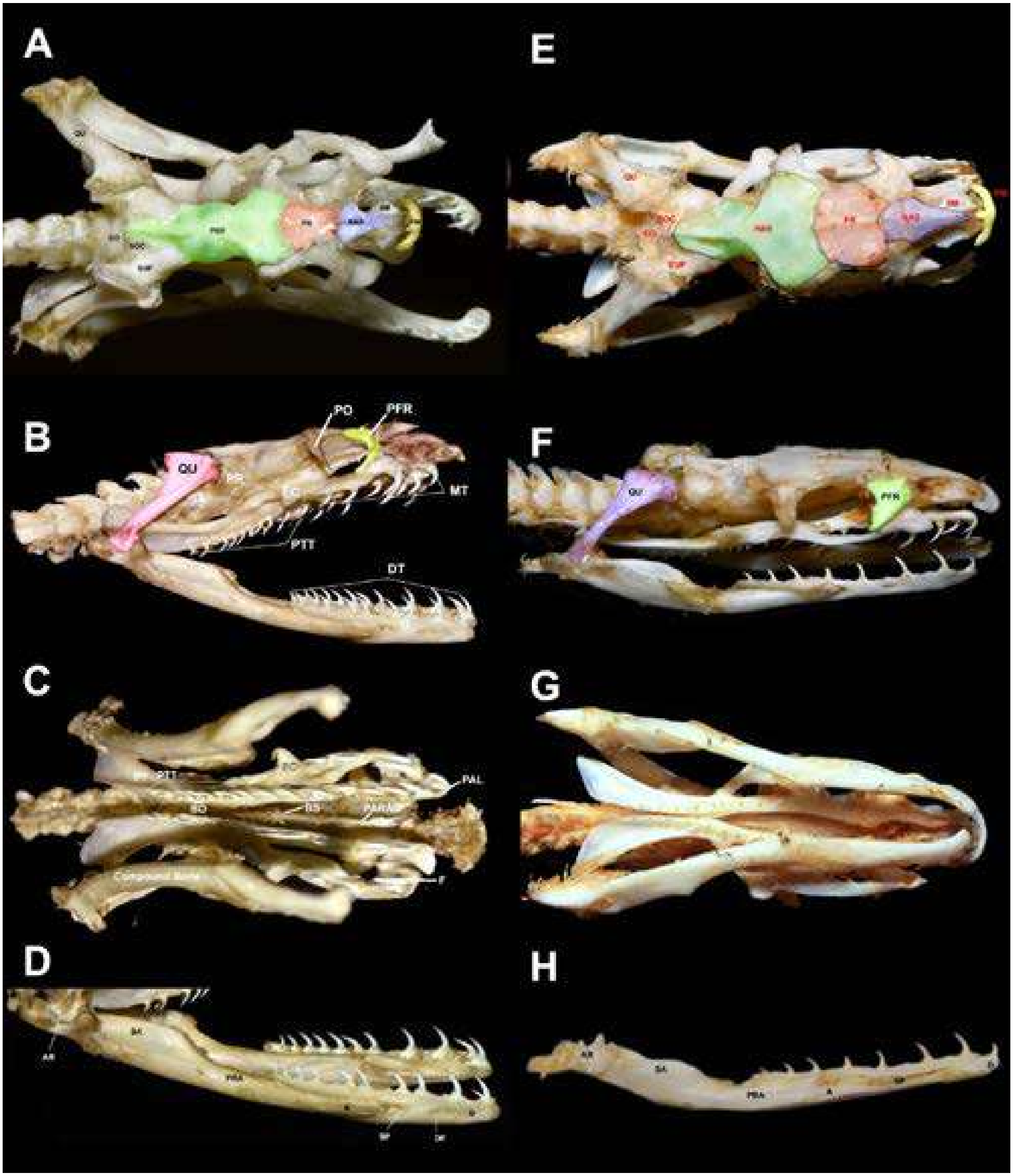

Figure 1: A-D Skull and Mandible of *Hydrophis schistosus*: A. Dorsal View, B. Lateral view, C. Ventral View, D. Mandible; and E-H Skull and Mandible of *Hydrophis platurus*: E. Dorsal View, F. Lateral view, G. Ventral View, H. Mandible.

Acknowledgements

We thank the Director, ZSI Kolkata, for her kind support all throughout. We thank the staff members of Reptilia section, FPS building for their kind support. We thank the anonymous reviewers for their constructive comments that helped improve the manuscript.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Descriptions of poorly known marine sponges (Phylum Porifera) from the Andaman Islands India with notes on their Ecology

Preeti Pereira[1*] and Chelladurai Raghunathan[1,2]

[1]Andaman and Nicobar Regional Centre, Zoological Survey of India
Haddo-744 102, Port Blair, Andaman and Nicobar Islands, India.
E-mail: preeti0018@yahoo.co.in, preetipereira@unigoa.ac.in;
https://orcid.org/0000-0003-1281-8080
[2]Zoological Survey of India, M-Block, New Alipore-700 053, Kolkata, West Bengal, India.
E-mail: raghuksc@rediffmail.com; https://orcid.org/0000-0003-1417-5496
Present address of the first author: Zoology Discipline,
School of Biological Sciences and Biotechnology, Goa University, Taleigao, Goa, India

Abstract

In the present manuscript taxonomic descriptions of 20 species of sponges distributed among 18 genera, 14 families and 10 orders are provided along with notes on their geographic distribution and ecology. A total of 10 growth forms were observed of which, thin sheets were the most dominant growth form (25%) followed by massive globose (15%); massive lobose (15%) and massive flanged (10%). Seven growth forms were found to be rare, represented only by one species each. Most sponge species preferred a rocky substrate followed by dead coral and live coral. Sponges exhibiting thin sheet type of growth form were found to colonise on all hard substrates such as rocky substrates, dead and live corals. Only one species, *Oceanapia sagittaria*, exhibiting cylindrical growth form, was found in sandy bottom. *Stylissa massa* and *Phyllospongia foliascens* were found to be present invariably in all depths. *Spheciospongia vagabunda*, and two varieties *viz*., *Spheciospongia inconstans* var. *meandrina* and *S. inconstans* var. *digitata* were found in the shallow waters (0 – 1 m). Species-specific information on taxonomy, zoogeography and bathymetric distribution of the sponges of the Andaman Islands provided herein would be valuable for future biomonitoring programs for their conservation and management.

Keywords: Demospongiae; Distribution; Diversity; Taxonomy; Zoogeography

Introduction

Marine sponges (Phylum Porifera) of the Andaman and Nicobar Islands are probably one of the most diverse in India, yet have poorly represented apart the species names being included in a few checklists. Although a large number of studies on marine sponges of the Islands have been carried out in the recent years (Sautya *et al.* 2010; Immanuel & Raghunathan 2011; Vinod *et al.* 2012; Dam Roy *et al.* 2013; Immanuel *et al.* 2015; Ubare & Mohan 2016; Ubare & Mohan 2018; Das *et al.* 2019) from this relatively understudied region, most of them are restricted to the accessible areas of the Islands and have dealt with checklists, providing no scope for ascertaining the validity of the listed species. Detailed descriptions and illustrated taxonomic treatments of 20 poorly known sponges are provided in this report along with notes on their geographic distribution and ecology. The reported species are distributed in 18 genera, 14 families and 10 orders.

*Author for correspondence :
Article Received on: 02.04.2023

Accepted on: 24.04.2023

Material and Methods

Study area

This study is a part of sponge taxonomy and diversity studies conducted at several localities using SCUBA (up to 20m) and rocky shore explorations during the low tides in the Andaman Islands during 2015–2018 (Table 1; Figure 1).

Sampling

The habitats covered were coral reef with various substrates, *viz*., coral rubble, boulders, shelf grit, rocky, sandy and muddy bottoms. The survey sites were accessed through a combination of road and motorized boats. Bathymetric ranges for all the reported species were recorded using a SCUBAPRO depth gauge and details pertaining to substrates (live coral, dead coral, rock and sand) were recorded. Sponge species were identified by preparing permanent slides by mounting the sections and spicules using DPX following Pereira and Raghunathan (2020). Sections were then examined and photographed using a stereo-zoom microscope (make: Leica; model: M205A) and a compound microscope (make: Omax; model: XM82ESC02). The original descriptions were used for comparing and ascertaining the identity of the species. The specimens were registered and deposited at the National Zoological Collections of the Zoological Survey of India, Andaman Nicobar Regional Centre (ZSI/ANRC), Port Blair.

Table 1. Survey locations in the Andaman Islands (Abbreviations: MGMNP = Mahatma Gandhi Marine National Park; RJMNP = Rani Jhansi Marine National Park; WLS = Wildlife Sanctuary).

No.	Locality	GPS coordinates	
		Latitude (N)	Longitude (E)
NORTH ANDAMAN			
1	West Island WLS	13°34.491’	92°53.452’
2	White Cliff Island WLS	13°32.184’	92°52.440’
3	Thornhill Island	13°31.820’	92°54.305’
4	Elizabeth Bay	13°30.642’	92°54.812’
5	Reef Island WLS	13°29.826’	92°52.430’
6	Mayo Island WLS	13°27.900’	92°51.945’
7	Duncan Bay	13°27.860’	92°52.229’
8	Paget Island WLS	13°26.553’	92°50.745’
9	Tree Islet WLS	13°25.948’	93°04.644’
10	Table Excelsior Island WLS	13°25.612’	93°05.868’
11	Trilby Island WLS	13°25.327’	93°03.927’
12	Table Delgarno Island WLS	13°24.413’	93°05.100’
13	Point Island WLS	13°24.137’	92°49.106’
14	Temple Island WLS	13°22.047’	93°04.795’
15	Turtle Island WLS	13°21.586’	93°04.351’
16	Mackey Point	13°20.111’	92°49.438’
17	Smith Island	13°18.406’	93°04.375’
18	Ross Island WLS	13°17.545’	93°04.110’

No.	Locality	GPS coordinates	
		Latitude (N)	Longitude (E)
19	Durgapur	13°16.323’	93°02.548’
20	Rowe Island WLS	13°14.913’	92°50.419’
21	Casuarina Bay	13°14.262’	92°50.491’
22	Craggy Island	13°13.588’	93°03.447’
23	Kalipur	13°13.451’	93°02.731’
24	Lamiya Bay	13°12.222’	93°02.449’
25	Shark Island WLS	13°12.064’	92°45.255’
26	Kwangtung Island WLS	13°10.204’	92°47.996’
27	North Reef Island WLS	13°05.785’	92°43.355’
28	Latouche Island WLS	13°05.580’	92°43.666’
29	Roper Point, Sound Island	12°56.469’	92°57.660’
30	German Jetty	12°55.505’	92°54.024’
31	Fisheries Colony	12°54.984’	92°53.932’
32	Avis Island	12°54.943’	92°55.927’
33	Pokka Dera	12°54.194’	92°55.031’
34	Karmatang	12°50.594’	92°56.357’
35	North Passage	12°15.643’	92°56.202’
RITCHIE’S ARCHIPELAGO			
36	Outram Island (RJMNP)	12°15.680’	93°06.510’
37	Henry Lawrence Island (RJMNP)	12°12.620’	93°04.516’
38	Inglis Island (RJMNP)	12°08.801’	93°06.836’
39	John Lawrence Island (RJMNP)	12°04.717’	93°00.415’
40	Wall (dive site)	12°03.296’	92°58.038’
41	Govind Nagar	12°02.540’	92°58.651’
42	Beach No. 3	12°02.003’	92°59.993’
43	Vijay Nagar	12°0.976’	93°00.606’
44	Margarita (dive site)	11°51.191’	93°02.339’
45	Lakshmanpur	11°50.807’	93°01.280’
46	Lighthouse	11°50.592’	93°02.027’
47	Bharatpur	11°50.596’	93°02.780’

No.	Locality	GPS coordinates	
		Latitude (N)	Longitude (E)
48	Neil Island Jetty	11° 50.295’	93°01.760’
49	Bus stop (dive site)	11°50.195’	93°00.479’
50	Natural Bridge	11°49.513’	93°00.511’
51	Sir Hugh Ross Island WLS	11°47.339’	93°04.796’
SOUTH ANDAMAN			
52	North Bay	11°41.977’	92° 45.250’
53	Ross Island	11°40.265’	92° 45.582’
54	Scissostris Bay	11°40.094’	92°44.904’
55	Lohabarrack WLS	11°38.765’	92°35.837’
56	Redskin Island (MGMNP)	11°34.037’	92°35.444’
57	Burmanallah	11°33.787’	92°44.051’
58	Pongibalu	11°30.983’	92°39.213’
59	Rifleman Island (MGMNP)	11°30.837’	92°38.767’
60	Rutland Island (MGMNP)	11°29.365’	92°40.717’
61	Twins Island (MGMNP)	11°23.371’	92°32.986’
LITTLE ANDAMAN			
62	South Brother Island WLS	10°56.343’	92°36.915’
63	Butler Bay	10°39.999’	92°34.660’
64	Kalapathar	10°39.361’	92°34.814’
65	Hut Bay	10°37.724’	92°33.906’
66	Hut Bay Jetty	10°35.549’	92°33.773’
67	Lighthouse	10°30.615’	92°29.143’

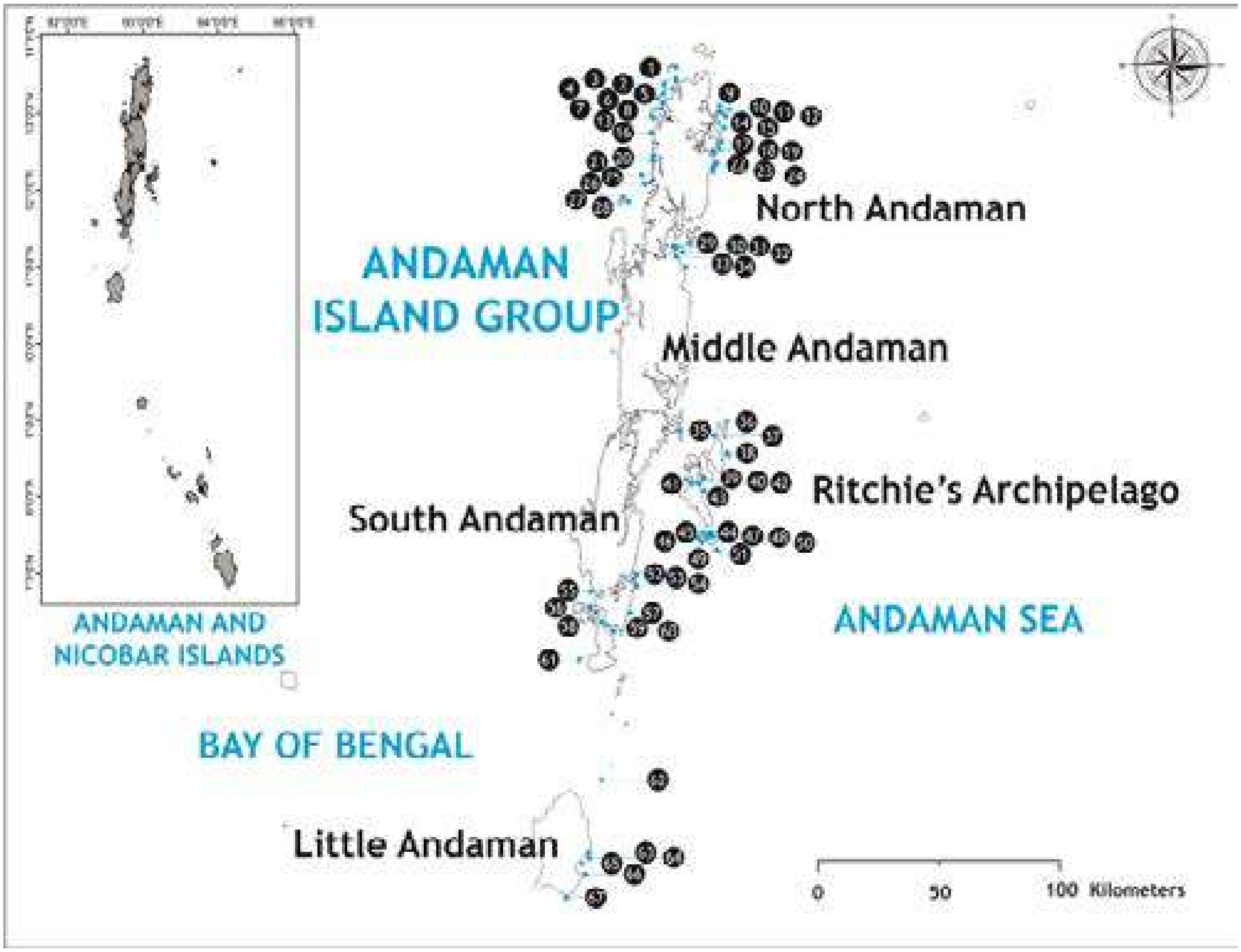

Figure 1. Map of the Andaman Islands showing survey locations. (See Table 1 for names and geographical coordinates of sites).

Results

The classification of the studied sponges follows WoRMS (2023). Taxonomic descriptions for all the species are provided based on the material examined. Synonymies include original description and all the key references.

Taxonomic treatment

Systematics

Class Demospongiae Sollas, 1885

Order Tetractinellida Marshall, 1876

Family Ancorinidae Schmidt, 1870

Genus *Rhabdastrella* Thiele, 1903

***Rhabdastrella globostellata* (Carter, 1883)**

Synonyms

Aurora globostellata (Carter, 1883); *Geodia globostellata* (Carter, 1883); *Jaspis carteri* (Ridley, 1884); *Stellettinopsis carteri* Ridley, 1884; *Stellettinopsis purpurea* Carter, 1886

Taxonomic references

Carter, 1883, p. 353, pl. 14, figs. 5a-h

Material examined: 1 specimen, ZSI/ANRC –14855, 23.v.2016, Turtle Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15167, 17.vi.2016, Trilby Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15168,22.vi.2016, Ross Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–15573, 21.vii.2016, Craggy Island, Coll. Sudhanshu Dixit; 1 specimen, ZSI/ANRC–15895, 21.ix.2016, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–17501, 29.v.2017, Durgapur, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–20014, 15.vi.2018, Outram Island, Coll. Preeti Pereira.

Description: sponge large, massive and sub-spherical, collected fragment measured 5 cm in length and about 4 cm thick; colour, when alive brownish yellow (Fig. 2A), light yellow on preservation (Fig. 2B), preservative stained dull yellow and has an oily residue exuded by the sponge; surface irregular, bumpy with 1 to 3 depressions, in which numerous oscules of varying diameters are visible, with the larger sized oscules on the periphery of the depressions; ostia present all over the surface of the sponge; consistency firm and slightly compressible.

Skeleton: Radial, with tracts of oxeas and orthotriaenes radiating towards the periphery; ectosome thick, comprises of oxyasters and oxyspherasters (Fig. 2C); choanosome consists of loosely arranged bundles of oxeas and orthotriaenes deeper in the choanosome (Fig. 2D), with the arrangement is more well-organized towards the periphery.

Spicules: Megascleres are of 2 types oxeas and orthotriaenes. Oxeas (Fig. 2E) smooth, slightly curved with pointed or telescoped ends measuring 624.10 – 865.45 – 979.95 × 9.23 – 15.26 – 22.57 µm. Orthotriaenes (Fig. 2F) with straight rhabds tapering to a sharp end measuring 185.58 – 516.84 – 779.61 × 6.26 – 11.92 – 18.22 µm, clades curved backwards, measuring 54.84 – 102.64 – 156.37 × 6.07 – 10.74 – 20.65 µm.

Microscleres are oxyspherasters 8.91 – 26.09 – 38.22 µm (Fig. 2G) and oxyasters measuring 2.40 – 4.17 – 7.59 µm (Fig. 2H).

Distribution: This species has a widespread distribution in the Indo- Pacific ranging from Western Indo-Pacific to the Temperate Australasian realm. The type locality of the species is Galle, Sri Lanka (Carter, 1883b, Thomas, 1985).

Remarks: The genus *Rhabdastrella* in India is represented by three species *viz*., *R. globostellata* (Carter, 1883), *R. providentiae* (Dendy, 1916) and *R. rowi* (Dendy, 1916). *Rhabdastrella globostellata* is differentiated from its congeners by the growth form and spicule composition, as it has a massive globular growth form with spicules comprising of oxeas, orthotriaenes, oxyasters and oxyasters while *R. providentiae* exhibits a thin, encrusting growth form and has anatriaenes megascleres, while *R. rowi* has a massive lobose growth form and sterrospherasters microscleres.

Family HETEROXYIDAE Dendy, 1905

Genus *Myrmekioderma* Ehlers, 1870

***Myrmekioderma granulatum* (Esper, 1794)**

Synonyms

Alcyonium granulatum Esper, 1794; *Acanthoxifer ceylonensis* Dendy, 1905; *Myrmekioderma tylota* de Laubenfels, 1954; *Neoprosypa atina* de Laubenfels, 1954; *Acanthoxifer fourmanoiri* Lévi, 1956

Taxonomic references

Dendy, 1905, 157 – 158, Plate IX, fig. 5

De Laubenfels, 1954, 121 – 122

Hooper, 2002, 765 – 769

Material examined: 1 specimen, ZSI/ANRC–16169, 5.x.2016, Natural Bridge, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16372, 5.viii.2016, North Bay, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16378, 20.viii.2016, Point Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16383, 20.ix.2016, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16386, 6.x.2016, Laxmanpur, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16861, 21.ii.2017, Bus Stop, Coll. M.P. Goutham Bharathi; 1 specimen, ZSI/ANRC–23661, 16.vi. 2018, Henry Lawrence Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23662, 18.vi.2018, John Lawrence Island, Coll. Preeti Pereira.

Description: Sponge massive, branched, irregular and sometimes lobate with a hispid or granular surface, surface has a distinct crust with a characteristic "peel" appearance with grooves of indistinct sizes between peels, peels generally polygonal, sponge usually covered in sediment such that only oscules are sometimes visible (Fig. 3A); the sponge measured ca. 6 cm across; oscules measured 2– 8 mm in diameter; colour when alive bright orange, although covered in sediment, On preservation, light orange (Fig. 3B).

Skeleton: The ectosome is formed by a palisade of densely arranged spicules making up the "peel", with spicules projecting through the surface giving it a hispid appearance. The choanosome is made up of little spongin with loosely arranged bundles of oxeas giving it a vaguely reticulated appearance (Fig. 3C).

Spicules: The spicules comprise of oxeas (Fig. 3D) with a great degree of variation.

I: 551.36 – 747.59 – 994.12 × 10.18 – 20.98 – 48.41 µm

II: 324.07 – 390.44 – 465.67 × 9.11 – 12.57 – 16.42 µm

In addition, a few thin forms of oxeas are present, measuring 337.76 – 426.28 – 508.81 × 4.80.

Microscleres are trichodragmata (Fig. 3E), 116.11 – 116.87 – 117.64 × 14.40 – 16.80 –19.20 µm.

Distribution: This species has a widespread distribution in the Indo- Pacific. The type locality of this species is South India and Sri Lanka (Dendy, 1905), West and South Indian Shelf and Western and Northern Madagascar (Lévi, 1956), in the Western Indian Ocean.

Remarks: The genus *Myrmekioderma* is represented by a single species, *M. granulatum* in India including the Andaman and Nicobar Islands. This species is known to have a high degree of variation in spicule sizes and presence or absence of spines corresponding to its geographical distribution (Bergquist, 1965). The specimen described herein lacked the spines that have been reported in other specimens across the Indo-Pacific.

Order BUBARIDA Morrow & Cárdenas, 2015

Family DICTYONELLIDAE Van Soest, Diaz & Pomponi, 1990

Genus *Acanthella* Schmidt, 1862

***Acanthella cavernosa* Dendy, 1922**

Synonyms

Phakellia cavernosa (Dendy, 1922)

Taxonomic references

Dendy, 1922, 120–121

Material examined: 1 specimen, ZSI/ANRC–14579, 9.xii.2016, Shark Island, Coll. C. Raghunathan; 1 specimen, ZSI/ANRC–14588, 12.v.2016, Pongibalu (3m), Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14856, 3.vi.2016, Latouche Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–15169, 11.vi. 2012, Twins Island, Coll. C. Raghunathan; 1 specimen, ZSI/ANRC–15371, 12.vi. 2016, Craggy Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15893, 21.ix.2016, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–17495, 28.v.2017, Trilby Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–20017, 16.vi. 2018, Henry Lawrence Island, Coll. Preeti Pereira.

Description: The sponge exhibits a massive globular growth form, attached to the substratum. The sponge is comprised of trabeculae that end abruptly at the surface. The surface is highly conulose with a large number of pseudoscules (Fig. 4A). Bright orange when alive, the colour lightens on preservation (Fig. 4B). The consistency is tough, slightly compressible and difficult to tear. A large number of polycheates and crabs are observed within the pseudoscules.

Skeleton: The skeleton has a dense network of spicules, spicules project through the surface of the sponge (Fig. 4C) Spongin fibre is very sparse. The network was dense in the centre, the bundles sparsely distributed at the periphery.

Spicules: Spicules (Fig. 4D) comprise of styles that are slender, straight or slightly curved, the ends tapering to a point, measuring 239.32 – 423.07 – 573.20 × 5.47 – 8.40 – 11.05 µm; Strongyles are long, slender and sinuous, measuring 335.31 – 749.80 – 1069.69 × 3.39 – 5.59 – 7.59 µm.

Distribution: *Acanthella cavernosa* has been reported previously from the Andaman and Nicobar Islands (see Dam Roy *et al.*, 2013; Immanuel *et al.*, 2015), although its distribution in the Islands is yet to be updated in international databases (see WoRMS, 2023). The type locality of this species is Amirante Islands (Dendy, 1922) Seychelles (Thomas, 1973), Western Indian Ocean and Eastern India (Thomas, 1982), Bay of Bengal in the Western Indo-Pacific.

Remarks: *Acanthella cavernosa* is the only species of the genus *Acanthella* reported to be present in the Andaman and Nicobar Islands. The species has a very characteristic growth form and appearance and dimensions of spicules.

Genus *Liosina* Thiele, 1899

***Liosina paradoxa* Thiele, 1899**

Synonyms

Auletta bia de Laubenfels, 1954; *Migas porphyrion* Sollas, 1908; *Milene porphyrion* (Sollas, 1908)

Taxonomic references

Laubenfels, 1954, 170 – 171, fig. 111, Plate VIII, fig. a.

Jabeen *et al.,* 2018, 1296 – 1299

Material examined: 1 specimen, ZSI/ANRC–14107, 8.iii.2016, Kwangtung Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14110, 9.iii.2016, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14113, 10.iii.2016, Paget Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–14589, 12.v.2016, Pongibalu, Coll. Preeti Pereira; 1 specimen, ZSI/

ANRC– 14595, 13.v. 2016, North Bay, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14862, 22.v. 2016, Trilby Island, Coll. Preeti Pereira; ZSI/ANRC–14871, 23.v. 2016, Turtle Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15901, 22.ix.2016, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16161, 26.x.2016, Table Delgarno Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16394, 27.x.2016, Craggy Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16869, 22.ii.2017, Natural Bridge, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–17889, 9.ix.2017, White Cliff Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–18055, 20.x.2017, Durgapur, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC – 19001, 24.ii.2018, Ross Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20990, 16.vi. 2018, Henry Lawrence Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23604, 25.x. 2017, Tree Islet, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23606, 11.ix.2018, Roper Point, Sound Island, Coll. M.P. Goutham Bharathi.

Description: Massive-lobose sponge, growing upright from a broad base (4–10 cm), branches growing vertically up to 7 cm in height (Fig. 5A). The oscules are apical, 3–6 mm in diameter. Surface has a tuberculated appearance. The colour when alive is dark muddy gray and is retained on preservation (Fig. 5B). The sponge is soft, compressible and easily torn.

Skeleton: The skeleton is made up very little spongin interspersed with few oxeas. Mud particles are incorporated into the skeleton of the sponge, dense in the ectosome as compared to the choanosome (Fig. 5C).

Spicules: Long slender oxeas, straight, rarely curved, blunt ended (Fig. 5D), measuring 391.66 – 575.02 – 799.71 × 4.80 – 9.59 – 14.40 μm.

Distribution: Though *Liosina paradoxa* has previously been reported from the Andaman and Nicobar Islands (see Dam Roy *et al.,* 2013; Immanuel *et al.,* 2015), this has not been updated in the databases. The type locality is Sulawesi Sea/ Makassar Strait (Thiele, 1899) in the Western Coral Triangle. Further records include Gulf of Mannar, (Thomas, 1985), Karachi, Pakistan (Jabeen *et al.,* 2018) of the Western Indo-Pacific.

Remarks: *Liosina* is represented in India only by a single taxon, *L. paradoxa*. It differs from its closely resembling congener *L. granularis* Kelly-Borges & Bergquist, 1988 reported from Papua New Guinea by the spiculation and the amount of pigmented granules.

Order CLIONAIDA Morrow & Cárdenas, 2015

Family CLIONAIDAE d'Orbigny, 1851

***Spheciospongia vagabunda* Ridley, 1884**

Synonyms

Spirastrella vagabunda Ridley, 1884; *Anthosigmella vagabunda* (Ridley, 1884);*Spirastrella cylindrica* Kieschnick, 1896

Taxonomic references

Dendy, 1905, 122–123

Sutcliffe *et al.,* 2010, 19–22

Material examined: 1 specimen, ZSI/ANRC– 23675, 17.xii. 2015, Burma Nallah (intertidal), Coll. Preeti Pereira.

Description: Excavating sponge having a digitate growth form with a fistule growing through basal portion on a rocky substrate. Foreign bodies such as fragments of shells, sand and rock are incorporated in the body of the sponge (Fig. 6A), especially in the basal portion. The surface is irregular and smooth. The colour is brown when alive and is retained on preservation. Oscules are apical. The surface has a slightly pitted appearance. The consistency is firm, slightly compressible and easily torn.

Skeleton: The skeleton is made up of dense bundles of tylostyles, which are fewer in the choanosome. The tylostyles are arranged in a confused manner (Fig. 6B) with sand particles included in the skeleton.

Spicules: Spicules comprise of tylostyles with a slightly elongated or oval shaped head (Fig. 6C), slightly curved or straight in two size categories:

I – 151.01 – 210.66 – 282.36 × 6.07 – 9.26 – 13.63 μm

II – 316.12 – 460.29 – 535.77 × 9.6 – 14.85 – 21.31 μm

Microscleres are spirasters of two types, one is long and slender with upto 4 rotations and the other one is shorter regular spiraster (Fig. 6D).

I – 17.54 – 20.30 – 25.25 × 1.88 – 2.39 – 3.29 μm

II – 8.90 – 12.24 – 14.41 × 1.56 – 2.17 – 2.46 μm

Distribution: Immanuel *et al.* (2015) has reported the occurrence of *Spheciospongia vagabunda* from the Andaman and Nicobar Islands. The type locality of this species is Thursday Island, Torres Strait, Arnhem coast to Gulf of Carpentaria, Sahul Shelf in the Central Indo-Pacific and

Galle, Sri Lanka (South India and Sri Lanka Ecoregion), West and South Indian Shelf in the Western Indo-Pacific (Ridley, 1884).

Remarks: *Spheciospongia vagabunda* has a widespread distribution in the Indo-Pacific. This species is known to have a great degree of variability in morphology and growth form. The characteristic features of this species are the size categories and number of rotations in spirasters.

***Spheciospongia inconstans* var. *meandrina* (Dendy, 1887)**

Synonyms

Suberites inconstans Dendy, 1887; *Suberites inconstans var. maeandrina* Dendy, 1887

Taxonomic references

Dendy, 1889, 154.

Material examined: 1 specimen, ZSI/ANRC–23615, 19.ix.2017, Kalapathar (intertidal), Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23626, 21.i. 2017, Duncan Bay (intertidal), Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23637, 11.i.2018, Karmatang (intertidal), Coll. Preeti Pereira.

Description: Massive sponge with a broad base, partially buried in sediment found inhabiting rocky tide pools. Surface uneven and pitted with numerous closely spaced grooves (Fig. 7A) or pits spaced 4–5 mm apart, measuring 2–3 mm. The sponge is brown when alive and lightens on preservation (Fig. 7B). Consistency hard and incompressible.

Skeleton: Skeleton comprised of dense and irregularly interconnected and loosely arranged bundles of spicules (Fig. 7C). Spongin fibre is very sparse.

Spicules: Tylostyles in two size categories (Fig. 7D): 137.07 – 239.38 – 380.14 × 4.20 – 7.35 – 10.73 µm and 352.36 – 401.92 – 459.01 × 7.77 – 11.70 – 13.75 µm.

Microscleres comprise of spirasters (Fig. 7E), measuring 9.41 – 13.03 – 18.05 × 1.21 – 1.87 – 2.97 µm.

Distribution: *Spheciospongia inconstans* var. *meandrina* is reported herein as a new record to the Andaman and Nicobar Islands. The type locality is Chennai in Eastern India (Dendy, 1889), Bay of Bengal in the Western Indo-Pacific.

Remarks: Dendy (1887) described three varieties of *Spheciospongia inconstans* based on external growth form, shape and size of spicules, *viz*., *S. inconstans* var *globosa, S. inconstans* var. *meandrina* and *S. inconstans* var. *digitata*. The characteristic feature of this variety is the massive growth form and uneven and pitted surface.

***Spheciospongia inconstans* var. *digitata* (Dendy, 1887)**

Synonyms

Suberites inconstans var. *digitata* Dendy, 1887; *Spirastrella inconstans* var. *digitata* (Dendy, 1887)

Taxonomic references

Dendy, 1889, 155–156.

Material examined: 1 specimen, ZSI/ANRC–23647, 28.x.2016, Mackey Point, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23674, 27.v.2017, Table Excelsior Island, Coll. Preeti Pereira.

Description: Massive, digitate sponge with a broad base, partially buried in sediment found inhabiting the rocky tide pools. Surface uneven and slightly pitted, measuring 2 – 3 cm. The sponge is brown when alive and lightens on preservation (Fig. 8A). The consistency is hard and incompressible.

Skeleton: Skeleton comprised of dense and irregularly interconnected and loosely arranged bundles of spicules (Fig. 8B). Spongin fibre is very sparse.

Spicules: Tylostyles (Fig. 8C) in two size categories:

449.77 – 510.54 – 583.6 × 11.86 – 16.16 – 19.02 µm

321.73 – 427.02 – 489.73 × 8.17 – 12.31 – 17.17 µm

Microscleres are spirasters (Fig. 8D) measuring 11.21 – 12.64 – 14.12 × 1.22 – 1.46 – 1.76 µm

Distribution: *Spheciospongia inconstans* var. *digitata* is reported herein as a new record to the Andaman and Nicobar Islands. The type locality is Chennai (Dendy, 1889).

Remarks: Dendy (1887) described three varieties of *Spheciospongia inconstans* based on external growth form, shape and size of spicules *viz*., *S. inconstans* var *globosa, S. inconstans* var. *meandrina* and *S. inconstans* var. *digitata*. The characteristic of this variety is the massive digitate growth form.

Genus *Cliona* Grant, 1826

***Cliona orientalis* Thiele, 1900**

Synonyms

Anthosigmella orientalis (Thiele, 1900)

Taxonomic references

Thomas, 1972, 347–348

Schönberg, 2000, 168–174.

Material examined: 2 specimens, ZSI/ANRC–23677, 13.vii.2016, Reef Island, Coll. Seepana Rajendra.

Description: Excavating sponge, observed burrowing into rock and dead coral (Fig. 9A). The substrate is covered by a thin layer of sponge. The oscules are spread over the substrate with yellow circular rims. The sponge when alive is dark brown with yellow oscules measuring 2–5 mm in diameter. On preservation, the colour lightens to a dull gray (Fig. 9B).

Skeleton: The skeleton comprises of bundles of tylostyles running towards the surface and forms a brush-like pattern in the periphery.

Spicules: Megascleres are smooth, straight and sharply pointed tylostyles (Fig. 9C) with a spherical head in a single size category measuring 145.64 – 287.37 – 375.15 × 3.73 – 9.14 – 12.12 µm; Microscleres are spirasters bent or curved in a „c" shape with teeth-like ridges on the convex surface (Fig. 9D), measuring 11.04 – 12.79 – 14.96 × 1.16 – 1.35 – 1.69 µm.

Distribution: This species is reported for the first time from the Andaman and Nicobar Islands. The type locality is in Halmahera (Thiele, 1900) Western Coral Triangle, Western and Northern Australia (Fromont *et al.,* 2005), NW Australian shelf. It has also been reported from Gulf of Mannar and Palk Bay (Thomas, 1972), South India and Sri Lanka Ecoregion of the West and South Indian shelf in the Western Indo-Pacific.

Remarks: Altogether, five species of *Cliona* are reported from the Andaman and Nicobar Islands viz., *Cliona varians* Duchassaing & Michelotti, 1864 from Pongibalu, (Dam Roy *et al*., 2013; Immanuel *et al*., 2015); *C. ensifera* Sollas, 1878 from Avis Island, (Annandale, 1915); *C. kempi* Annandale, 1915 from Port Blair (Annandale, 1915), *C. lobata* Hancock, 1849 (Immanuel *et al*., 2015) and *C. mucronata* Sollas, 1888 from Port Blair (Annandale, 1915). It is pertinent to note that two species viz., *C. varians* and *C. lobata* are not Indo–Pacific species, the type locality being Eastern Caribbean and Celtic Seas respectively, while the distribution of *C. ensifera* and *C. mucronata* is yet to be updated in the international databases. *Cliona orientalis* is differentiated from the other species by its colour, single size tylostyles and the characteristic C – shaped spirasters with ridges on the convex surface.

Order HAPLOSCLERIDA Topsent, 1928

Family CHALINIDAE Gray, 1867

Genus *Chalinula* Schmidt, 1868

***Chalinula nematifera* (de Laubenfels, 1954)**

Synonyms

Nara nematifera Laubenfels, 1954; *Haliclona nematifera* (De Laubenfels, 1954)

Taxonomic references

Laubenfels, 1954, 76 – 77

Material examined: 1 specimen, ZSI/ANRC–16854, 19.ii.2017, Margarita, Coll. Tamal Mondal; 1 specimen, ZSI/ANRC–17902, 15.ix.2017, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20020, 16.vi.2018, Henry Lawrence Island, Coll. Preeti Pereira.

Description: Thinly encrusting sponge, 1 – 3 mm in thick, light purple with white veins running on the surface of the sponge (Fig. 10A&B). The sponge releases copious amounts of mucous when damaged. The sponge was observed encrusting on a dead *Acropora* coral. Oscules wide, measuring 1 – 2 mm in diameter. The sponge is fragile, soft and must be collected along with the substrate. On preservation, the colour changes to dull brown (Fig. 10C).

Skeleton: The skeleton is of isodictyal reticulation with very sparse spongin joining the spicule ends.

Spicules: Spicules comprise of short, straight, thin oxeas (Fig. 10D) measuring 84.26 – 95.52 – 106.66 × 2.44 – 4.51 – 6.37 µm.

Distribution: *Chalinula nematifera* has been reported previously from the Andaman and Nicobar Islands (Dam Roy *et al.,* 2013; Immanuel *et al.,* 2015). The type locality of the species is the Ebon Atoll in the Marshall Islands (Laubenfels, 1954), Marshall, Gilber and Ellis Islands Province in the Eastern Indo- Pacific.

Remarks: This is the only species of the family Chalinidae to be reported from the Andaman and Nicobar ecoregion. The species is easily identified by its characteristic growth form, colour and unique pattern of white "veins" on the surface and also by the type and dimensions of oxeas.

Suborder PETROSINA Boury-Esnault & Van Beveren, 1982

Family PETROSIIDAE Van Soest, 1980

Genus *Neopetrosia* de Laubenfels, 1949

***Neopetrosia chaliniformis* (Thiele, 1899)**

Synonyms

Petrosia chaliniformis Thiele, 1899; *Petrosia (Petrosia) chaliniformis* Thiele, 1899; *Petrosia exigua* Kirkpatrick, 1900; *Neopetrosia pandora* de Laubenfels, 1954; *Haliclona exigua* (Kirkpatrick, 1900); *Neopetrosia exigua* (Kirkpatrick, 1900); *Xestospongia exigua* (Kirkpatrick, 1900); *Xestospongia pacifica* Kelly-Borges & Bergquist, 1988

Taxonomic references

Thiele, 1899.

Bergquist, 1965, 149, fig. 14, plate i–iii

de Laubenfels, 1949, 126

Material examined: 1 specimen, ZSI/ANRC–14599, 13.v.2016, North Bay, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14853, 22.v.2016, Trilby Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15391, 10.viii.2016, Lohabarrack crocodile sanctuary, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16355, 9.iii.2016, Shark Island, Coll. C. Raghunathan; 1 specimen, ZSI/ANRC–17487, 26.v.2017, Craggy Island, Coll. Sudhanshu Dixit; 1 specimen, ZSI/ANRC–19941, 15.v.2018, North Passage Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–20027, 18.vi. 2018, John Lawrence Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20983, 11.ix.2018, Roper Point, Sound Island, M.P. Goutham Bharathi.

Description: Encrusting sponge, 1 – 3 mm thick, growing over the substrate. The surface is smooth and bumpy, with numerous oscules, 1 – 2 mm in diameter. The sponge was observed exhibiting two types of growth forms *viz.*, thin sheets on rocks, dead corals and live corals and an upright growth form. The colour when alive is dark brown (Fig. 11A) on preservation it lightens to a pale brown (Fig. 11B).

Skeleton: The skeleton has an isodictyal reticulation with bundles of 3-5 spicules forming round meshes (Fig. 11C) of 100 – 200 µm in diameter.

Spicules: Spicules are smooth, straight oxeas (Fig. 29D) measuring 114.58 – 147.61 – 173.15 × 3.97 – 7.05 – 9.56 µm.

Distribution: The type locality of this species is Flying Fish Cove, Christmas Island (Kirkpatrick, 1900), Java Transitional Province and East of Ponapé (Laubenfels, 1954), East Caroline Islands, Tropical NW Pacific. This species is restricted to the Indo-Pacific. It was also reported from the Gulf of Mannar (Thomas, 1985), South India and Sri Lanka, West and South Indian Shelf and Kawaratti, Lakshadweep (Thomas, 1989), in the Easten Indo-Pacific.

Remarks: Three species of *Neopetrosia* are reported from the Andaman and Nicobar Islands *viz.*, *Neopetrosia carbonaria* (Lamarck, 1814), *Neopetrosia chaliniformis* (both reported by Dam Roy *et al.,* 2013, Immanuel *et al.,* 2015) and *Neopetrosia tenera* (described by Carter, 1887). *Neopetrosia chaliniformis* is differentiated from its congeners by growth form, colour and spicule dimensions.

Genus *Petrosia* Vosmaer, 1885

Sub genus *Petrosia (Strongylophora)* Dendy, 1905

***Petrosia (Strongylophora) strongylata* Thiele, 1903**

Synonyms

Petrosia strongylata Thiele, 1903; *Strongylophora strongylata* (Thiele, 1903)

Taxonomic references

Thiele, 1903, 938.

De Voogd and Van Soest, 2002, 201–202.

Material examined: 1 specimen, ZSI/ANRC–23596, 16.vi.2018, Henry Lawrence Island, Coll. Preeti Pereira

Description: The sponge is massive, cone-shaped with a large oscule on top. The surface of the sponge is irregular with slight bumps and ridges. Dark pinkish–maroon in colour (Fig. 12A), lighter cream–yellow towards the basal and interior portion. The oscula measure about 1.8 cm in diameter. The sponge is hard and tough to collect, though brittle within. Numerous canals are visible; juvenile barnacles are observed within the canals. On preservation, the sponge turns dull creamish yellow in colour (Fig. 12B).

Skeleton: The skeleton is made up of sub-rectangular meshes (Fig. 12C), comprising of 4–6 strongyles. Few strongyles are found scattered within the meshes. The ends of the strongyles along with short strongyles and oxeas make up the nodes of these rectangular meshes, the interior resembling a ladder–like arrangement. Minute triangular meshes are visible on the surface of the sponge.

Spicules: The spicules are stout, slightly curved strongyles (Fig. 12D) in three size categories; I – 212.96 – 303.22 × 6.69 – 14.61 µm;

II – 113.94 – 268 × 4.62 – 11.37 µm;

III – 46.15 – 127.95 × 2.96 – 9.85 µm.

Microscleres are comprised of microxeas (Fig. 30D) measuring 55.77 – 264.83 × 2.37 – 4.27 µm.

Distribution: This species was previously reported form Ritchie's Archipelago in the Andaman and Nicobar Islands by Immanuel *et al.* (2015) though without species description. The type locality of the species is contained in Ternate (Thiele, 1903), Western Coral Triangle in the Central Indo–Pacific.

Remarks: Two species of the genus *Petrosia* are reported from the Andaman and Nicobar Islands viz., *Petrosia (Petrosia) nigricans* Lindgren, 1897 and *Petrosia (Strongylophora) strongylata* (Thiele, 1903). *Petrosia (Strongylophora) strongylata* is differentiated from *Petrosia (Petrosia) nigricans* in general morphology, type and dimensions of spicules as the latter possesses modified oxeas and strongyles.

Xestospongia testudinaria **(Lamarck, 1815)**

Synonyms

Alcyonium testudinarium Lamarck, 1815; *Petrosia testudinaria* (Lamarck, 1815); *Reniera crateriformis* Carter, 1882; *Reniera testudinaria* (Lamarck, 1815)

Taxonomic references

Desqueyroux-Faúndez, 1987, 198–200.

Lévi and Lévi, 1989, 84–85.

Material examined: 1 specimen, ZSI/ANRC–14590, 12.v.2016, Pongibalu, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14863, 24.v.2016, Durgapur, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14876, 19.xi.2015, Hut Bay, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–15163, 22.vi.2016, Ross Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15586, 12.vi.2016, Craggy Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16385, 6.x. 2016, Bus Stop, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–18069, 25.x.2017, Tree Islet, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–19943, 15.v.2018, North Passage Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–20028, 18.vi.2018, John Lawrence Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20440, 21.vi.2018, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20977, 19.vi.2018, Wall, Coll. Preeti Pereira.

Description: Massive cup shaped sponge, with ridges on its outer surface, growing attached on a rocky substrate covered in sand. The sponge measures 4 cm in length and 1 cm in thickness. Colour in life is reddish-brown (Fig. 13A). On preservation, the colour turns dull brown (Fig. 13B). The consistency is firm, slightly compressible and friable.

Skeleton: The skeleton shows a multispicular reticulation, forming round or oval meshes measuring 300 – 500 µm in diameter, bounded by bundles of stout oxeas (Fig. 13C).

Spicules: The spicules comprise of stout, slightly curved oxeas (Fig. 13D) measuring 185.60 – 322.03 – 322.61 × 7.59 – 11.72 – 16.97 µm.

Distribution: *Xestospongia testudinaria* was listed from the Andaman and Nicobar Islands previously (see Dam Roy *et al.,* 2013; Immanuel *et al.,* 2015). This species has a wide spread distribution in the Indo-Pacific.

Remarks: *Xestospongia* is represented by two species in the Andaman and Nicobar Islands: *Xestospongia testudinaria* (listed by Immanuel *et al.,* 2015) and *Xestospongia viridinigra* (listed by Dam Roy *et al.,* 2013). No description has been provided for either of the species. *Xestospongia testudinaria* is differentiated from *X. viridinigra* mainly by the colour and growth form. *Xestospongia testudinaria* bears very close resemblance to *X. bergquistia* in its morphology, the difference being consistency. *Xestospongia bergquistia* is softer and friable as compared to *X. testudinaria*, which is firm and requires more force to break apart.

Family PHLOEODICTYIDAE Carter, 1882

Genus *Oceanapia* Norman, 1869

Oceanapia sagittaria **(Sollas, 1902)**

Synonyms

Gellius sagittarius Sollas, 1902

Taxonomic references

Sollas, 1902, 212 – 213.

Hooper *et al.,*1993, 62.

Material examined: 1 specimen, ZSI/ANRC–15888, 13.ix.2016, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16155, 26.x.2016, Table Delgarno Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16365, 12.viii.2016, Craggy Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–18065, 24.x.2017, Smith Island, Coll. Oishinee Chakraborty;

1 specimen, ZSI/ANRC–19934, 24.v.2018, Scissostris Bay, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20974, 23.iii.2018, Sir Hugh Ross Island, Coll. Preeti Pereira.

Description: Sponge found with the base completely buried in sediment and fistules projecting above the surface. Fistules ending in a complex, translucent spherical capitate structure with dendritic fibres visible. The basal portion is dark brown in colour while the fistules and capitulum is red-maroon in when alive (Fig.14A). On preservation the colour darkens to gray brown (Fig.14B). The surface is lightly hispid, and triangular, cobweblike network is visible within the fistules. The consistency is soft, compressible and fragile with the capitulum detaching after collection.

Skeleton: The skeletal arrangement is of uni and paucispicular tracts of oxeas. The transverse section through the fistule (Fig.14C) shows bundles of oxeas loosely arranged within the fistule with large cavernous spaces in between. Tangential section through the fistule (Fig. 14D) shows uni and paucispicular tracts of oxeas while the basal root is dense and not organised (Fig. 14E)

Spicules: Spicules comprise of long, thin, smooth and slightly curved oxeas (Fig. 14F) measuring 329.31 – 347.44 – 375.28 × 8.41 – 9.98 – 11.67 µm.

Microscleres are of two types C-shaped sigmas measuring 2.20 – 3.01 – 4.51 × 1.20 – 1.63 – 1.91 µm and toxas of two types (Fig. 14G); larger V-shaped toxas measuring 23.15 – 31.01 – 35.91 × 1.02 – 1.49 – 2.11 µm and smaller centrangulate toxas.

Distribution: *Oceanapia sagittaria* (Sollas, 1902) has been listed from the Andaman and Nicobar Islands previously (Immanuel *et al.,* 2015). The type locality is Palau Bidang (Sollas, 1902), Sunda Shelf, Central Indo-Pacific. Burton (1928) extended the distribution of *Oceanapia sagittaria* to West Indo- Pacific. Other records Gulf of Mannar (Thomas, 1985), South India and Sri Lanka, West and South India Shelf in the Western Indian Ocean.

Remarks: *Oceanapia sagittaria* is commonly distributed in the Andaman and Nicobar Islands and can be easily identified *in situ* by its characteristic growth form, presence of capitulum and colour in addition to the distinctive skeletal characters.

Order POECILOSCLERIDA Topsent, 1928

Family CRAMBEIDAE Lévi, 1963

Genus *Monanchora* Carter, 1883

***Monanchora unguiculata* (Dendy, 1922)**

Synonyms

Amphilectus unguiculatus Dendy, 1922; *Hymedesmia unguiculata* (Dendy, 1922); *Neofolitispa unguiculata* (Dendy, 1922); *Okadaia unguiculata* (Dendy, 1922)

Taxonomic references

Dendy, 1922, 58.

Material examined: 1 specimen, ZSI/ANRC–14594, 13.v.2016, North Bay, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15171, 22.vi.2016, Ross Island, Coll. Tamal Mondal; 1 specimen, ZSI/ANRC–15903, 22.ix.2016, Rifleman Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16391, 26.x.2016, Table Delgarno Island, Coll. Preeti Pereira; 1specimen, ZSI/ANRC–23676, 19.vi.2018, Wall, Coll. Preeti Pereira.

Description: Sponge forms encrusting sheets with a smooth, glabrous surface and may encrust on dead/live corals, rock or even live barnacles, thereby camouflaging them. The sponge is bright red with pink or white streaks (Fig. 15A). A thin, almost translucent membrane can be separated from the sponge. The sponge is soft and almost disintegrates when handled, has to be collected along with the substrate. The colour after preservation changes to pale brown (Fig.15B). Consistency soft and fragile.

Skeleton: The skeleton is made up of loosely arranged bundles of tylostyles. In some cases, foreign spicule fragments may be visible. (Fig. 15C)

Spicules: Megascleres comprising slender tylostyles, with slightly oval heads, measuring 225.45 – 293.95 – 348.00 × 2.51 – 5.59 – 7.71 µm (Fig. 15D).

Microscleres comprising strongly curved isochelae, measuring 29.87 – 32.10 – 33.74 × 2.44 – 3.12 – 3.79 µm (Fig. 15E).

Distribution: *Monanchora unguiculata* was listed from the Andaman and Nicobar Islands previously by Dam Roy *et al.* (2013) and Immanuel *et al.* (2015), though without species description. The type locality of this species is Egmont reef, Chagos (Dendy, 1922) in the Central Indian Ocean islands. The species is restricted to the Western Indo-Pacific.

Remarks: The genus *Monanchora* is represented by two species in the Andaman and Nicoabr Islands *viz*., *M.*

unguiculata (Dendy, 1922) and *M. enigmatica* (Burton and Rao, 1932). The growth form exhibited by *M. enigmatica* is massive with lobose outgrowths "thrown into a number of irregular conulations" (Burton and Rao, 1932) which is very distinct from the thin sheets exhibited by *M. unguiculata*. The spicules of *M. enigmatica* comprise of styles and tornote spicules while the spicules of *M. unguicuilata* comprise of tylostyles and isochelae.

Family MICROCIONIDAE Carter, 1875

Genus *Clathria* Schmidt, 1862

Sub Genus *Clathria (Thalysias)* Duchassaing & Michelotti, 1864

***Clathria (Thalysias) vulpina* (Lamarck, 1814)**

Synonyms

Clathria reinwardti var. palmata Ridley, 1884; *Clathria corallitincta* Dendy, 1889

Taxonomic references

Dendy, 1889, 85–86.

Hooper, 1996, 401–405

Material examined: 1 specimen, ZSI/ANRC–16369, 14.vii.2016, Paget Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16568, 22.i.2017, Reef Island, Coll. Oishinee Chakraborty; 1 specimen, ZSI/ANRC–17890, 9.ix.2017, White Cliff Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–19935, 24.v.2018, Scissostris Bay (intertidal), Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–23621, 18.x.2018, South Brother Island, Coll. Preeti Pereira.

Description: Branching repent sponge, growing attached on live or dead corals and rocks. The surface is highly tuberculated and lightly hispid. Oscules are spread over the surface in no apparent pattern. The colour is light orange or dull white when alive (Fig. 16A). On preservation the colour lightens to a dull cream (Fig. 16B). A large number of juvenile polychaetes are usually found within the sponge. The consistency is soft and compressible.

Skeleton: The skeleton is reticulate with primary fibres interconnecting with secondary and tertiary fibres forming regular to oval meshes (Fig. 16C). The meshes are bound by 3–4 spicules, also arranged reticulately. Echinating acanthostyles are abundant and echinate fibres along with styles. Auxillary spicules are scattered between fibres.

Spicules: Megascleres comprised of smooth stout styles, slightly curved (Fig. 16D) measuring 102.02 – 181.22 – 240.10 × 3.23 – 9.11 – 14.00 µm.

Microscleres comprise of small echinating styles (Fig. 16E) measuring 57.20 – 72.14 – 89.23 × 4.01 – 6.45 – 10.14 µm.

Distribution: *Clathria (Thalysias) vulpina* has been recorded earlier from the Andaman and Nicobar Islands (Hooper, 1996). The type locality is Australia (Lamarck, 1814) and Arafura Sea (Hentschel, 1912), Sahul Shelf in the Central Indo-Pacific. *Clathria (Thalysias) vulpina* has a widespread distribution in the Indo- Pacific. Records from western Indo-Pacific Gulf of Mannar, South India and Sri Lanka (Dendy, 1889; Dendy, 1905; Thomas, 1970; Thomas, 1985), Beyt Island, Gujarat, Western India (Dendy, 1916), West and South Indian Shelf, Eastern India (Hooper, 1996), Bay of Bengal in the Western Indo-Pacific.

Remarks: *Clathria (Thalysias) vulpina* has previously been reported from the Andaman and Nicobar by Burton and Rao (1932) as *Tenacia frondifera* (Bowerbank, 1875). The species is characterized by its repent branching form and reticulate skeleton with rectangular meshes. This species was observed to act as an excellent host for polychaetes, an association reported by Hooper (1996).

Order SCOPALINIDA Morrow & Cárdenas, 2015

Family SCOPALINIDAE Morrow, Picton, Erpenbeck, Boury-Esnault, Maggs & Allcock,

2012

Genus *Stylissa* Hallmann, 1914

***Stylissa massa* (Carter, 1887)**

Synonyms

Axinella massa Carter, 1887; *Axinella virgultosa var. massa* Carter, 1887; *Auletta celebensis* Thiele, 1899; *Hymeniacidon aldis* de Laubenfels, 1954; *Stylotella conulosa* Topsent, 1897

Hymeniacidon conulosa (Topsent, 1897); *Suberites mollis* Kieschnick, 1900; *Stylotella gracilis* Hentschel, 1912; *Phakellia conulosa var. mauritiana* Dendy, 1922; *Phakellia mauritiana* Dendy, 1922; *Stylissa aurantium* (Kelly-Borges & Bergquist, 1988); *Stylissa conulosa var. mauritiana* (Dendy, 1922); *Stylissa digitata var. gracilis* (Hentschel, 1912); *Stylotella aurantium* Kelly-Borges & Bergquist, 1988

Taxonomic references

Carter, 1887, 68 Plate VII, fig. 6,7

Laubenfels, 1954, 187–188

Kelly-Borges and Bergquist, 1988, 130–131, Plate 2. b,c

Material examined: 1 specimen, ZSI/ANRC–13592, 18.xii.2015, Burma Nallah (intertidal), Coll. Preeti Pereira; 1 specimen, 1 specimen, ZSI/ANRC–13942, 18.xi.2015, Light House, Little Andaman, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14108, 9.iii.2016, Shark Island, Coll. C. Raghunathan and Party; 1 specimen, ZSI/ANRC–16561, 19.i.2017, Paget Island, Coll. C. Raghunathan and Party; 1 specimen, ZSI/ANRC–20025, 18.vi.2018, John Lawrence Island, Coll. M. P. Goutham Bharathi; 1 specimen, ZSI/ANRC– 22078, 18.x. 2018, South Brother Island, Coll. Preeti Pereira.

Description: Massive lobate growth form, the sponge growing upright with a narrow base. Surface is irregular, bumpy and lightly hispid. Oscules are generally apical and remain open after preservation. The colour when alive is bright yellow (Fig. 17A) and darkens to brown on preservation (Fig. 17B). Consistency is soft, highly compressible and easily torn.

Skeleton: The skeletal arrangement is confused with spongin cored by spicule tracts (Fig. 17C). There is no distinction between the ectosome and choanosome. The spicules project through the surface of the sponge giving it a hispid appearance.

Spicules: Spicules are entirely comprised of styles (Fig. 17D), some with modified ends, measuring 448.23 – 513.10 – 608.51 × 9.60 – 14.03 – 19.79 µm.

Distribution: *Stylissa massa* (Carter, 1887) was reported previously from the Andaman and Nicobar Islands. The holotype is described from King Island, Mergui Archipelago (Carter, 1887), Andaman Sea Coral Coast, Andaman province in the Western Indo–Pacific.

Remarks: The genus *Stylissa* is represented by two species in the Andaman and Nicobar Islands *viz.*, *Stylissa massa* and *Stylissa carteri*. The species S*tylissa massa* is quite distinct from *Stylissa carteri* in its general morphology and skeletal characters.

***Stylissa carteri* (Dendy, 1889)**

Synonyms

Acanthella carteri Dendy, 1889; *Acanthella aurantiaca* Keller, 1889; *Axinella carteri* (Dendy, 1889); *Phakellia carteri* (Dendy, 1889)

Taxonomic references

Dendy, 1889, 93–94.

Alvarez and Hooper, 2010, 26–27.

Material examined: 1 specimen, ZSI/ANRC–14105, 8.iii.2016, Kwangtung Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–14109, 9.iii.2016, Shark Island (10m), Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–14584, 12.v.2016, Pongibalu, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15177, 14.vi.2016, Red Skin Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–15584, 20.viii.2016, Point Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16558, 19.i.2017, Paget Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16573, 23.i. 2017, Point Island, Coll. Sudhanshu Dixit; 1 specimen, ZSI/ANRC–16873, 23.ii.2017, Laxmanpur, Coll. M.P. Goutham Bharathi; 1 specimen, ZSI/ANRC–20433, 21.vi.2018, Rutland Island, Coll. Preeti Pereira.

Description: Thick flabellate sponge, growing upright, with meandering ridges on the surface, sometimes branching irregularly and project from several planes. The sponge is bright orange in colour (Fig. 18A) when alive and gets lighter or dull yellow on preservation (Fig. 18B). Oscules are few and scattered on the surface, not visible on preservation. Tough and compressible.

Skeleton: The skeletal arrangement is comprised of bundles of spicules interspersed with sparse spongin, arranged more or less in a longitudinal pattern. The overall arrangement appears confused with spicules occurring freely in the choanosome (Fig. 18C).

Spicules: Styles are long, smooth and curved (Fig. 40D) measuring 380.53 – 481.79 – 595.46 × 10.18 – 15.66 – 23.57 µm.

Distribution: *Stylissa carteri* has a widespread distribution in the Indo-Pacific. Dam Roy *et al.* (2013) and Immanuel *et al.* (2015) have listed this species from the Andaman and Nicobar Islands. The type locality is from Gulf of Mannar (Dendy, 1889; Thomas, 1985), South India and Sri Lanka, West and South Indian Shelf in the Western Indo-Pacific.

Remarks: Two species of S*tylissa* are reported from Andaman and Nicobar Islands *viz.*, *Stylissa massa* and *Stylissa carteri*. *S. carteri* can be differentiated from *S. massa* by its orange colour, meandering ridges on the surface, consistency and spicule dimensions.

Order VERONGIIDA Bergquist, 1978

Family PSEUDOCERATINIDAE Carter, 1885

Genus *Pseudoceratina* Carter, 1885

***Pseudoceratina purpurea* (Carter, 1880)**

Synonyms

Aplysina purpurea Carter, 1880; *Korotnewia desiderata* Poléjaeff, 1889; *Druinella ramosa* Thiele, 1899; *Psammaplysilla kelleri* Wilson, 1925; *Hexadella pleochromata* de Laubenfels, 1950; *Dendrilla verongiformis* de Laubenfels, 1954; *Druinella tyroeis* de Laubenfels, 1954; *Thorectopsamma xana* de Laubenfels, 1954; *Druinella purpurea* (Carter, 1880); *Psammaplysilla purpurea* (Carter, 1880)

Taxonomic references

Carter, 1880, 36.

de Laubenfels, 1954, 45–46.

Material examined: 1 specimen, ZSI/ANRC–14586, 12.vi.2016, Pongibalu, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14859, 8.iii.2016, Kwangtung Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–15386, 23.vi.2016, Turtle Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–15582, 12.vi.2016, Craggy Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16375, 19.viii.2016, Paget Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16567, 22.i.2017, Reef Island, Coll. Sudhanshu Dixit; 1 specimen, ZSI/ANRC–16858, 20.ii. 2017, Natural Bridge, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–18760, 27.v.2017, Table Excelsior Island, Coll. M.P. Goutham Bharathi.

Description: The sponge grows laterally or forms upright cushions in some cases. The surface is minutely conulose with oscules spread over the surface (Fig. 19A). The colour is light yellow to dark green when alive and on preservation, the sponge turns violet black (Fig. 19B) and stains the preservative a dark violet colour. The consistency is fleshy, soft, spongy and slightly elastic and difficult to tear.

Skeleton: The ectosome is a distinct layer and is easily separated. The skeleton is made up of heavily pigmented spongin fibres, which form a vaguely reticulate pattern as the fibres frequently anastomose. Some fibres appear cored by foreign materials, the pith is usually clear and the flagellate chambers are rounded or oval in shape (Fig. 19C & D).

Distribution: *Pseudoceratina purpurea* has previously been listed from the Andaman and Nicobar Islands by Dam Roy *et al.* (2013) and Immanuel *et al.* (2015) although without a complete species description. The type localities are Gulf of Mannar (Carter, 1880), South India and Sri Lanka in the Western Indo-Pacific.

Remarks: *Pseudoceratina purpurea* (Carter, 1880) is the only species of the genus *Pseudoceratina* reported from the Andaman and Nicobar Islands. A remarkable feature of this species is the colour change from light yellow-green to dark violet on preservation, a trait commonly observed in many keratose sponges. This attribute along with its morphology and skeletal architecture are characteristic to *Pseudoceratina purpurea.*

Order DICTYOCERATIDA Minchin, 1900

Family DYSIDEIDAE Gray, 1867

Genus *Lamellodysidea* Cook & Bergquist, 2002

***Lamellodysidea herbacea* (Keller, 1889)**

Synonyms

Spongelia herbacea Keller, 1889; *Carteriospongia cordifolia* Keller, 1889; *Dysideopsis palmata* Topsent, 1897; *Dysidea herbacea* (Keller, 1889); *Spongelia delicatula* Row, 1911; *Dysideopsis topsenti* Hentschel, 1912; *Phyllospongia complex* de Laubenfels, 1954; *Phyllospongia cordifolia* (Keller, 1889)

Taxonomic references

de Laubenfels, 1954, 18–19

Material examined: 1 specimen, ZSI/ANRC–14860, 27.x.2015, Burmanallah (intertidal), Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15593, 18.xi.2015, Light house, Little Andaman, Coll. Tamal Mondal; 1 specimen, ZSI/ANRC–15598, 19.viii.2016, Paget Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16362, 22.vi.2016, Ross Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–16399, 28.x.2016, Mackey Point, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–17512, 14.vi.2016, Red Skin Island, Coll. Tamal Mondal.

Description: The sponge grows encrusting on rock or dead coral laterally and usually occupying a considerable area. The surface of the sponge is minutely conulose. The sponge is soft, spongy and easily detached from the substrate. Colour when alive is drab gray or bluish and very rarely has a greenish tinge (Fig. 20A) (probably due to the algae encrusting the sponge). On preservation, the sponge turns a dull creamish colour (Fig. 20B).

Skeleton: The skeleton is made of spongin fibres with the inclusion of sand grains and other foreign particles (Fig. 20C & D). The fibres are indistinguishable into primary and secondaries with varying thickness and are heavily cored with foreign particles.

Distribution: *Lamellodysides herbacea* was reported previously from the Andaman and Nicobar Islands (Dam Roy *et al.* 2013; Immanuel *et al.* 2015). The type locality is located in Indonesia (Topsent, 1897), Banda Sea, Central Indo-Pacific. This species is widely distributed in the Indo-Pacific. Records from Western Indo- Pacific Minicoy Island, Lakshadweep, Maldives (Thomas, 1979) in the Central Indian Ocean Islands, Palk Bay, Sri Lanka, South India and Sri Lanka (Thomas, 1985) in the West and South Indian Shelf.

Remarks: The genus *Lamellodysidea* is represented only by two species of Indo-Pacific origin *viz*. *Lamellodysidea herbacea* and *Lamellodysidea chloreae* (de Laubenfels, 1954). These two congeners can be distinguished based on their morphological attributes and skeletal arrangement. *Lamellodysidea chloreae* has a distinctive colour, a pale yellowish green (Laubenfels, 1954) as compared to the drab grey-blue of *L. herbacea*. In addition, fibres in *L. chloreae* are thinner than *L. herbacea*.

Family THORECTIDAE Bergquist, 1978

Genus *Phyllospongia* Ehlers, 1870

***Phyllospongia foliascens* (Pallas, 1766)**

Synonyms

Spongia foliascens Pallas, 1766; *Spongia otahitica* Esper, 1797; *Spongia penicillata* Esper, 1794; *Spongia othaitica* Lamarck, 1814; *Spongia fissurata* Lamarck, 1814; *Cacospongia poculum* Selenka, 1867; *Halispongia mantelli* Bowerbank, 1874; *Halispongia ventriculoides* Bowerbank, 1874; *Carteriospongia vermifera* Hyatt, 1877; *Carteriospongia otahitica var. aplanata* Hyatt, 1877; *Phyllospongia elegans* Lendenfeld, 1888; *Phyllospongia (Carteriospongia) elegans* Lendenfeld, 1888; *Phyllospongia (Carteriospongia) spiralis* Lendenfeld, 1889; *Phyllospongia mantelli var. reticulata* Lendenfeld, 1889; *Phyllospongia spiralis* Lendenfeld, 1889; *Carteriospongia elegans* (Lendenfeld, 1888); *Carteriospongia fissurata* (Lamarck, 1814); *Carteriospongia otahitica* (Esper, 1794); *Carterispongia mantelli* (Bowerbank, 1874); *Carterispongia otahitica* (Esper, 1794); *Hircinia (Polyfibrospongia) flabellifera* (Bowerbank, 1877); *Phyllospongia (Carteriospongia) foliascens* (Pallas, 1766)

Phyllospongia (Carteriospongia) mantelli (Bowerbank, 1874); *Phyllospongia foliacens* (Pallas, 1766); *Phyllospongia lekanis* de Laubenfels, 1954; *Phyllospongia mantelli* (Bowerbank, 1874)

Taxonomic references

Pallas, 1766

Lendenfeld, 1888, 116.

Bergquist *et al.,* 1988, 297.

Material examined: 1 specimen, ZSI/ANRC – 13739, 18.xi.2015, Lighthouse, Little Andaman, Coll. Tamal Mondal; 1 specimen, ZSI/ANRC–14103, 7.iii.2016, Latouche Island, Coll. Tamal Mondal; 1 specimen, ZSI/ANRC–14106, 8.iii.2016, Kwangtung Island, Coll. C. Raghunathan and Party; 1 specimen, ZSI/ANRC–14583, 12.v.2016, Pongibalu, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–14852, 22.v.2016, Trilby Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–17897, 12.ix.2017, Mayo Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–17905, 10.ix.2017, Thornhill Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC –18061, 24.x.2017, Smith Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–18764, 25.x.2017, Tree Islet, Coll. M.P. Goutham Bharathi; 1 specimen, ZSI/ANRC–20016, 16.vi. 2018, Henry Lawrence Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–20434, 9.ix. 2017, White Cliff Island, Coll. Preeti Pereira.

Description: Foliose, cup like sponge attached to the substratum by a short, hard stalk (Fig. 21A). The sponge grows massive with subsequent generations growing from the notch at the peduncle. The sponge appears grey white when alive and the colour is retained on preservation (Fig. 21B). The surface of the sponge is armoured by nodules or verrucae, formed by the primary fibres which penetrate through the surface. Oscules are scattered irregularly on the surface. The sponge measures 7 cm across and the peduncle measures 2 cm in length.

Skeleton: Skeleton is made up of spongin fibres and incorporated foreign bodies such as sand particles (Fig. 21C, D). The fibres show an irregular reticulation with primary fibres being heavily cored by sand particles; secondary fibres are slightly less cored and sometimes clear. There are no spicules present, which is compensated by the sand particles to provide additional support to the sponge.

Distribution: Although Dam Roy *et al.* (2013) and Immanuel *et al.* (2015) reported the occurrence of *Phyllospongia foliascens* from the Andaman and Nicobar, it has not been updated in the international databases. The type localities include Philip Island, Bassian (Hyatt, 1877) in the SE Australian Shelf and Port Chalmers, New Zealand, Southern New Zealand (Lendenfeld, 1889), Temperate Australasia and Iwayana Bay, Koror, West Caroline Islands (Bergquist, 1965), Tropical NW Pacific, Central Indo- Pacific. *Phyllospongia foliascens* has a widespread distribution in the Indo-Pacific. Reports from the Western Indo-Pacific Minicoy Island, Lakshadweep, Maldives (Thomas, 1979), Central Indian Ocean islands in the Western Indo-Pacific.

Remarks: The genus *Phyllospongia* is represented by a single species in the Andaman and Nicobar Islands and is easily recognizable in the field by its foliose growth form and strongly verrucose surface. This species is widely distributed in this archipelago. A few other thorectid species from the Indo-Pacific share similar growth form, although the verrucae are characteristic of *Phyllospongia foliascens.*

Genus *Hyrtios* Duchassaing & Michelotti, 1864

***Hyrtios erectus* (Keller, 1889)**

Synonyms

Duriella nigra Row, 1911; *Dysidea fusca* Ridley, 1884; *Dysidea nigra* Keller, 1889; *Dysideopsis fusca* (Ridley, 1884); *Heteronema erecta* Keller, 1889; *Heteronema erectum* Keller, 1889; *Hyrtios erecta* (agreement in gender); *Hyrtios fusca* (Ridley, 1884); *Inodes erecta* (Keller, 1889); *Thorectopsamma irregularis* Burton, 1934; *Thorectopsamma mela* de Laubenfels, 1954

Taxonomic references

Keller, 1889, 340–341.

Material examined: 1 specimen, ZSI/ANRC–15565, 20.viii.2016, Point Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15887, 21.ix.2016, Rutland Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–15908, 14.vii.2016, Red Skin Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–16160, 6.x.2016, Neil Island, Coll. Preeti Pereira; 1 specimen, 1 specimen, ZSI/ANRC–16360, 23.v.2016, Turtle Island, Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–17056, 19.i.2017, Paget Island, Coll. M.P. Goutham Bharathi; 1 specimen, ZSI/ANRC–17893, 9.ix.2017, White Cliff Island, Coll. M. P. Goutham Bharathi; 1 specimen, ZSI/ANRC–18770, 15.i.2018, Avis Island, Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC– 18997, 19.ii. 2018, Table Delgarno Island (13m), Coll. Preeti Pereira; 1 specimen, ZSI/ANRC–19940, 15.v.2018, North Passage Island (7m), Coll. Seepana Rajendra; 1 specimen, ZSI/ANRC–20019, 16.vi. 2018, Henry Lawrence Island, Coll. Preeti Pereira.

Description: The sponge has a branching erect growth form, with branches growing upright from sponge base as finger like projections (Fig. 22A); branches in some cases appear fused. In some cases, the surface is highly conulose, 2–3 mm distance between the conules, with numerous lines radiating and appears as a star pattern (Fig. 22B). The oscules are scattered over the surface of the sponge. The sponge is dark grey to black in colour and retains it on preservation (Fig. 22C). The sponge is supported internally by spongin fibres and by foreign particles, mostly sand particles and in a few cases shell fragments.

Skeleton: The skeleton comprises of spongin fibres densely cored by foreign material such as sand particles (Fig. 22D) and molluscan shell fragments. The primary fibres are thick and considerably more densely cored as compared to the secondary fibres, which are thinner. These fibres interconnect to form oval meshes measuring 50–100 µm.

Distribution: *Hyrtios erectus* has previously been listed from the Andaman and Nicobar Islands by Dam Roy *et al.* (2013) and Immanuel *et al.* (2015). However, its occurrence in the islands has not been updated in the international databases. The type locality is in Thursday Island, Arnhem Coast to Gulf of Carpenteria (Ridley, 1884), Sahul Shelf in the Central Indo-Pacific.

Subsequent reports are from, Palk Bay, Sri Lanka, South India and Sri Lanka (Thomas, 1985) in the West and South Indian Shelf, Kalpeni, Lakshadweep, Maldives (Thomas, 1989), Central Indian Ocean islands Province, in the Western Indo-Pacific realm.

Remarks: *Hyrtios erectus* has a widespread distribution in the Indo-Pacific and is the only taxon to be reported from the Andaman and Nicobar Islands. The species has a characteristic upright growth form and conule pattern.

Notes on ecology

A total of 10 growth forms were observed of which, thin sheets were the most dominant growth form (25%) followed by massive globose (15%); massive lobose (15%) and massive flanged (10%) (Fig. 23). Seven growth forms were found to be rare, represented only by one species each. Most sponge species preferred a rocky substrate followed by dead coral and live coral. Sponges exhibiting thin sheet type of growth form were found to colonise on all hard substrates such as rocky substrates, dead and live corals. Only one species, *Oceanapia sagittaria*, exhibiting cylindrical growth form, was found in sandy bottom. Sponges were found to show different distribution patterns at different depths (Fig. 24). *Stylissa massa* and *Phyllospongia foliascens* were found to be present invariably in all depths. *Spheciospongia vagabunda*, and two varities *viz*., *Spheciospongia inconstans* var. *meandrina* and *S. inconstans* var. *digitata* were found in the shallow waters (0 – 1 m).

Discussion

Andaman and Nicobar Islands are known to harbour high sponge diversity (Immanuel *et al.*, 2015; Pereira & Raghunathan 2018). However, sponges of these Islands have been poorly represented due to knowledge gaps on taxonomy and ecology. Conservation of poorly known species is challenging as lack of knowledge on their specific requirements may impede designing species-specific strategies (Feijó *et al.*, 2023). The present report is significant as it provides detailed descriptions and illustrated taxonomic treatments of 20 poorly known sponges from the Andaman and Nicobar Islands. The data reported in this study is envisioned to fill large knowledge shortfalls on sponge species biology and ecology. Species-specific information on taxonomy, zoogeography, ecology and bathymetric distribution of the sponges of the Andaman Islands provided herein would be valuable for future biomonitoring programs for their conservation and management. Future research must be focused on developing local expertise for effective regional-scale management and conservation of sponges (George *et al.*, 2020).

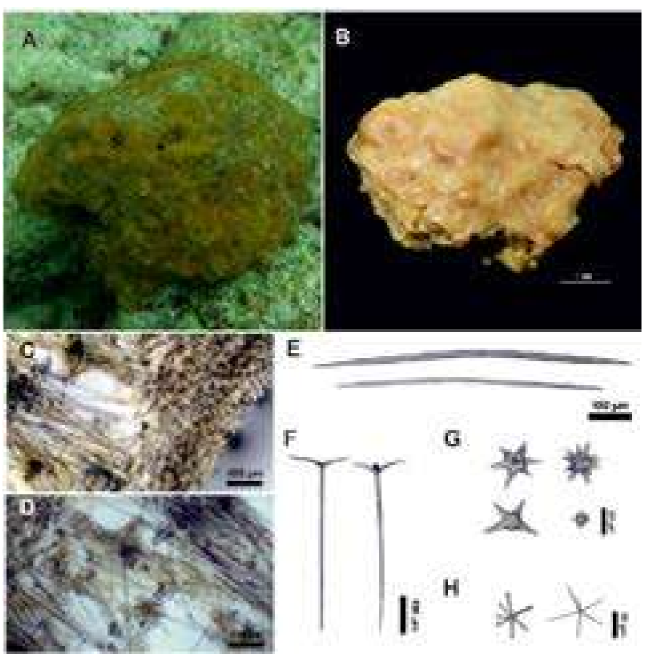

Figure 2. *Rhabdastrella globostellata* (Carter, 1883): A. *In situ* photograph, B. Preserved specimen, C. Transverse section Showing cortex, D. Transverse section showing choanosome, E. Oxeas, F. Orthotriaenes, G. Oxyspherasters, H. Oxyasters

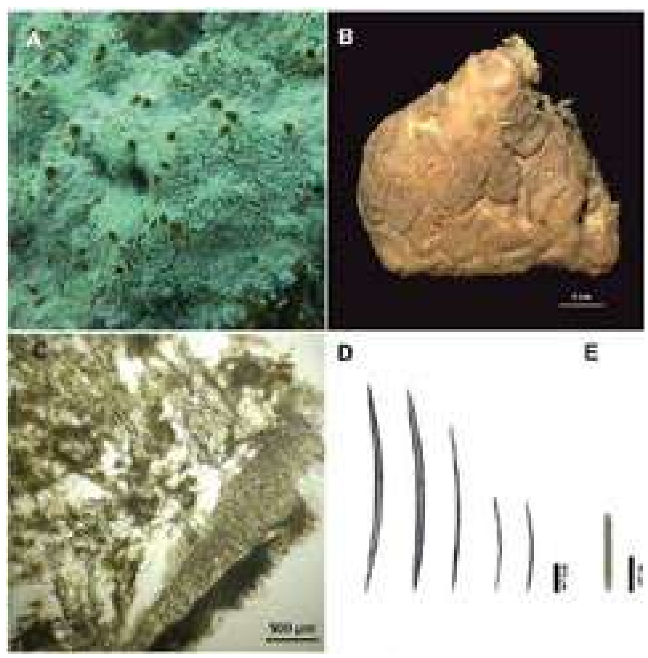

Figure 3. *Myrmekioderma granulatum* (Esper, 1794): A. *In situ* photograph, B. Preserved specimen, C. Tangential section, D. Oxeas, E. Trichodragmata

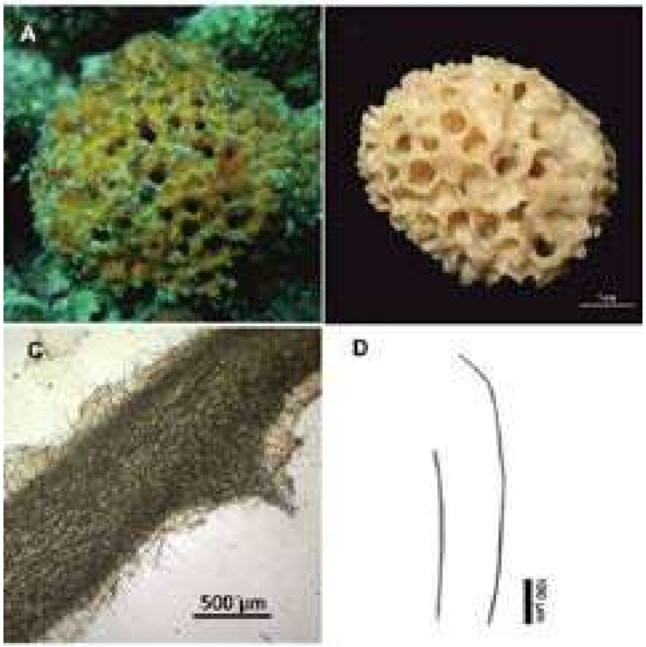

Figure 4. ***Acanthella cavernosa*** **Dendy, 1922: A.** ***In situ*** **photograph, B. Preserved specimen, C. Transverse section, D. Spicules**

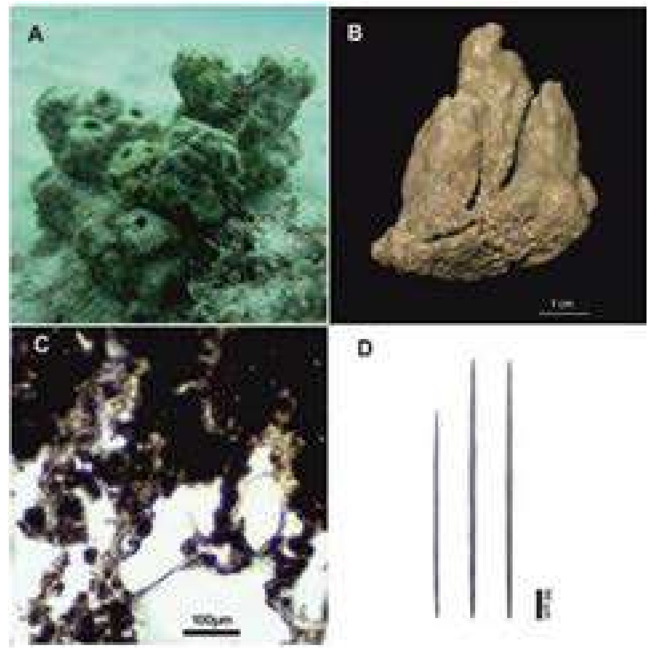

Figure 5. ***Liosina paradoxa*** **Thiele, 1899: A.** ***In situ*** **photograph, B. Preserved specimen, C. Tangential section through ectosome and choanosome, D. Oxeas**

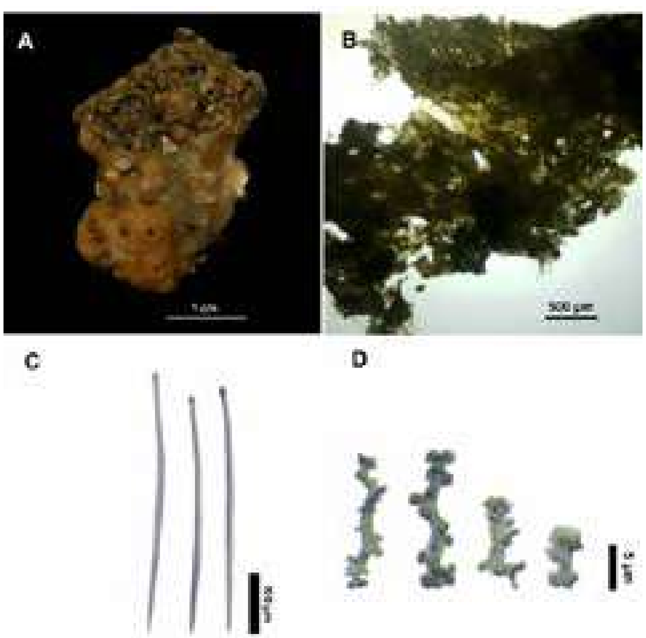

Figure 6. ***Spheciospongia vagabunda*** **Ridley, 1884: A. Preserved specimen, B. Tangential section, C. Tylostyles, D. Spinispire.**

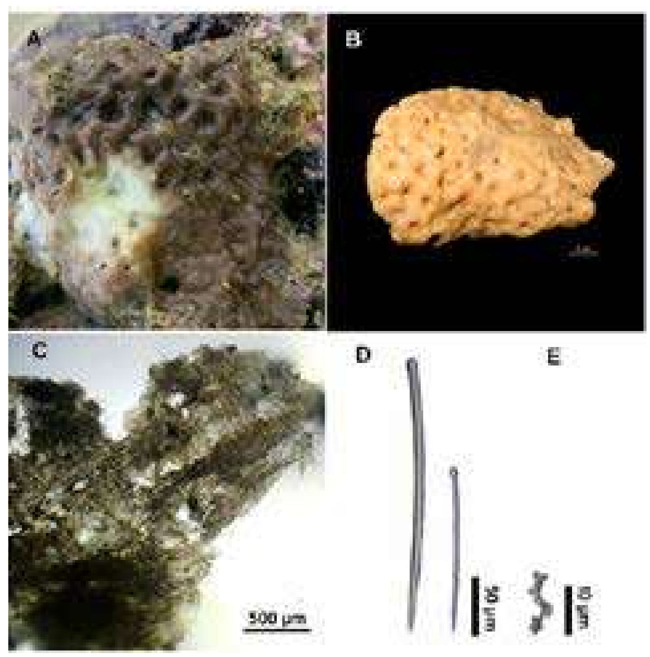

Figure 7. ***Spheciospongia inconstans*** **var.** ***meandrina*** **(Dendy, 1887): A.** ***In situ*** **photograph, B. Preserved specimen, C. Tangential section, D. Tylostyles, E. Spiraster.**

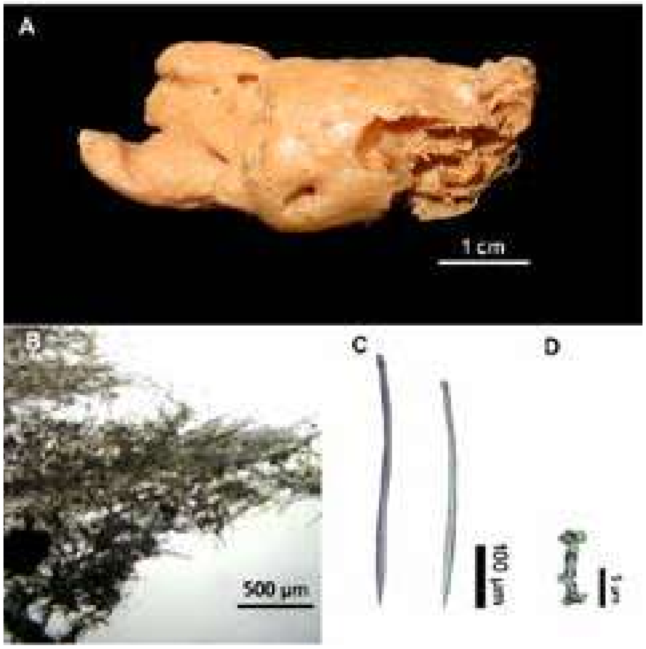

Figure 8. ***Speciospongia inconstans*** **var.** ***digitata*** **(Dendy, 1887): A. Preserved specimen, B. Tangential section, C. Tylostyles, D. Spiraster.**

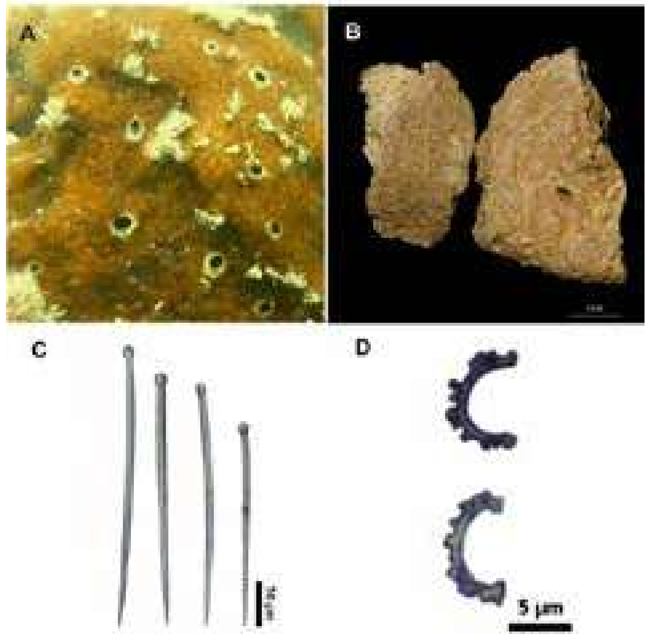

Figure 9. ***Cliona orientalis*** **Thiele, 1900: A.** ***In situ*** **photograph, B. Preserved specimen, C. Tylostyles, D. Spirasters.**

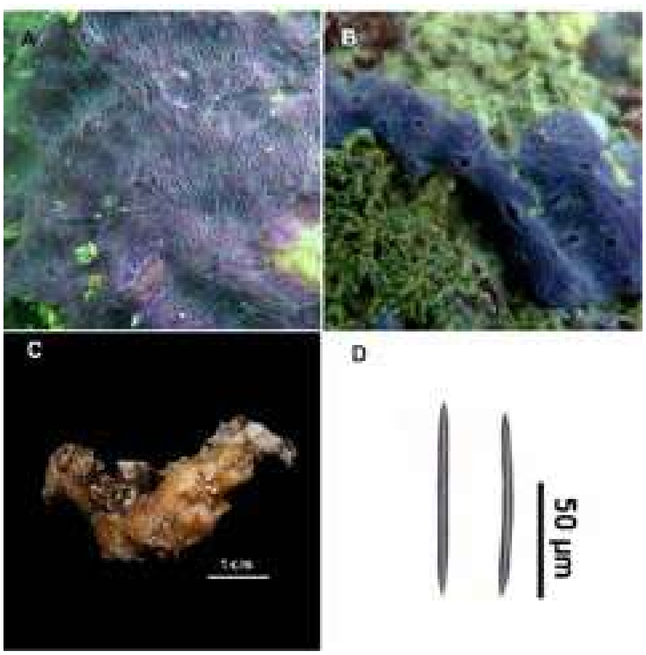

Figure 10. ***Chalinula nematifera*** **(de Laubenfels, 1954): A, B.** ***In situ*** **photographs, C. Preserved specimen, D. Oxeas.**

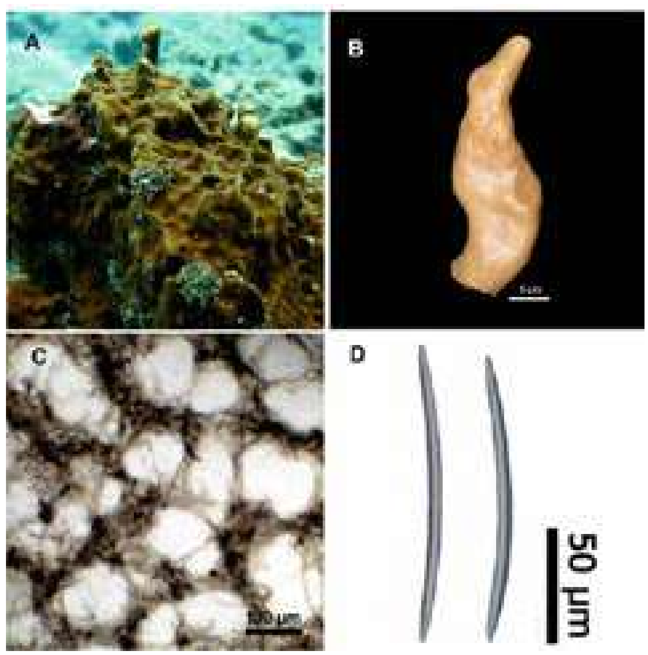

Figure 11. ***Neopetrosia chaliniformis*** **(Thiele, 1899): A.** ***In situ*** **photograph, B. Preserved specimen, C. Tangential section, D. Oxeas.**

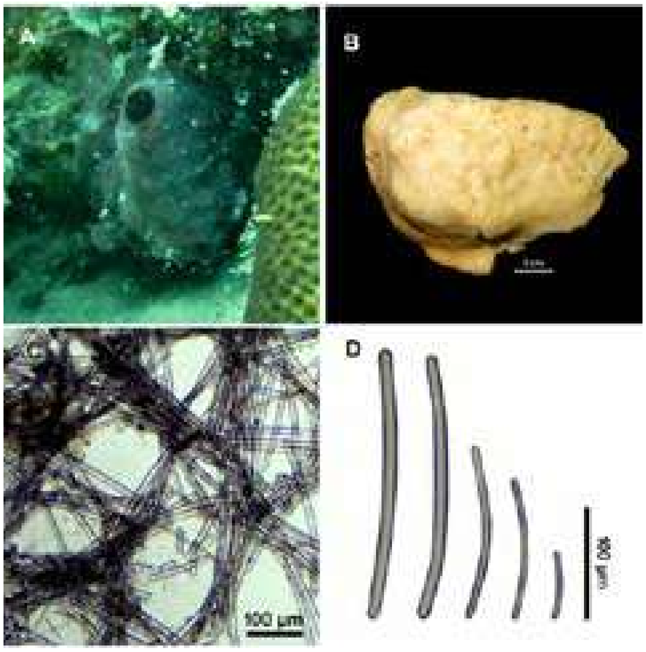

Figure 12. ***Petrosia (Strongylophora) strongylata*** **Thiele, 1903: A. *In situ* photograph, B. Preserved specimen, C. Tangential section, D. Strongyles.**

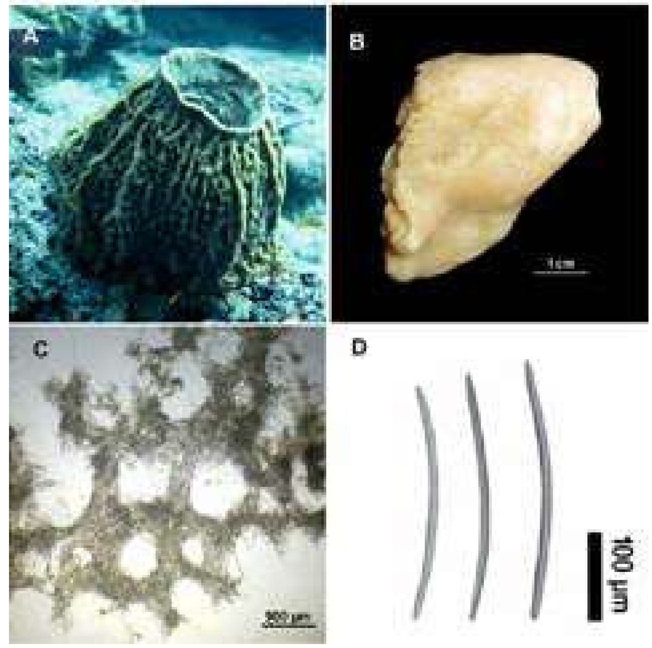

Figure 13. *Xestospongia testudinaria* (Lamarck, 1815): A. *In situ* photograph, B. Preserved specimen, C. Tangential section, D. Oxeas.

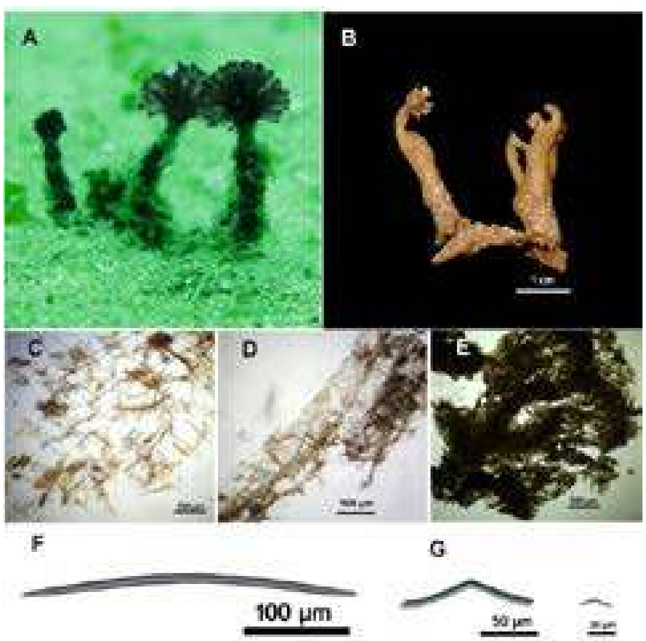

Figure 14. *Oceanapia sagittaria* (Sollas, 1902): A. *In situ* photograph, B. Preserved specimen, C. Traverse section through the fistula, D. Tangential section through the fistula, E. Tangential section through the base, F. Oxea, G. Toxas.

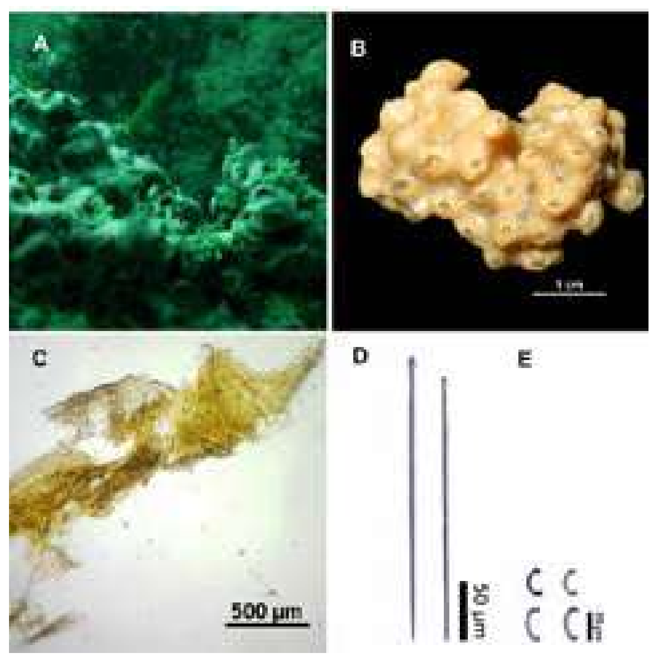

Figure 15. *Monanchora unguiculata* (Dendy, 1922): A. *In situ* photograph, B. Preserved specimen, C. Tangential section, D. Oxeas, E. Strongly curved isochelae.

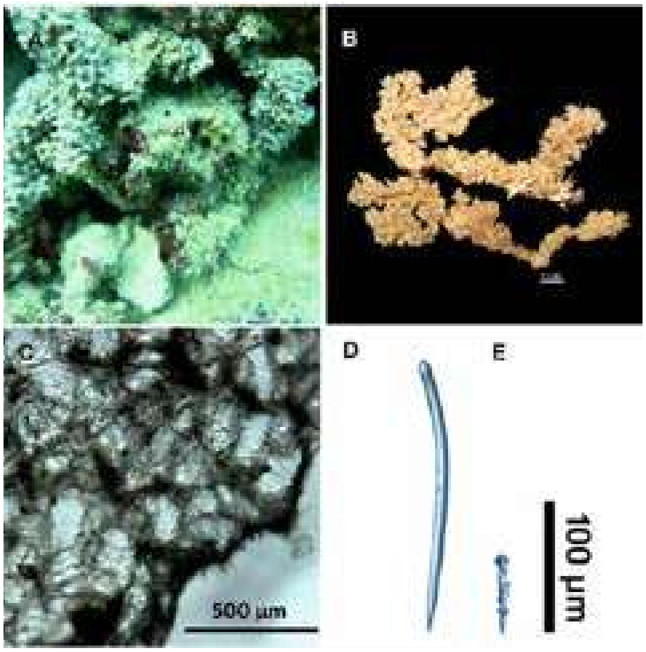

Figure 16. ***Clathria (Thalysias) vulpina*** **(Lamarck, 1814): A.** ***In situ*** **photograph, B. Preserved specimen, C. Tangential section, D. Style, E. Echinating style.**

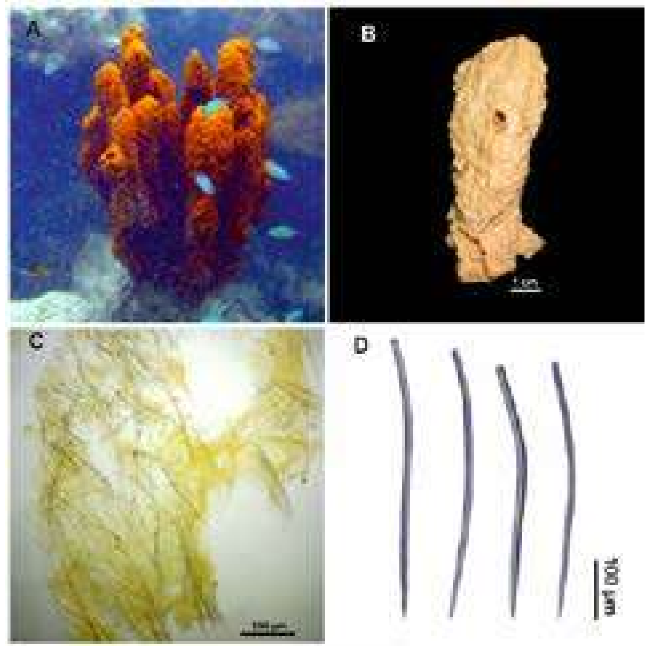

Figure 17. ***Stylissa massa*** **(Carter, 1887): A.** ***In situ*** **photograph, B. Preserved specimen, C. Tangential section, D. Styles.**

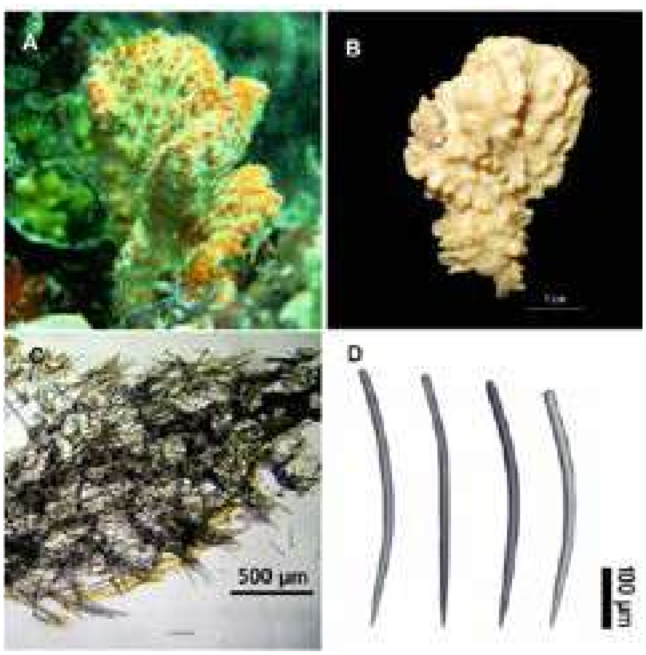

Figure 18. ***Stylissa carteri*** **(Dendy, 1889): A.** ***In situ*** **photograph, B. Preserved specimen, C. Tangential section, D. Styles.**

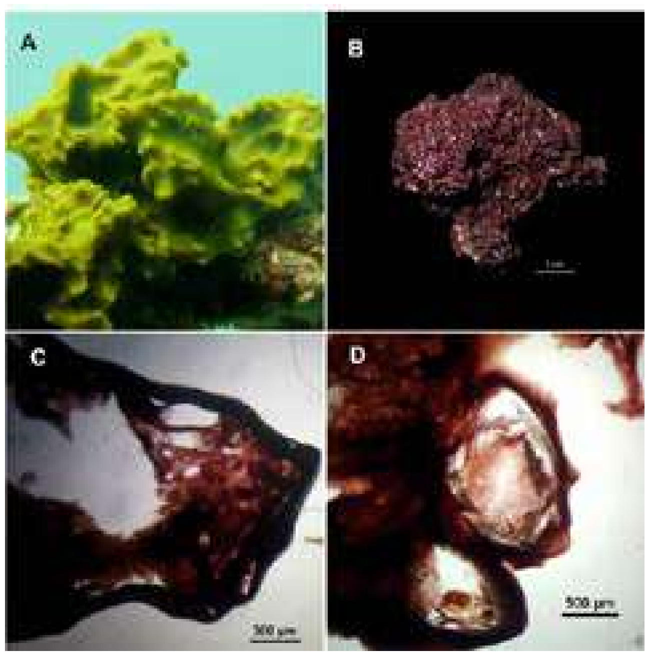

Figure 19. ***Pseudoceratina purpurea*** **(Carter, 1880): A.** ***In situ*** **photograph, B. Preserved specimen, C. & D. Tangential section showing the pigmented fibres.**

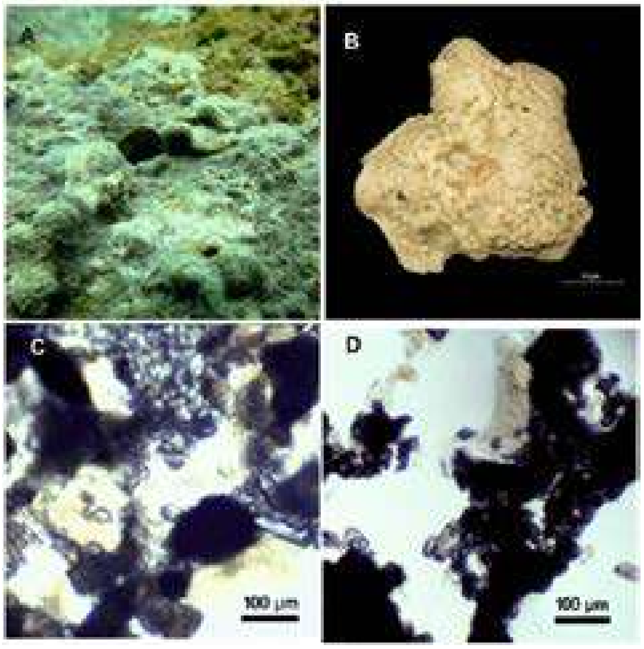

Figure 20. ***Lamellodysidea herbacea*** **(Keller, 1889): A. *In situ* photograph, B. Preserved specimen, C & D. Tangential section.**

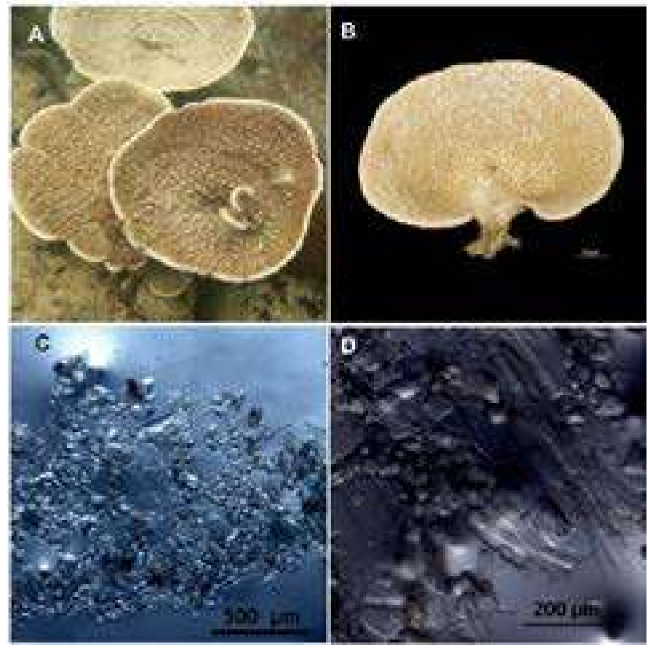

Figure 21. ***Phyllospongia foliascens*** **(Pallas, 1766): A. *In situ* photograph, B. Preserved specimen, C. Tangential section, D. Closeup of skeletal arrangement.**

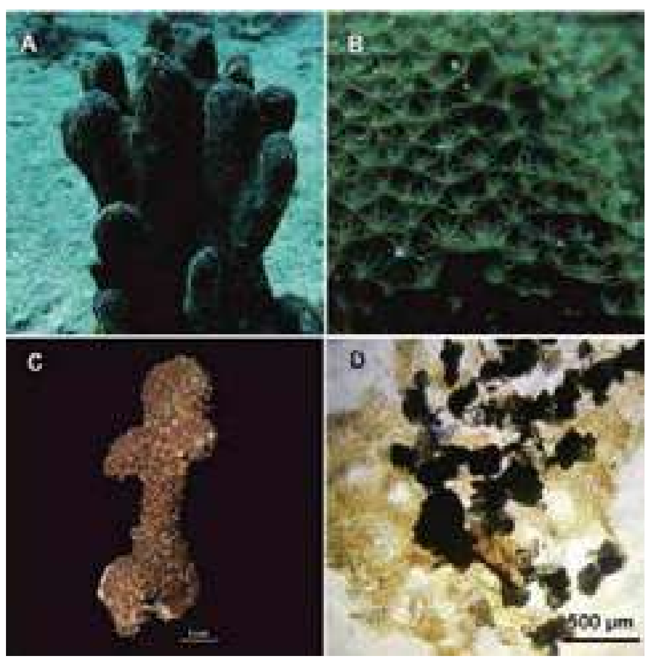

Figure 22. ***Hyrtios erectus*** **(Keller, 1889): A. *In situ* photograph, B. Close-up of the colony showing conules, C. Preserved specimen, D. Tangential section.**

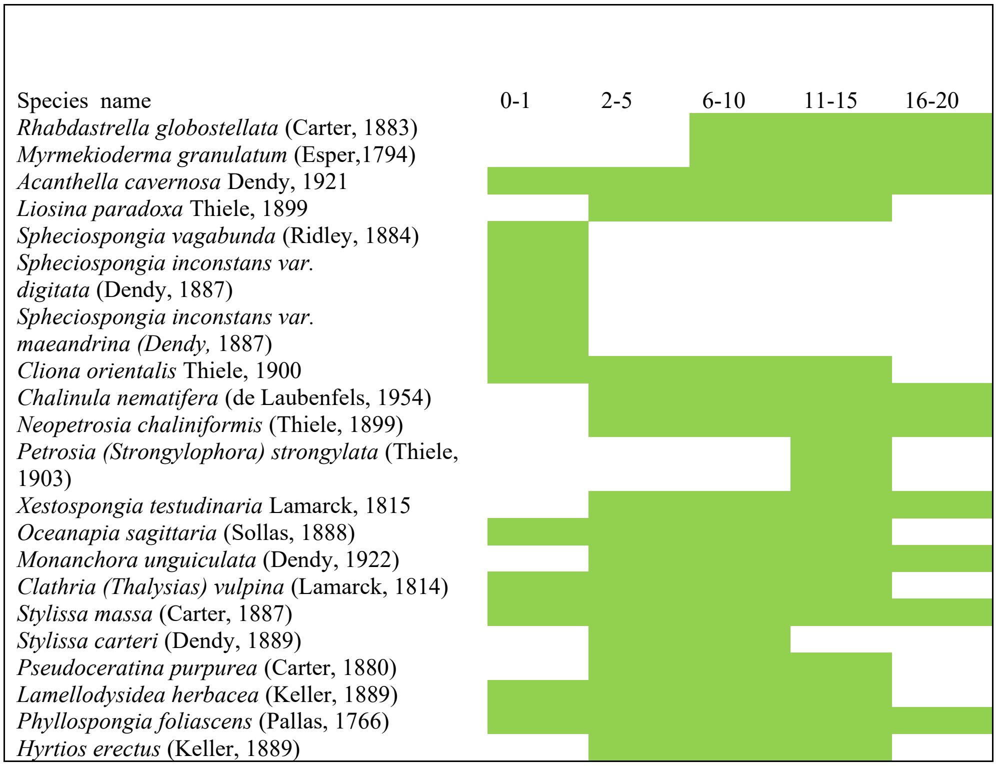

Figure 23. Depth-wise distribution of sponges

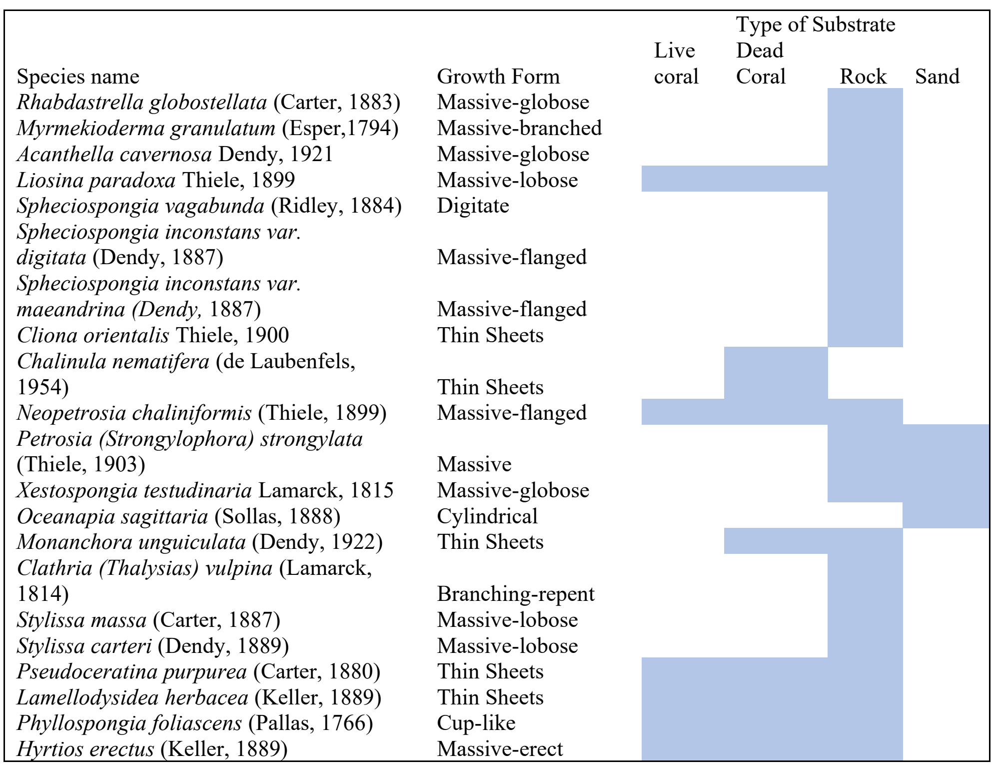

Figure 24. Substrate specificity of sponges

Acknowledgements

The authors are grateful to the Director, Zoological Survey of India, Kolkata and the Officer-in-Charge, Andaman and Nicobar Regional Centre of Zoological Survey of India, Port Blair for the facilities. The Department of Environment and Forest, Andaman and Nicobar Administration is gratefully acknowledged for the logistics. The first author would also like to thank M.P. Goutham-Bharathi and Dr. Seepana Rajendra for their assistance during the field study.

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ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Zoogeographic affinities of Silverfishes (Zygentoma: Lepismatidae) of India

Debanjan Jana and Ashis Kumar Hazra*

Zoological Survey of India, M Block, New Alipore
Kolkata-700053, India

Abstract

The poorly known Indian fauna of Zygentoma of the family Lepismatidae is presently represented by seventeen species. All these species are known to occur from fourteen States and two Union Territories of India. Available data indicates that absence of records of the family Lepismatidae in almost half of the states. Data concerning the species like *Acrotelsa collaris*, *Ctenolepisma (Ctenolepisma) longicaudatum, Lepisma saccharina, Thermobia domestica* are referred only to cosmopolitan synanthrops, therefore without any zoogeographic interest. The Lepismatidae, excluding those species, which are distributed from one country to other due to anthropogenic activities have lost all their zoogeographical weight. The genus *Lepidospora* with two species and *Ctenolepisma alticola* these are only known to occur from north-western states. However, the genus *Ctenolepisma* presents along Africa, Palearctic and Oriental Asia, Mediterranean Europe Australia and Central northern South America. *Afrolepisma* and *Xenolepisma* show a clear Afro-Indian distribution. The genus *Xenolepisma* being exclusive from Cape Province of South Africa and from India are discussed.

Keywords: Zygentoma*, Ctenolepisma,* Lepismatidae, Zoogeographic affinities, Indian fauna

Introduction

The order Zygentoma (commonly known as Silverfish) comprises of one of the earliest insects, are considered to be the sister group of the winged insects (Blanke *et al.*, 2014). The poorly known Indian fauna of Zygentoma under the family Lepismatidae is presently represented by seventeen species from which nine belongs to genus *Ctenolepisma*, two of *Acrotelsella* and one each of *Acrotelsa, Afrolepisma, Lepisma, Tricholepisma, Xenolepisma* & *Thermobia* (Fabricius, 1793; Hazra, Jana & Smith, 2022; Hazra, 1980, Silvestri, 1913, 1935, 1938; Hazra, Jana & Mandal, 2022; Paclt, 1961; Escherich, 1905; Oudemans, 1890; Hazra, Biswas & Mitra, 2000; Hazra, Jana, Mandal & Molero-Baltanás, 2022; Linnaeus, 1758; Packerd, 1873; Hazra, Jana, Mandal & Molero-Baltanás, 2023 in press).

Materials and Methods

Data from various materials was used including National Zoological specimens of Apterygota section, Zoological Survey of India, Kolkata and individuals collected by the authors during collecting survey trips in various localities of Indian states. from 2019 to 2021. The data as a whole were used to map the presence/absence of Lepismatidae species in Indian states. The species recoded only from India, and that therefore appear to be endemic, were considered to have undetermined affinities.

Results

The known taxa present in India has been summarized in Table 1. All these species are known to occur from fourteen states and two union territories of India and the table clearly shows the absence of records in almost half of the states in India. In this table, *Acrotelsa collaris* (Fabricius) Escherich, 1905, *Ctenolepisma (Ctenolepisma) longicaudatum* Escherich, 1905, *Lepisma saccharina* Linnaeus, 1758 and *Thermobia domestica* (Packerd) Bergroth, 1890 ascribed with a 'C', belonging to cosmopolitan synanthropous species with no zoogeographic interest due to anthropogenic

*Author for correspondence : dr.ashishazra@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

activities. Moreover, rest of the species ascribed with an 'E', are endemic to Indian fauna. Map 1 comprises of the known geographical distribution of the Zygentoma species in India. The Zoogeographical relationship of Zygentoma species of India is shown in Table 2, which clearly indicates that most of the species are endemic to India, except *Acrotelsa collaris, Ctenolepisma (Ctenolepisma) longicaudatum, Lepisma saccharina* and *Thermobia domestica***.**

Discussion

The Lepismatidae, excluding those species which anthropophily removes all their zoogeographical weight, *Ctenolepisma alticola* known to occur from the north-western state, the genus *Ctenolepisma* presents a wide geographical range along Africa, Palaearctic and oriental Asia. Mediterranean Europe, Australasia and central and northern South America, *Afrolepisma* & *Xenolepisma* show a clear Afro-Indian distribution, the *Xenolepisma* being exclusive from the Cape Province of Southern Africa and from India. *Afrolepisma* with a number of described species in the Afrotropical region, suggest that the only Indian known species will be no more than an Oriental extension of the genus (Mendes, 1988).

In conclusion to this preliminary approach, we can suggest, with little number of data available that:

i. *Afrolepisma* (Map 2) & *Xenolepisma* (Map 3) actually known distribution seem to point to their very ancient origin, almost certainly before the breakup of the Afro-Indian tectonic plate; this means that they would be already individualized before the late Jurassic (Smith & Briden, 1979).

ii. As the collision of the Indian & Eurasian plates must have occurred some 45 -35 million years ago (Eocenic time) which resulted in the Himalayas lift up (Smith *et al.* 1981).

Legends to the Tables and Maps

Table 1. (1) Packard, 1873; (2) Oudemans, 1890; (3) Silvestri, 1913; (4) Silvestri, 1935; (5) Silvestri, 1938; (6) Wygodzinsky, 1954; (7) Paclt, 1961; (8) Hazra, 1980; (9) Hazra, 1993; (10) Hazra, Mitra & Biswas, 2000; (11) Hazra, Biswas & Mitra, 2004; (12) Hazra, Biswas, Kumar & Mandal, 2004; (13) Hazra, Mandal & Kumar, 2007; (14) Hazra & Mandal, 2010; (15) Hazra, Mandal & Kumar, 2012; (16) Hazra, Jana & Mandal, 2020; (17) Hazra, Jana, Mandal & Molero-Baltanás, 2022; (18) Hazra, Jana & Mandal, 2022; (19) Hazra, Jana & Smith, 2022; (20) Hazra, Jana, Mandal & Molero-Baltanás, 2023. [C=Cosmopolitan, E=Endemic]

Table 2. Distribution of species occurring in different Zoogeographical realms.

Map 1: Known geographical distribution of the Zygentoma species in India.

A. *Acrotelsa collaris*; B. *Acrotelsella jhargramensis*; C. *Acrotelsella wygodzinskyi*; D. *Afrolepisma nigrina*; E. *Ctenolepisma (C.) alticola*; F. *Ctenolepisma (C.) amrabadense*; G. *Ctenolepisma (C.) boettgerianum*; H. *Ctenolepisma (C.) kawalense*; I. *Ctenolepisma (C.) longicaudatum*; J. *Ctenolepisma (C.) nigrum*; K. *Ctenolepisma (C.) tripurense*; L. *Ctenolepisma (C.) udumalpetense*; M. *Ctenolepisma (C.) venkataramani*; N. *Lepisma saccharina*; O. *Tricholepisma gravelyi*; P. *Xenolepisma subnigrina*; Q. *Thermobia domestica*.

Map 2: Distribution of genus *Afrolepisma* (Adapted from Mendes, 1989)

Map 3: Distribution of genus *Xenolepisma* (Adapted from Mendes, 1989)

Table 1. (1) Packard, 1873; (2) Oudemans, 1890; (3) Silvestri, 1913; (4) Silvestri, 1935; (5) Silvestri, 1938; (6) Wygodzinsky, 1954; (7) Paclt, 1961; (8) Hazra, 1980; (9) Hazra, 1993; (10) Hazra, Mitra & Biswas, 2000; (11) Hazra, Biswas & Mitra, 2004; (12) Hazra, Biswas, Kumar & Mandal, 2004; (13) Hazra, Mandal & Kumar, 2007; (14) Hazra & Mandal, 2010; (15) Hazra, Mandal & Kumar, 2012; (16) Hazra, Jana & Mandal, 2020; (17) Hazra, Jana, Mandal & Molero-Baltanás, 2022; (18) Hazra, Jana & Mandal, 2022; (19) Hazra, Jana & Smith, 2022; (20) Hazra, Jana, Mandal & Molero-Baltanás, 2023. [C=Cosmopolitan, E=Endemic]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
	Acrotelsa collaris	***Acrotelsella jhargramensis***	***Acrotelsella wygodzinskyi***	***Afrolepisma nigrina***	***Ctenolepisma (C.) alticola***	***Ctenolepisma (C.) amrabadense***	***Ctenolepisma (C.) boettgerianum***	***Ctenolepisma (C.) kawalense***	***Ctenolepisma (C.) longicaudatum***	***Ctenolepisma (C.) nigrum***	***Ctenolepisma (C.) tripurense***	***Ctenolepisma (C.) udumalpetense***	***Ctenolepisma (C.) venkataramani***	***Lepisma saccharina***	***Tricholepisma gravelyi***	***Xenolepisma submigrina***	***Thermobia domestica***
	C	E	E	E	E	E	E	E	C	E	E	E	E	C	E	E	C
Jammu & Kashmir	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ladakh	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Himachal Pradesh	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-
Punjab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haryana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uttarakhand	14	-	-	-	-	-	-	-	14	-	-	-	-	14	-	-	-
Rajasthan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uttar Pradesh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bihar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sikkim	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
West Bengal	18	19	8	-	-	-	-	-	9	2	-	-	-	-	3	-	-
Arunachal Pradesh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nagaland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manipur	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-
Meghalaya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mizoram	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tripura	-	-	-	-	-	-	-	-	10	-	10	-	-	-	-	-	-
Gujarat	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
Madhya Pradesh	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
Jharkhand	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
Chhattisgarh	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
Odisha	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Maharashtra	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-
Telangana	-	-	-	-	-	18	-	20	-	-	-	-	-	-	-	-	-
Karnataka	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Andhra Pradesh	13								13				17	13	-	-	-
Goa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tamil Nadu	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	5	1
Kerala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andaman & Nicobar Islands	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-
Puducherry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Delhi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chandigarh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lakshadweep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dadra Nagar Haveli & Daman Diu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Distribution of species occurring in different Zoogeographical realms.

	Name of the Species	Zoogeographical realms							
		India	**Oriental**	**Palaearctic**	**Ethiopian**	**Australian**	**Neotropical**	**Nearctic**	
1	***Acrotelsa collaris***	+	+	+	+	+	+	+	
2	***Acrotelsella jhargramensis***	+	-	-	-	-	-	-	
3	***Acrotelsella wygodzinskyi***	+	-	-	-	-	-	-	
4	***Afrolepisma nigrina***	+	-	-	+	-	-	-	
5	***Ctenolepisma (C.) alticola***	+	-	-	-	-	-	-	
6	***Ctenolepisma (C.) amrabadense***	+	-	-	-	-	-	-	
7	***Ctenolepisma (C.) boettgerianum***	+	-	-	-	-	-	-	
8	***Ctenolepisma (C.) kawalense***	+	-	-	-	-	-	-	
9	***Ctenolepisma (C.) longicaudatum***	+	+	-	+	+	+	+	
10	***Ctenolepisma (C.) nigrum***	+	+	-	-	-	-	-	
11	***Ctenolepisma (C.) tripurense***	+	-	-	-	-	-	-	
12	***Ctenolepisma (C.) udumalpetense***	+	-	-	-	-	-	-	
13	***Ctenolepisma (C.) venkataramani***	+	-	-	-	-	-	-	
14	***Lepisma saccharina***	+	+	+	+	+	+	+	
15	***Tricholepisma gravelyi***	+	-	-	-	-	-	-	
16	***Xenolepisma subnigrina***	+	-	-	+	-	-	-	
17	***Thermobia domestica***	+	+	+	-	+	+	+	

Map 1: Known geographical distribution of the Zygentoma species in India.

A. *Acrotelsa collaris*; B. *Acrotelsella jhargramensis*; C. *Acrotelsella wygodzinskyi*; D. *Afrolepisma nigrina*; E. *Ctenolepisma (C.) alticola*; F. *Ctenolepisma (C.) amrabadense*; G. *Ctenolepisma (C.) boettgerianum*; H. *Ctenolepisma (C.) kawalense*; I. *Ctenolepisma (C.) longicaudatum*; J. *Ctenolepisma (C.) nigrum*; K. *Ctenolepisma (C.) tripurense*; L. *Ctenolepisma (C.) udumalpetense*; M. *Ctenolepisma (C.) venkataramani*; N. *Lepisma saccharina*; O. *Tricholepisma gravelyi*; P. *Xenolepisma subnigrina*; Q. *Thermobia domestica*.

Map 2: Distribution of genus *Afrolepisma* (Adapted from Mendes, 1989)

Map 3: Distribution of genus *Xenolepisma* (Adapted from Mendes, 1989)

Acknowledgement

The authors express their sincere thanks to MOEF & CC, Govt. of India, New Delhi for funding the project under AICOPTAX scheme on Zygentoma to the senior author. Our thanks are due to Dr. Dhriti Banerjee Director, Zoological Survey of India, Kolkata for providing the laboratory facilities. Thanks are also due to Dr. G. P. Mandal, Scientist-E and in-charge, Apterygota section, ZSI, Kolkata, for assisting the two Indian authors in various way and to Mr. K.K. Suman, Senior Zoological Assistant and Mr. Kaushik Bhattacharya, Senior Zoological Assistant, Apterygota section, ZSI, Kolkata for their constant help as and when required. Finally yet importantly, the authors are thankful to Principal, Vidyasagar College under the University of Calcutta, for providing the laboratory facilities as and when required.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Species Diversity of Phytophagous Scarab Fauna (Coleoptera: Scarabaeidae) in Western Ghats of Kerala, India

Judith Corolin Correya and Kolla Sreedevi*

Department of Zoology, JAIN (Deemed-to-be-University), Bengaluru, Karnataka
**Division of Germplasm Collection and Characterization, ICAR-National Bureau of Agricultural Insect Resources, Hebbal, Bengaluru, 560024, Karnataka*

Abstract

Surveys were carried out during March to August months of 2021 and 2022 to document the species diversity of phytophagous scarabs in selected locations of four districts of Kerala viz., Wayanad, Malappuram, Palakkad and Idukki, which cover rich biodiversity hotspots in the Western Ghats. The explorations yielded 1953 specimens belonging to 60 species under 18 genera of subfamilies Melolonthinae, Rutelinae and Dynastinae, of which Melolonthinae is the most speciose representing 11 genera. Various diversity indices revealed variations in species diversity in terms of species richness and evenness among the surveyed locations. Six species *viz.*, *Anomalachela bicolor* (Brenske, 1892), *Sophrops karschi* (Brenske, 1892), *Apogonia proxima* Waterhouse, 1877, *Apogonia* sp.1, *Maladera rufocuprea* (Blanchard, 1850) and *Anomala communis* (Burmeister, 1844) were found to be common in all the four surveyed districts while ten species each were observed to be specific to Palakkad and Idukki districts. The species distribution and dynamics across the districts are discussed.

Keywords: Scarabaeidae, Species diversity, Wayanad, Malappuram, Palakkad, Idukki, Kerala

Introduction

Insects are the most abundant of all life forms on the earth. Insecta is the largest class within the phylum Arthropoda, and Subphylum Hexapoda. More than 40% of all living things and nearly 80% of all animal species in the Kingdom Animalia are insects. Out of the 10,32,000 documented species of animals on earth, it is estimated that 9,50,000 species are insects and this number is rising every year (Kumar, 2014). Order Coleoptera comprising beetles and weevils, is the largest order of Class Insecta occuring in almost all habitats and ecosystems. The diversity and abundance are mainly due to structural and physiological adaptations (Booth *et al.*, 1979). Coleoptera has four suborders, Adephaga, Polyphaga, Myxophaga and Archostemata, with Polyphaga being the largest with 144 families and 16 superfamilies. The superfamily Scarabaeoidea is divided into 12 families, 43 subfamilies, 118 tribes and 94 subtribes (Smith 2006) and is one of the largest superfamilies that include family Scarabaeidae. It is estimated that around 30, 000 species of Scarabaeids occur worldwide (Ratcliffe and Jameson, 2004), consisting of six major subfamilies: Scarabaeinae, Aphodiinae, Cetoniinae, Rutelinae, Melolonthinae, and Dynastinae. The first two of these include coprophagous (dung feeders) and are termed as Laprosticti, while the last four are phytophagous and are termed as Pleurosticti.

The Western Ghats in Indian Subcontinent is a 1,600 km long chain of mountains running parallel to India's western coast. It is one of the world's eight "biodiversity hotspots" attributed to the high levels of biodiversity and endemism. It has outstanding geological, scenic, and cultural values and has a significant impact on the peninsular India's rainfall patterns. (Bawa *et al.*, 2007). Hence, a study has been carried

*Author for correspondence : kolla.sreedevi@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

out to explore and document the diversity of phytophagous scarab fauna in the Western Ghats region of Kerala.

Methodology

A systematic study was carried out in three to four locations in four districts in the Western Ghats region of Kerala viz. Wayanad (11°27'-15°58'N, 75°47'-70°27' E) Malappuram (10°09'-12°0'N, 75°53'-77°0' E), Palakkad (10°21'-11°14'N, 76°02'-76°45'E) and Idukki (09°16'-10°21'N, 76°38'-77°24'E) at regular intervals for collection of scarabs during their emergence period from March to August, 2021 and 2022. The collection of adult scarab beetles was made through light traps with mercury vapour lamp of 160 Watt as light source and manual scouting at selected locations. The light traps were operated between 6 pm to 12 midnight and collections were made at fortnight intervals. Adult beetles attracted towards the light trap were collected into the bottles containing 95% alcohol and brought to the laboratory. The specimens were cleaned under running tap water to remove the dirt and mud and then relaxed in a relaxing chamber with several layers of wet paper towels. The specimens were sorted based on morphological characters, pinned, stretched and labelled. The male specimens were identified based on the shape of the hind tibial spurs and the genitalia was extracted, which was mounted on the point card and pinned along with the adult specimen. The specimens were then identified up to species level with the reference collection and available literature (Brenske, 1892; Arrow, 1910; 1917; Frey, 1972; Ahrens and Fabrizi, 2009 2016).

The number of species and relative abundance were calculated for each district. Species abundance and diversity analysis were carried out through diversity indices viz., Shannon-Weiner Index, Simpson dominance index (Magurran, 1988), Margalef's diversity index, Menhinick's index, Jaccard's coefficient and Pielou's evenness index.

Results and Discussion

A collection of 1953 beetle specimens resulted in 60 species belonging to 18 genera of subfamilies Melolonthinae, Rutelinae and Dynastinae. Melolonthinae represented by 11 genera is speciose and predominant over Rutelinae and Dynastinae which was represented by four and three genera, respectively. Houston and Weir (1992) reported that Melolonthinae is the largest of all the subfamilies of Scarabaeidae with nearly 800 genera comprising almost 12,000 species worldwide. The species *Anomalachela bicolor* (Brenske, 1892), *Sophrops karschi* (Brenske, 1892), *Apogonia proxima* Waterhouse, 1877, *Apogonia* sp.1, *Maladera rufocuprea* (Blanchard, 1850) and *Anomala communis* (Burmeister, 1844) were present in all the four surveyed districts. Ten species each were observed to be specific to Palakkad and Idukki districts. *Maladera keralensis* (Frey, 1972) (29.90%) and *Apogonia proxima* (26.21%) were found to be abundant which together constituted 56.11 % of the total population (Table 1). Genus *Apogonia* was found to be predominant in Wayanad, Malappuram and Palakkad districts (Fig 1-4), whereas *Sophrops karschi* was found to be the predominant species in Idukki district. The preliminary survey data subjected to various diversity indices revealed variations in species diversity in terms of species richness and evenness among the surveyed locations. Studies carried out by Suchithra Kumari and Kumar (2018) in cardamom ecosystem of Mudigere, Chikkamagaluru district, Karnataka revealed that Melolonthinae was the predominant subfamily with respect to species abundance and richness. Similarly, Aparna *et al.* (2018) has reported 34 species of phytophagous scarabs from six ecosystems of Puttur region in Dakshina Kannada during 2015, of which the subfamily Melolonthinae was speciose with 18 species.

In present investigation, the dominant genus in subfamily Melolonthinae was found to be *Maladera* represented by 13 species *viz., Maladera burmeisteri* alternans (Frey, 1975), *M. calicutensis* (Frey, 1972), *M. keralensis* (Frey, 1972), *M. magnicornis* (Moser, 1920), *M. rufocuprea* (Blanchard, 1850), *M. seriatoguttata* (Ahrens and Fabrizi, 2016), *M. vernacula* (Ahrens and Fabrizi, 2016), *M. indica* (Blanchard, 1850), *M. praviforceps* (Ahrens and Fabrizi, 2016), *Maladera nr. keralensis*, *Neoserica submaculosa (Ahrens and Fabrizi, 2016)*, *Maladera* sp.1 and *Maladera* sp.2.

Species diversity in terms of richness, evenness and abundance was calculated and compared using Shannon Wiener index, Simpson dominance index, Margalef's diversity index, Menhinick's index and Pielou's evenness. The species diversity was relatively high in Idukki district as evidenced by Shannon Wiener index (2.56), Simpson dominance index (0.88), Margalef's index and Menhinick's index (5.39 and 2.04 respectively) and Pielou's evenness (0.75). Wayanad district exhibited low diversity as indicated by Shannon-Wiener index (1.71), Simpson dominance index (0.70), Margalef's index and Menhinick's index being (3.74 and 0.75 respectively), while Pielou's evenness was 0.51 (Table 2).

The preliminary investigations revealed that the collections made from a few locations of Western Ghats region of Kerala resulted in 60 species belonging to subfamilies Melolonthinae, Rutelinae and Dynastinae. Among the surveyed locations, Idukki exhibited high species diversity in terms of species richness and evenness while Wayanad exhibited low diversity. More exploratory surveys need to be made to further document and interpret the scarab species diversity in these regions of Kerala.

Table 1. Species composition of Phytophagous scarab in Western Ghats of Kerala

Sl. No.	Name of the species	Wayanad		Malappuram		Palakkad		Idukki	
		Total	Relative abundance (%)	Total	Relative abundance (%)	Total	Relative abundance (%)	Total	Relative abundance (%)
1.	*Holotrichia serrata*	1	0.07	5	3.78	-	-	2	0.93
2.	*Holotrichia sculpticollis*	78	5.72	2	1.51	-	-	4	1.86
3.	*Holotrichia fissa*	-	-	1	0.75	39	15.98	11	5.11
4.	*Holotrichia* sp. 1	-	-	-	-	-	-	1	0.46
5.	*Holotrichia* sp. 2	-	-	-	-	-	-	3	1.39
6.	*Holotrichia* sp. 3	-	-	-	-	-	-	1	0.46
7.	*Holotrichia* sp. 4	-	-	-	-	-	-	1	0.46
8.	*Holotrichia* sp. 5	-	-	-	-	1	0.40	-	-
9.	*Holotrichia* sp. 6	3	0.22	-	-	-	-	-	-
10.	*Holotrichia* sp. 7	1	0.07	-	-	-	-	-	-
11.	*Anomalachela bicolor*	33	2.42	2	1.51	4	1.63	22	10.23
12.	*Brahmina mysorensis*	-	-	-	-	18	7.37	-	-
13.	*Miridiba excisa*	6	0.44	-	-	1	0.40	-	-
14.	*Luecopholis burmeisteri*	1	0.07	2	1.51	-	-	-	-
15.	*Sophrops karschi*	17	1.24	6	4.54	9	3.68	53	24.65
16.	*Sophrops* sp.1	-	-	-	-	-	-	5	2.32
17.	*Sophrops* sp.2	-	-	-	-	-	-	1	0.46
18.	*Apogonia proxima*	434	31.86	52	39.39	25	10.24	1	0.46
19.	*Apogonia* sp.1	50	3.67	11	8.33	46	18.85	6	2.79
20.	*Apogonia* sp.2	-	-	10	7.57	3	1.22	7	3.25
21.	*Apogonia* sp.3	-	-	-	-	1	0.40	-	-
22.	*Schizonycha fuscescens*	-	-	-	-	39	15.98	-	-
23.	*Schizonycha ruficollis*	-	-	1	0.75	-	-	-	-

Sl. No.	Name of the species	Wayanad		Malappuram		Palakkad		Idukki	
		Total	Relative abundance (%)	Total	Relative abundance (%)	Total	Relative abundance (%)	Total	Relative abundance (%)
24.	*Maladera keralensis*	582	42.73	-	-	-	-	2	0.93
25.	*Maladera burmeisteri*	6	0.44	-	-	-	-	5	2.32
26.	*Maladera magnicornis*	1	0.07	-	-	-	-	-	-
27.	*Maladera vernacula*	5	0.36	-	-	-	-	1	0.46
28.	*Maladera rufocuprea*	5	0.36	3	2.27	7	2.86	1	0.46
29.	*Maladera calicutensis*	-	-	1	0.75	-	-	-	-
30.	*Maladera indica*	-	-	6	4.54	-	-	1	0.46
31.	*Maladera praviforceps*	-	-	2	1.51	-	-	-	-
32.	*Maladera* nr. *keralensis*	-	-	-	-	-	-	1	0.46
33.	*Maladera seriattoguttata*	-	-	-	-	-	-	1	0.46
34.	*Neoserica submaculosa*	-	-	-	-	-	-	1	0.46
35.	*Neoserica granigera*	-	-	-	-	1	0.40	6	2.79
36.	*Tetraserica* sp.	1	0.07	-	-	-	-	-	-
37.	*Maladera* sp. 1	8	0.58	-	-	-	-	-	-
38.	*Maladera* sp. 2	-	-	-	-	1	0.40	-	-
39.	*Adoretus mus*	-	-	-	-	1	0.40	-	-
40.	*Adoretus* nr. *nitidus*	-	-	-	-	16	6.55	-	-
41.	*Adoretus bicaudatus*	-	-	-	-	1	0.40	-	-
42.	*Adoretus* sp	-	-	5	3.78	1	0.40	1	0.46
43.	*Adoretus* sp.1	6	0.44	-	-	-	-	-	-
44.	*Adoretus* sp.2	22	1.61	-	-	1	0.40	-	-
45.	*Adoretus* sp. 3	-	-	2	1.51	1	0.40	-	-
46.	*Adoretus* sp. 4	-	-	-	-	2	0.81	-	-
47.	*Adoretus versutus*	23	1.68	-	-	16	6.55	-	-
48.	*Anomala communis*	11	0.80	3	2.27	3	1.22	35	16.27
49.	*Anomala varicolor*	1	0.07	-	-	-	-	27	12.55
50.	*Anomala elata*	5	0.36	-	-	-	-	3	1.39
51.	*Anomala ruficapilla*	5	0.36	2	1.51	-	-	1	0.46

Sl. No.	Name of the species	Wayanad		Malappuram		Palakkad		Idukki	
		To-tal	Relative abun-dance (%)	To-tal	Relative abun-dance (%)	To-tal	Relative abun-dance (%)	Total	Relative abun-dance (%)
52.	*Anomala dussumieri*	9	0.66	6	4.54	-	-	-	-
53.	*Anomala* sp. 1	-	-	-	-	2	0.81	4	1.86
54.	*Anomala* sp. 2	-	-	4	3.03	-	-	-	-
55.	*Anomala* sp. 3	-	-	-	-	1	0.40	-	-
56	*Popillia* sp.	1	0.07	-	-	2	0.81	-	-
57.	*Mimela xanthorhina*	46	3.37	2	1.51	-	-	-	-
58.	*Deplicus bidens*	-	-	1	0.84	1	0.40	-	-
59.	*Xylotrupes gideon*	-	-	-	-	-	-	7	3.25
60.	*Heteronychus* sp.	1	0.07	3	2.27	1	0.40	-	-
	TOTAL	**1362**		**132**		**244**		**215**	

Table 2. Diversity indices of Phytophagous scarab in Western Ghats of Kerala

Diversity indices	Wayanad	Malappuram	Palakkad	Idukki
Total number of individuals (N)	1362	132	244	215
Number of species (S)	28	23	28	30
Shannon-Weiner index (H)	1.71	2.54	2.49	2.56
Simpson dominance index (D)	0.70	0.82	0.88	0.88
Evenness (J)	0.51	0.81	0.74	0.75
Margalef's' s index	3.74	4.50	4.91	5.39
Menhinick's index	0.75	2.00	1.79	2.04

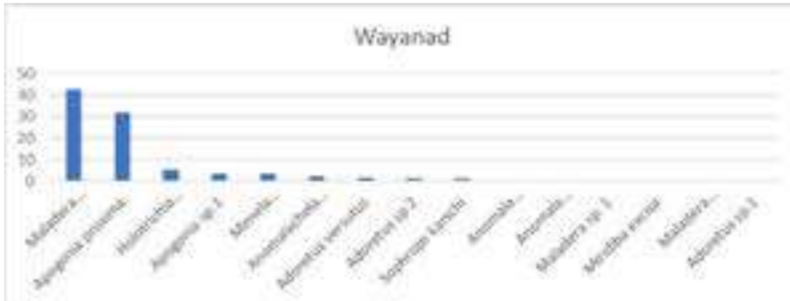


Fig. 1

Fig. 2

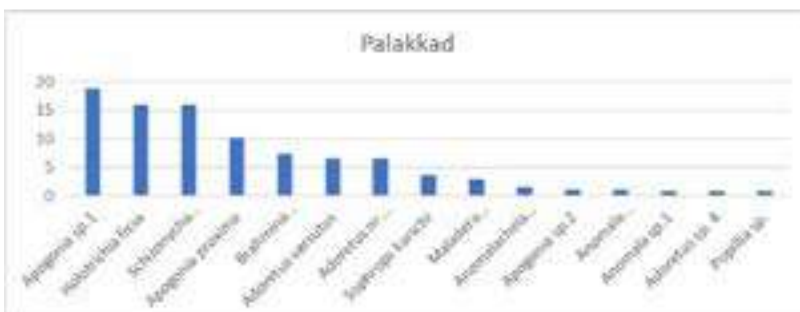


Fig. 3

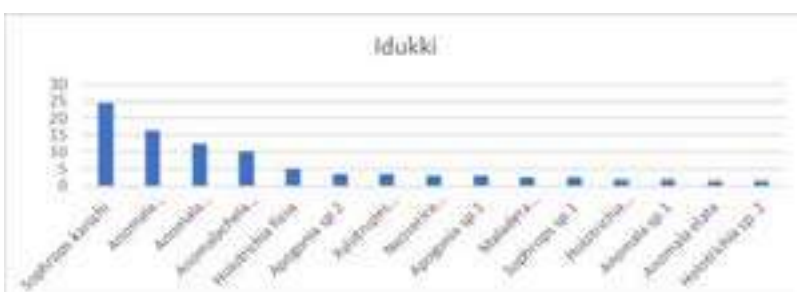
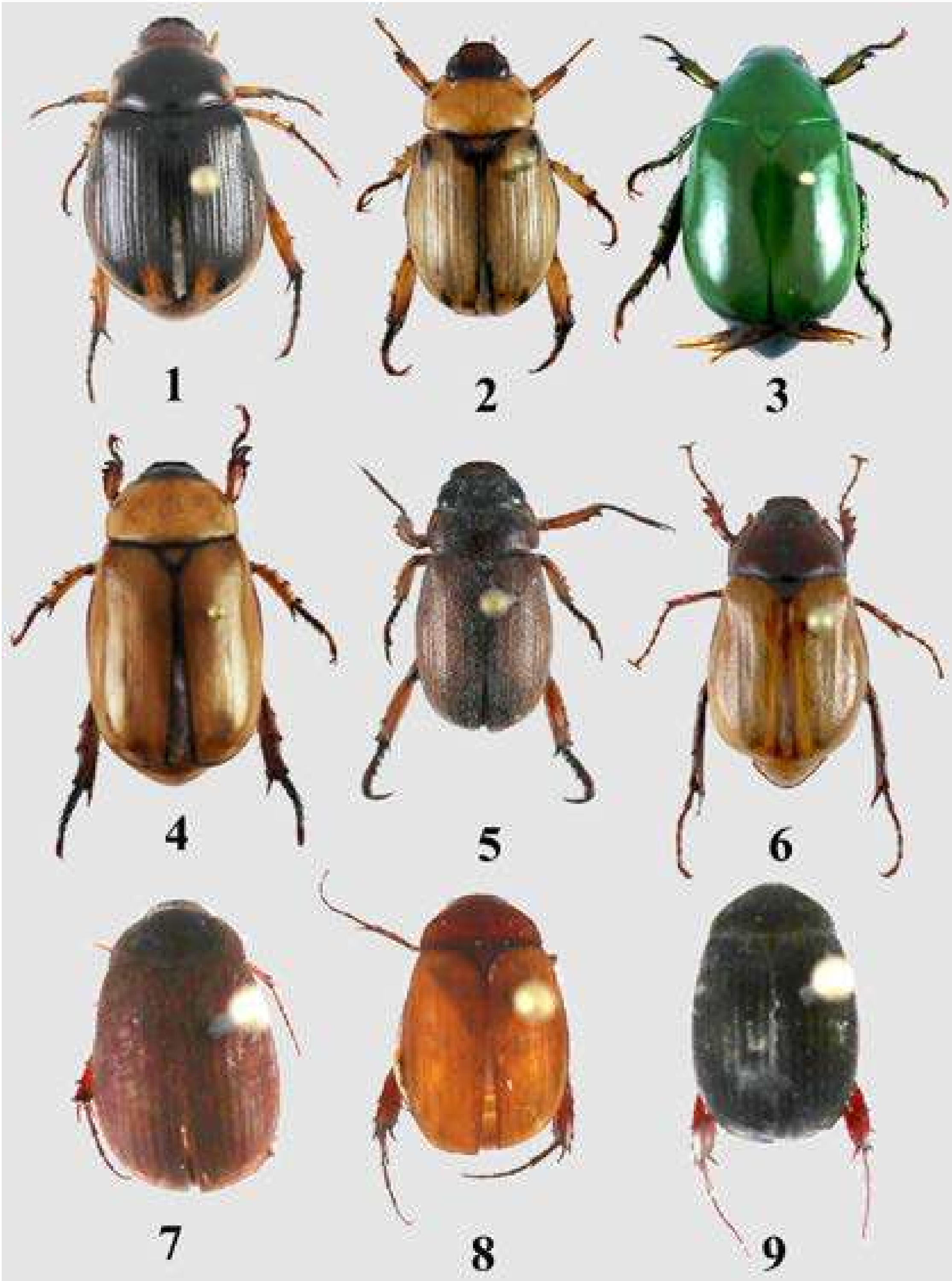
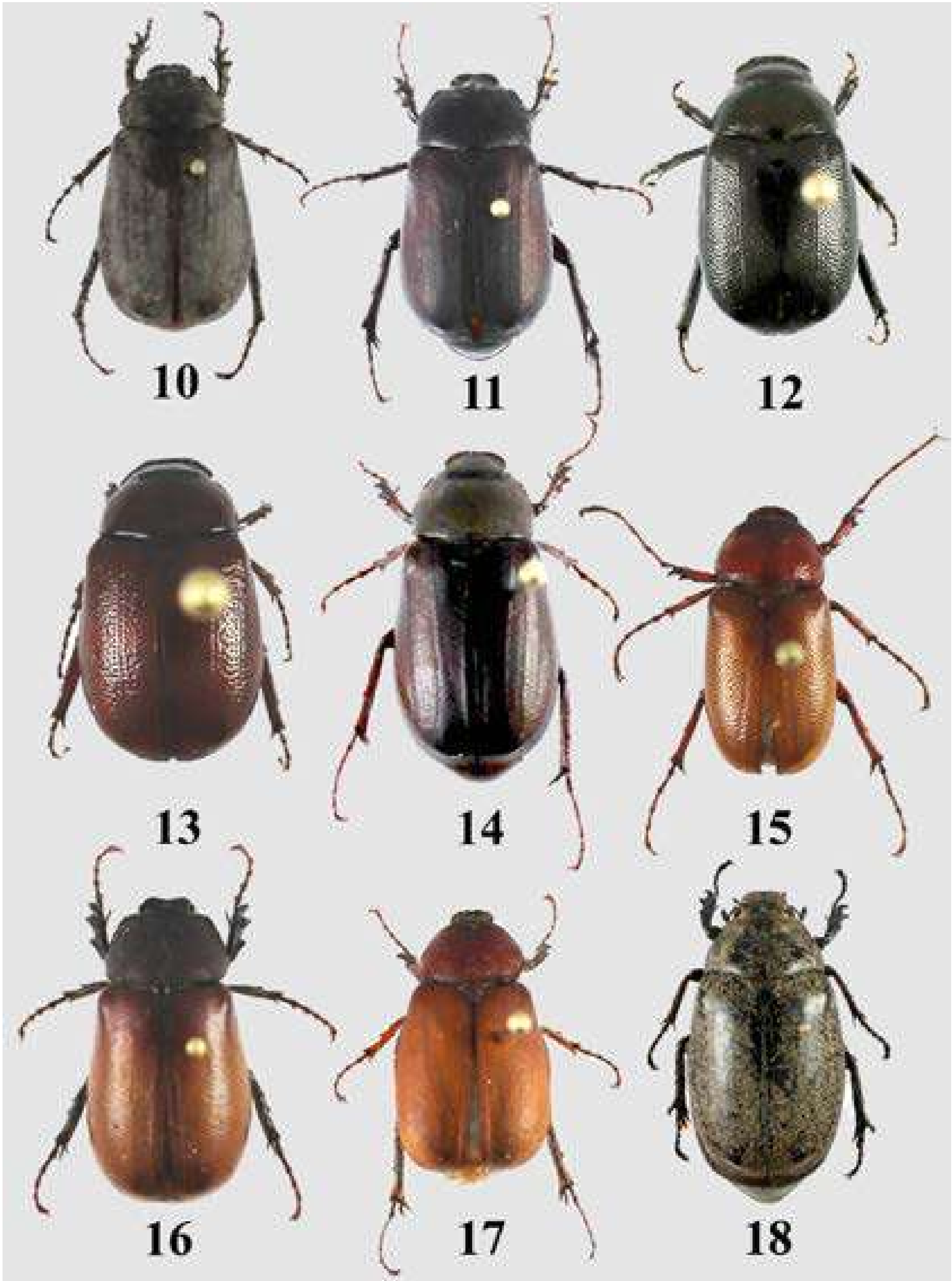


Fig. 4

Fig. 1-4 Relative abundance (%) of phytophagous scarabs in surveyed districts



1. *Anomala* sp*;* 2. *Anomala communis* (Burmeister, 1844)*;* 3. *Anomala dussumieri* (Blanchard, 1850)*;* 4. *Anomala elata* (Fabricius,1792)*;* 5. *Adoretus versutus* Harold, 1869; 6. *Anomalachela* Brenske, 1892*;* 7. *Maladera keralensis* (Frey, 1972)*;* 8. *Maladera rufocuprea* (Blanchard, 1850); 9. *Maladera burmeisteri* (Brenske, 1898)



10. *Holotrichia serrata* (Fabricius, 1781)*;* 11. *Holotrichia fissa* Brenske, 1894*;* 12. *Apogonia proxima* Waterhouse, 1877*;* 13. *Apogonia* sp. 1*;* 14. *Sophrops karschi* (Brenske, 1892)*;* 15. *Schizonycha ruficollis* (Fabricius, 1781)*;* 16. *Miridiba excisa* (Moser, 1913)*;* 17. *Brahmina mysorensis* Frey, 1971*;* 18. *Leucopholis burmeisteri* Brenske, 1894

Acknowledgments

The authors thank the Director, ICAR-NBAIR for facilitating the study and the KVK, RARS, Krishibhavan and farmers for their cooperation and support during surveys.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Diversity of Zooplankton in Mountainous Organic based Paddy cum Fish Cultivation ecosystem in Ziro, Arunachal Pradesh

[1]Rajashree Saikia, [2]Dipankar Debnath, [3]Tapati Das, [4]D. N. Das

[1] Dept. of Environmental Science, Gauhati University, Assam
[2]Dept. of Biological Science, Indian Institute of Science, Education and Research, Kolkata,
[3]Dept. of Ecology and Environmental Science, Assam University, Silchar, Assam,
[4]Dept. of Zoology, Rajiv Gandhi University, Arunachal Pradesh

Abstract

Zooplankton in the organic based mountainous paddy fields play an important role for the holistic development of fisheries and aquaculture sector, promoting livelihoods, food and nutritional security. Five major communities of zooplankton namely Cladocera, Copepoda, Rotifera, Protozooplanktonand Ostracoda were found in the study area where 34 species under Cladocera, 7 species under Copepoda along with some nauplii, 17 species under Rotifera and 1 species under Ostracoda and among protozooplankton 5 species under Protozooplankton, were recorded. Simpson dominance index revealed that *Bosmina*, *Chydorus*, *Cyclops*, *Diaptomus*, *Brachionus*, *Keratella*, *Arcella* were found as the most dominant zooplankton species. Shannon diversity index showed that Cladocera (2.45)> Copepoda (1.44)>Rotifera (1.30)>Protozooplankton (1.27). Margelef richness index showed that Cladocera (5.64)> Copepoda (1.65)> Rotifera (1.10)>Protozooplankton (1.33). The physico-chemical parameters of the rice field water as well as the structure and dynamics for the growth and abundance of zooplankton in the rice field also the productivity of rice and fish yield. It can be concluded that diversified zooplankton species has found in the organic nature paddy fields which have the reflection of the healthy ecosystem of Organic paddy fields. This type of ecosystems will be helped to attain of the three goals of sustainable development viz. **Goal 12** (Responsible consumption and production), **Goal 13** (Climate action), **Goal 14** (Life below water) by enhancement of blue revolution of the country.

Keywords: Diversity, paddy field, zooplankton, mountainous, SDG

Introduction

The mountainous paddy cum fish cultivation ecosystem in Ziro, Arunachal Pradesh is an organic based and eco-friendly culture practice (Noorhosseini and Bagherzadeh, 2013). The Apatani farmers stock mainly three strains of Common carp viz., *Cyprinus carpio specularis*, *Cyprinus carpio communis*, *Cyprinus carpio nudus* into the paddy fields (Das *et al*., 2007). The stocked fishes depend on the natural food sources like agricultural wastes, excreta of domestic animals like pig (*Sus scrofa scrofa*), cow (*Bos taurus*), Mithun (*Bos frontalis*) and goat (*Capra aegagrus hircus*) rather they use any supplementary fish feed (Ali, 1988; Saikia & Das, 2009). As the rice growing season starting from of May till end of September, the stocked fishes are harvested twice in a season. i.e. in the middle of July and October. They dependent on natural sources of water like diverted mountain streams and trickle down rain water of the monsoon season. Bamboo pipes are used to maintain the water level as well as dewatering the field at time of harvest (Saikia & Das, 2004).

Zooplankton, the free floating aquatic microorganisms are

*Author for correspondence
Article Received on: 02.04.2023 Accepted on: 24.04.2023

influencing the biogeochemical role towards the development of paddy field fishery. These organisms cope up with the frequently changing different growth phases of paddy and forms a congenial habitat for rich number of diversified species (Heckman, 1979; Simpson & Roger, 1995; Simpson *et al.*, 1994). Zooplankton enter into the paddy fields through both irrigation water and to form microhabitat underneath the paddy field water (Fernando, 1995 & 1996). Although, the paddy fields drastically change its limnology within a very short period of time, zooplankton can inhabit and flourish in such condition (Bambaradeniya *et al.*, 2004) and become readily available to the different categories of consumers in the paddy fields including stocked young carps (Shil *et al.*, 2013; Guangjun, 2013). Hence, zooplankton has immense role for the sustenance of the organic paddy practices.

Material and Methods:

Study area: The mountainous paddy cum fish culture site is located in Ziro valley of Lower Subansiri district of Arunachal Pradesh, India (**Figure 1**). It is located between 26°50'-98°21' N latitude and 92°40'-94°21' E longitude with an altitude about 5000 ft. above mean sea level (asl). The total area of where paddy-fish culture is approximately 10,135 km^2 out of 592.0 ha of irrigated paddy lands (Saikia and Das, 2004).

Sampling and analysis

Plankton samples were randomly collected by filtering 25 L of field water through 60 μm diameter mesh in the rice growing season of 2013 & 2014. The concentrated samples were preserved immediately in 4% formaldehyde solution. The preserved samples were identified by using binocular light microscope (Model: Nikon, ECLIPSE E200, Olympus CX4 and Leica DM 5000). Lackey's (1938) drop count method was used for quantification Zooplankton samples. Species of zooplankton was identified by following standard keys and monographs of Smirnov (1971); Needham & Needham, (1972); Tonapi, (1980); Battish, (1992); Edmonson, (1992); Kotov *et al.* (2012). The frequency of sampling whether it is monthly or yearly or seasonal to be mentioned, the details of the localities and how many localities collected also to be mentioned. Water samples collected monthly for physico-chemical parameters and analyzed by using APHA (2012). The yield records of rice and fish for each of the rice fields were obtained from the farmer (owner) through personal interview of the study plots.

Formula for calculation:

$$\text{Number of individuals per liter} = \frac{N_1 \times V_1}{N_2 \times V_2}$$

Where,

N_1= Number of organisms per drop

V_1= Volume of concentrated sample (ml)

V_2= Volume of original sample (L)

N_2= Volume of 1 drop (ml)

Shannon Weiner index (H), Buzas Gibson index (e^H/S), Margelef index were used to estimate month wise and village wise species diversity, richness and evenness of the zooplankton community (**Table 3-8**). The equations are as follows.

(a) Shannon-Weiner diversity index

$$H' = -\sum_{i=1}^{s} \frac{ni}{N} ln \frac{ni}{N}$$

[Where, n_i= number of individuals of taxon i, n= Total number of individuals]

(b) Buzas-Gibson evenness index

$$e^\wedge = \frac{eH'}{S}$$

[Where eH' = Shannon-Weiner index, calculated using natural logarithms, S = Number of species]

(c) Margalef richness index

$$D_{mg} = \frac{S-1}{lnN}$$

[Where S= Number of species, N= Total number of individuals in the sample]

Results and Discussion

From the results, it was recorded that the village wise of water physico-chemical parameters (**Table 1)** were varied different sampling stations. Pine grobe has highest mean value of DO (7.87 mgl^{-1}), TDS (415.93 mgl^{-1}), TA (32.38 mgl^{-1}), CaH (12. 10 mgl^{-1}), SC (726.50 μScm^{-1}), NO_3-N (0.08 mgl^{-1}), PO_4-P (0.15 mgl^{-1}), WD (16.50 cm), TH (20.22 mgl^{-1}), pH (6.66). Mudang tage has highest WT (27. 13° C) and AT (28.99° C) was during 2013. Similarly, Pine grobe showed highest peak mean value of DO (9.90 mgl^{-1}), TDS (349.90 mgl^{-1}), TA (31.11 mgl^{-1}), CaH (20.26 mgl^{-1}), SC (642.84 μScm^{-1}), NO_3-N

(0.76 mgl^{-1}), PO_4-P (0. 16 mgl^{-1}), WD (15.52 cm), Cl^{-1} (46.15 mgl^{-1}), TH (31.36 mgl^{-1}), pH (7.63) in 2013. The WT (27.83° C) and AT (28.19° C) was maximum in Mudang tage during 2014. However, in 2013, Cl^{-1} (48.98 mgl^{-1}) was maximum respectively in Mudang tage while minimum value of 2013 and 2014 was respectively in Tajang (28.94 mgl^{-1}) and Dutta (35.59 mgl^{-1}). The CaH (5.45 mgl^{-1}), NO_3-N (0.06 mgl^{-1}), pH (5.10) was lowest in Nenchalya, 2013. Mudang tage showed the lowest value of SC (398.67 μScm^{-1}) and WD (8.53 cm) where PO_4-P (0.05 mgl^{-1}) was lowest in Dutta in 2013. In 2014 also SC (400.23 μScm^{-1}) and WD (9.39 cm) was lowest in Mudang tage and PO_4-P (0.12 mgl^{-1}) was lowest in Dutta. The TDS (219.00 mgl^{-1}), TA (24.75 mgl^{-1}), NO_3-N (0.30 mgl^{-1}), TH (22.83 mgl^{-1}) and DO (5.59 mgl^{-1}) was also lowest in Mudang tage during 2014 only. In 2013, the lowest value of FCO_2 (12.97 mgl^{-1}), WT (25.51° C) and AT (27.69° C) was in Pine grobe and DO (5.60 mgl^{-1}) and PO_4-P (0.05 mgl^{-1}) was lowest in Dutta. In 2014, the lowest value of FCO_2 (7.74 mgl^{-1}), WT (23.08° C), AT (25.78° C) and PO_4-P (0.12 mgl^{-1}) followed similar trend. CaH (14.95 mgl^{-1}) and Cl^{-1} (35.59 mgl^{-1}) depicted their minimum value in Dutta during 2014. It was also observed that the TDS (266.36 mgl^{-1}), TH (9.71 mgl^{-1}), Cl^{-1} (28.94 mgl^{-1}) was lowest in Tajang, 2013. The minimum value of both pH (5.10) and TA (28.43 mgl^{-1}) as well as the maximum value of FCO_2 (19.68 mgl^{-1}) was in Nenchalya during 2013. The low pH (6.05), TA (22.83 mgl^{-1}) and high FCO_2 (12.97 mgl^{-1}) of Nenchalya was again noticed in 2014. Hossain *et al.* (2013) reported that the WT, 18.30˚C to 37.90˚C is suitable for growth of planktonic organisms. The low pH in April have occurred due to sudden submergence and decomposition of dry land flora and fauna and leftover rice stalks including metabolic wastes of the stocked fishes (Chowdhary *et al.*, 2000; Siddhartha *et al.*, 2012). Apatani farmers most frequently used to clear weeds in their wet rice fields that allowed sufficient solar influx into field water enhancing the multiplication of zooplankton.

It was also observed that Cladocera, Copepoda, Rotifera, Protozooplankton and Ostracoda under Zooplankton were recorded in the mountainous paddy fields of Ziro valley (**Figure 2**). A total of 34 species of Cladocera, 7 species of Copepoda with larval stages of nauplii, 17 species of Rotifera and 5 species of Protozooplankton, and only one species of Ostracoda (**Table 2**) were observed in the study period. Copepod nauplii were frequently occurring during the whole sampling periods indicated their active reproductive phases (Sharma, 2011; Bhat *et al.*, 2014) in the flooded fields. Zooplankton community structure showed significant variability in terms of diversity, richness and evenness within a very short period of time which probably governed by the cumulative effect of physico-chemical and biological parameters. Shannon diversity index (**Table 3**) showed that Cladocera (2.45)>Copepoda (1.44)>Rotifera (1.30)>Protozooplankton (1.27). Margelef richness index (**Table 4**) showed that Cladocera (5.64)>Copepoda (1.65)>Rotifera (1.10)>Protozooplankton (1.33). The diversity and richness indices indicated that Cladocera has the highest diversity which was matched with the findings Ali (1990) in the flooded paddy fields.

Cladocera (0.515) and Copepoda (0.404) showed highest evenness in Pine grobe and lowest (0.226, 0.297) in Tajang (**Table 3** & **4**). However, Protozooplankton showed its peak (0.980) value in Tajang and dip (0.926) value in Dutta (**Table 6**). Rotifera was highest (0.671) evenness in Nenchalya and lowest (0.509) in Mudang tage (**Table 7**). The species (*Cypris* sp.) under Ostracoda had equal value of evenness in the sampling villages (**Table 8**). Zooplankton and some other invertebrates select phytoplankton and periphyton as the most preferable source of trophic resource for their growth and survival (Feminella & Hawkins, 1995). So, the abundance and diversity of both phytoplankton and periphyton are greatly influenced by the population fluctuation of Zooplankton, the herbivore grazers. The predatory action of Copepods might have decreased the abundances of Rotifers in the end phase of rice (Badsi *et al.*, 2010).

The Margelef index of Cladocera (5.111) and Copepoda (1.930) showed maximum richness in Pine grobe (**Table 3** & **4**). The minimum (4.201) richness of Cladocera was in Dutta and Copepoda (1.840) was in Nenchalya and Mudang tage (**Table 2** & **3**). Again, Rotifera (3.892) and Protozooplankton (0.814) respectively showed their highest richness in Tajang and Dutta (**Table 6** & **7)**. The rich diversity of both Protozooplankton and Rotifera perhaps due to the higher population of bacteria and low water flow which caused decomposition of household sewages that ultimately enhanced the production rate of organic materials (Sharma *et al.*, 2014). But lowest richness of Rotifera (3.607) was in Mudang tage and Protozooplankton (0.785) was in Pine grobe (**Table 6** & **7**). It was observed that Ostracoda had no richness value (**Table 8**).

The Shannon diversity index of Cladocera (2.670) and Copepoda (1.397) showed the highest diversity in Pine grobe (**Table 4** & **5**) whereas lowest diversity was observed in Tajang (1.846, 1.090). The highest diversity and species richness of

Cladocera and Copepoda in Pine grobe may be because of higher density of suspended algal population, relatively higher level of paddy field water depth, total dissolved solids, specific conductivity, nutrient contents like chloride, nitrate-nitrogen, phosphate phosphorus (Saikia *et al.* 2017). Idris (1983) observed that there was rich species diversity of Cladocera in rice fields and other wetlands of East and West Malaysia where 24 species were the newly recorded. Rotifera and Protozooplankton had the highest (2.398) diversity in Nenchalya and Tajang (1.590) respectively (**Table 6** & **7**) may be due to the higher population of bacteria and low water flow which caused decomposition of household sewages that ultimately enhanced the production rate of organic materials (Majagi and Vijaykumar, 2009; Dhembare, 2011; Bhat *et al.*, 2014, Sharma *et al.*, 2014). The lowest diversity of Rotifera (2.099) was in Mudang tage and Protozooplankton (1.533) was in Dutta. Ostracoda (**Table 8**) did not have any value in all the sampling villages. Ali (1990) found that the shallow littoral nature of rice fields is the suitable habitat of abundant Cladocera and Rotifer species, although copepods were also numerically more abundant. Presence of diversified species of Zooplankton make it assured that the high altitude paddy cum fish culture system of Ziro valley provides their congenial where certain species were in an advantageous position to be distributed equally in the paddy fields. But, sometimes frequent deweeding and agronomic activities caused low evenness of some species within the flooded rice field.

This ecofriendly and economically beneficial farmer's practice has made the paddy cum fish culture in the context of aquatic resource utilization (Singh *et al.*, 2011). The total productivity for fish ranges 300-500 kg/ha/season and 3000-4000 kg/ha/season (**Table 9** & **10**). Fish enhanced 10-15% of rice productivity (10-15%) by maintaining the growth of algae, weeds and injurious insects, providing nutrient input through fish excreta and promoting tillering of the rice through movement of fish inside the field. It is also to be mentioned that the mineralization process of organic matter, puddling of mud and soil aeration by other benthos caused better yield of rice (Mondal *et al.*, 2005) in such a fish co-cultural mountainous organic based Paddy cum Fish Cultivation ecosystem. The field dyke (height 0.9 m-1.5 m) used to cultivate with various nitrogen fixing vegetables and millets for enhanced productivity of rice. Additionally, the dyke is also use for complete drying of field water during harvesting of rice and fish. Bamboo fencing is done to avoid the runaway of fishes through the pipes. For sustainable utilization of the paddy fields. farmers basically use agro inputs like household and agricultural wastes, excreta of domestic animals like pig (*Sus scrofa scrofa*), cow (*Bos taurus*), Mithun (*Bos frontalis*), and goat (*Capra aegagrus hircus*) as energy subsidy (Saikia & Das, 2004). Moreover, Azolla and Lemna are allowed to grow in the field water as a nitrogen fixer (Saikia and Das, 2008b). Such mentioned organic foods formed in the field may play an important role in the detritivorous habitat of the stocked fishes.

Conclusion

The diversified population of zooplankton serves as natural food sources for the fishes which enhance unit land of aquatic productivity in paddy fields and better livelihood option for tribal framers. All the mentioned agro inputs with organic manures, decomposed rice stubbles and macrophytes impact on growth and abundance of such natural fish which in turn to attain sustainable development **Goal 12** (Responsible consumption and production), **Goal 13** (Climate action), **Goal 14** (Life below water) by greater profitability in blue revolution of unique Integrated Aquaculture Agriculture system. Therefore, this unique system needs special attention to develop mass culture for enhancement of Zooplankton which has greater contribution in blue revolution of India.

FIGURES

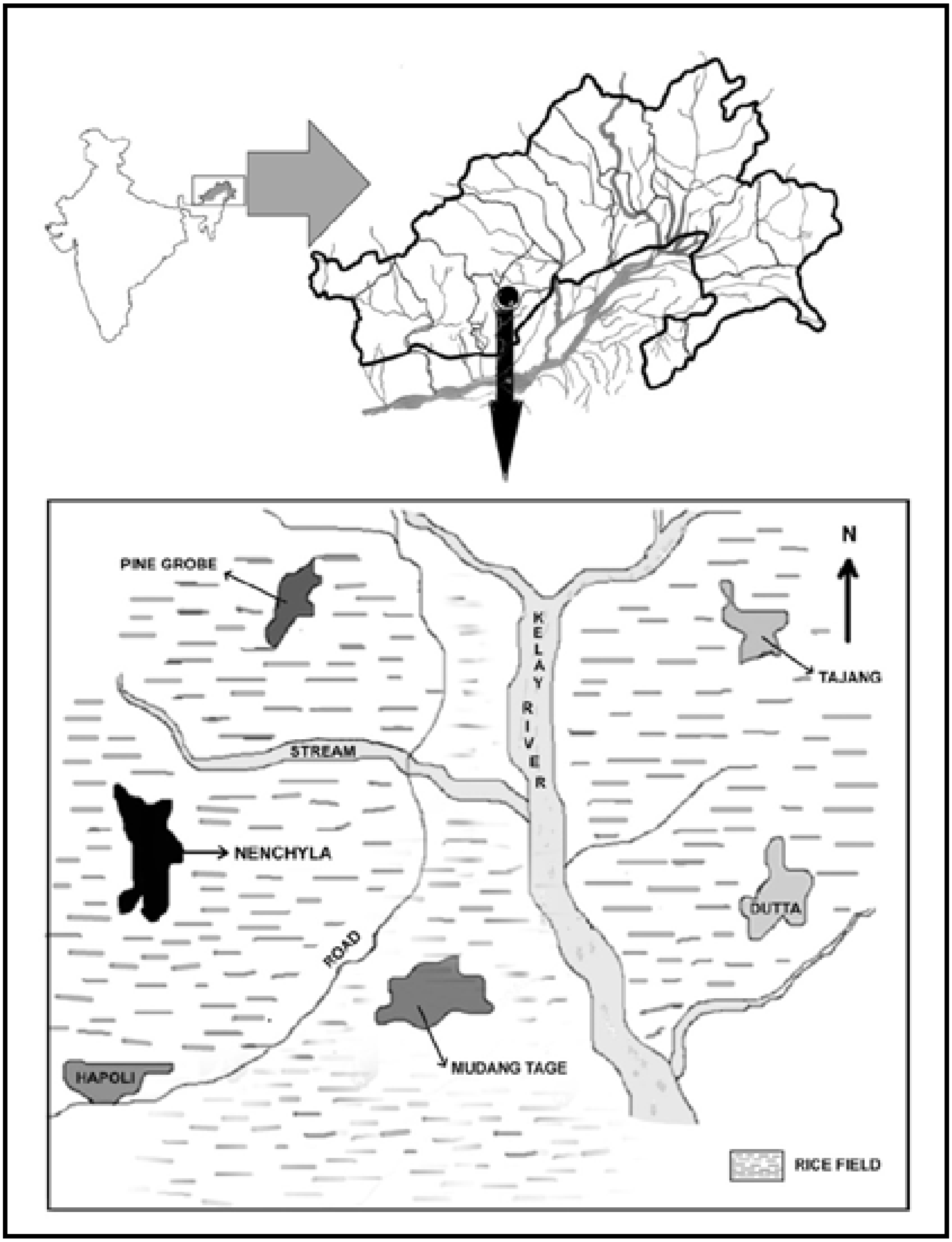

Figure 1: Sampling sites of the study area

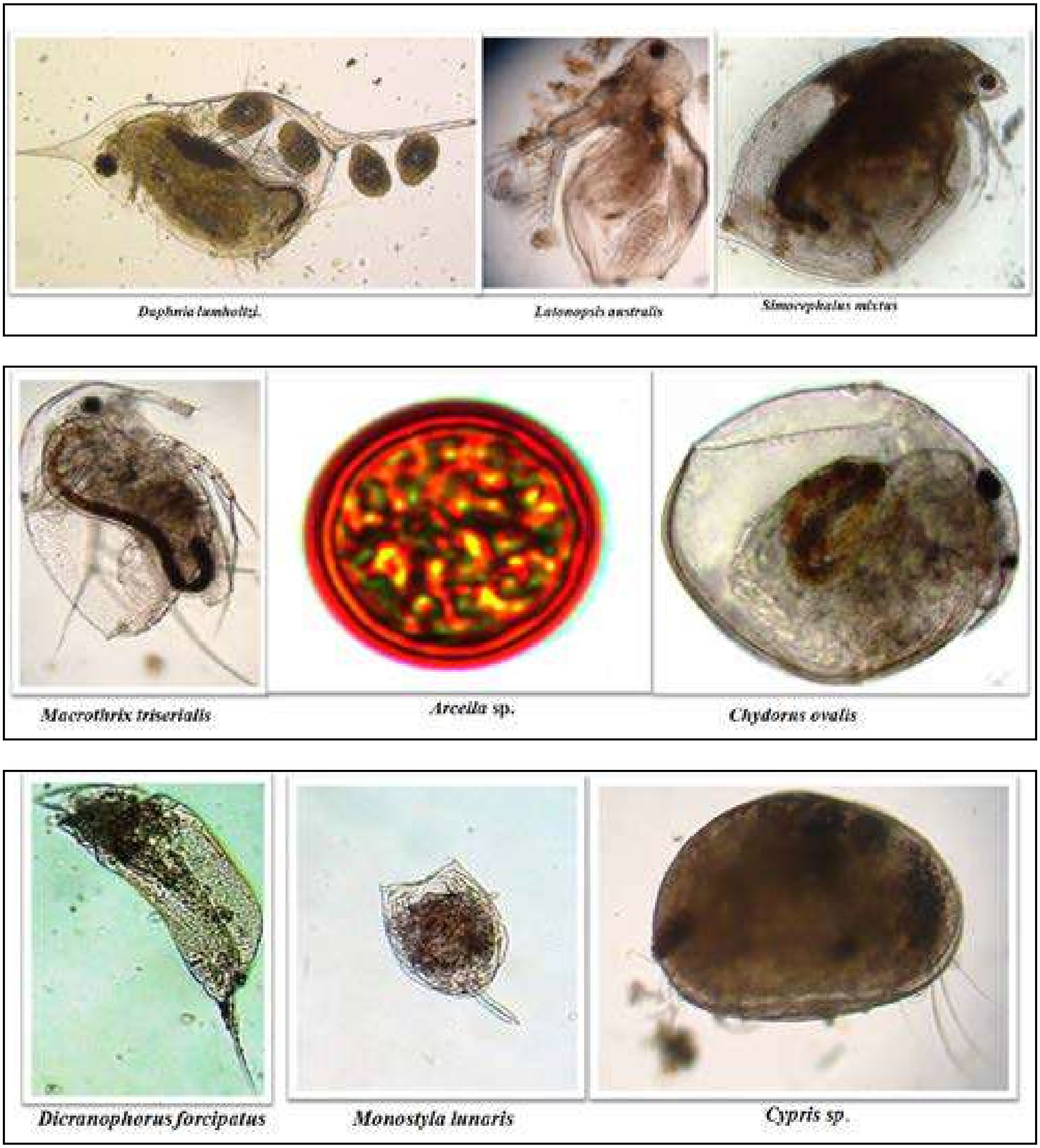

Figure 2: Some identified Zooplankton

TABLES

Table: 1. Village wise variation of physico-chemical parameters (Mean ± SD) of the rice field water in during the study season

Parameters	Year	Pine grobe	Tajang	Nenchalya	Dutta	Mudang tage
FCO_2 (mgl^{-1})	2013	12.40±1.82	15.79±7.74	19.68±6.93	16.54±11.94	12.97±1.77
	2014	7.74±4.46	8.08±4.69	10.02±4.28	9.49±3.29	9.14±4.36
DO (mgl^{-1})	2013	7. 71±3.71	7.34±4.52	6.19±2.70	5.49±3.38	6.83±4.31
	2014	9.90±2.23	8.84±1.48	5.77±2.22	5.74±2.22	5.59±2.90
TDS (mgl^{-1})	2013	415.93±79.70	266.36±77.60	266.85±77.44	304.43±103.79	326.85±60.40
	2014	349.90±97.27	308.95±50.30	253.09±65.63	307.53±93.09	219.00±70.68
TA (mgl^{-1})	2013	32.38±7.19	29.25±6.32	28.43±9.27	32.11±7.39	30.40±7.66
	2014	31.11±5.51	28.29±6.34	24.75±11.24	26.13±5.41	27.58±6.52
CaH (mgl^{-1})	2013	12.10±2.83	6.16±1.88	5.45±1.00	11.94±9.49	8.68±4.64
	2014	20.26±3.52	16.52±5.72	16.77±3.94	14.95±3.93	15.12±7.58
SC (μScm^{-1})	2013	726.50±189.68	549.36±129.24	468.27±106.54	555.98±195.65	398.67±60.48
	2014	642.84±148.34	500.15±103.06	524.17±118.83	535.64±143.25	400.23±139.19
PO_4-P (mgl^{-1})	2013	0.15±0.07	0.13±0.02	0.14±0.01	0.05±0.04	0.09±0.01
	2014	0.16±0.09	0.14±0.05	0.15±0.02	0.12±0.08	0.14±0.05
NO_3-N (mgl^{-1})	2013	0.08±0.03	0.08±0.03	0.06±0.01	0.07±0.02	0.07±0.02
	2014	0.78±0.28	0.44±0.08	0.64±0.02	0.54±0.03	0.30±0.01
WD (cm)	2013	16.50±3.79	13.53±4.35	14.17±4.07	9.12±5.99	8.53±3.46
	2014	15.52±4.47	10.08±4.44	10.29±4.45	9.52±5.27	9.39±4.72
Cl^{-1} (mgl^{-1})	2013	44.43±25.06	28.94±9.49	31.42±12.44	29.53±11.96	48.98±31.21
	2014	46.15±17.34	45.79±13.08	39.41±10.69	35.59±8.42	39.14±13.03
TH (mgl^{-1})	2013	20.22±7.42	9.71±2.73	11.25±8.62	13.08±4.33	10.13±2.65
	2014	31.36±6.63	27.16±6.26	26.40±7.67	24.18±5.68	22.83±6.63
pH	2013	6.66±0.40	6.42±0.41	5.10±0.74	6.10±1.38	6.23±0.52
	2014	7.03±0.51	6.26±0.77	6.05±1.39	6.49±0.48	6.53±0.31
WT (°C)	2013	25.51±4.64	26.61±2.91	26.69±2.64	27.08±3.44	27.13±3.17
	2014	23.08±2.42	23.94±4.80	25.24±1.56	25.83±3.26	27.83±2.73
AT (°C)	2013	27.69±4.72	28.69±2.38	29.27±2.11	28.70±2.09	28.99±2.86
	2014	25.78±2.82	26.19±4.83	27.18±1.50	26.90±2.75	28.19±2.36

Table 2: List of Identified Zooplankton

Group	Species
Cladocera	*Bosmina* sp.
	Bosmina cf. *tripurae* (Jurine 1820)
	Bosmina longirostris (O. F. Muller, 1776)
	Bosminopsis sp.
Cladocera	*Chydorus* sp.
	Dadaya macrops (Daday, 1898)
	Kurzia longirostris (Daday, 1898)
	Kurzia sp.
	Oxyurella sp.
	Alona sp.
	Disperalona caudata Smirnov, 1996
	Alona affinis (Leydig, 1860) s. lat.
	Alona guttata Sars, 1862
	Celsinotum macronyx (Daday, 1898)
	Ephimrous barroisi Richard 1894
	Anthalona sp.
	Chydorus sphaericus (O. F. Muller, 1776)
	Chydorus ventricosus Daday, 1898
	Chydorus cf. *ovalis* Kurz, 1874
	Pleuroxus denticulatus Birge, 1879
Cladocera	*Diaphanosoma dubium* (Manuilova, 1964)
	Latonopsis australis Sars, 1885 s.lat.
Cladocera	*Daphnia lumholtzi* Sars, 1885
	Ceriodaphnia cornuta Sars, 1885
	Ceriodaphnia sp.
	Simocephalus sp.
	Simocephalus mixtus Sars, 1903
Cladocera	*Moina* sp.
	Moina micrura Kurz, 1874
	Moinodaphnia sp.

Group	Species
Cladocera	*Macrothrix* sp.
	Macrothrix spinosa King, 1853
	Macrothrix triserialis (Brady, 1886
Copepoda	*Cyclops* sp.
	Mesocyclop sp.
	Mesocyclop edax Forbes, 1891
Copepoda	*Diaptomus* sp.
	Limnocalanus sp.
	Limnocalanus macrurus Sars G.O., 1863
	Bryocamptus sp.
	Helodiaptomus sp.
	Neodiaptomus sp.
	Nauplii of *Cyclops*
	Nauplii of *Diaptomus*
Rotifera	*Asplanchna* sp.
	Asplanchna brightwellii Gosse, 1850
Rotifera	*Keratella* sp.
	Keratella valga (Ehrenberg, 1834)
	Brachionus sp.
	Brachionus forficula Wierzejski, 1891
	Plationus patulus patulus (O. F. Muller 1786)
	Platyias quadricornisquadricornis (Ehrenberg, 1832)
	Testudinella patina (Hermann, 1783)
	Testudinella striata (Murray, 1913)
	Dicranophorus forcipatus (O. F. Muller, 1786).
Rotifera	*Lecane* sp.
	Lacane ungulata (Gosse, 1887)
	Lacane leontina (Turner, 1892)
	Lacane bulla bulla (Gosse, 1851)
	Monostyla sp.
	Eosphera sp.

Group	Species
Ostracoda	*Cypris* sp.
Protozooplankton	*Arcella* sp.
	Difflugia sp.
	Centropyxis sp.
	Ophryoglena sp.
	Epistylis sp.

Table: 3. Diversity, richness and evenness indices among Zooplankton groups during the rice growing season of 2013-14

Indices	**Cladocera**	**Copepoda**	**Rotifera**	**Ostracoda**	**Protozooplankton**
Diversity index	2.45	1.44	1.30	0	1.27
Evenness index	0.55	0.54	0.81	1.00	0.71
Richness index	5.64	1.65	1.33	0.26	1.10

Table: 4. Village wise diversity, richness and evenness indices of Cladocera during the rice growing season of 2013-14

Indices	**Pine grobe**	**Tajang**	**Nenchalya**	**Dutta**	**Mudang tage**
Diversity index	2.670	1.846	1.974	1.984	1.892
Evenness index	0.515	0.226	0.257	0.279	0.237
Richness index	5.111	4.499	4.602	4.201	4.668

Table: 5. Village wise diversity, richness and evenness indices of Copepoda during the rice growing season of 2013-14

Indices	**Pine grobe**	**Tajang**	**Nenchalya**	**Dutta**	**Mudang tage**
Diversity index	1.397	1.090	1.226	1.289	1.272
Evenness index	0.404	0.297	0.340	0.363	0.357
Richness index	1.930	1.890	1.840	1.873	1.840

Table: 6. Village wise diversity, richness and evenness indices of Protozooplankton during the rice growing season of 2013-14

Indices	**Pine grobe**	**Tajang**	**Nenchalya**	**Dutta**	**Mudang tage**
Diversity index	1.589	1.590	1.570	1.533	1.589
Evenness index	0.979	0.968	0.961	0.926	0.980
Richness index	0.785	0.787	0.791	0.814	0.787

Table: 7. Village wise diversity, richness and evenness indices of Rotifera during the rice growing season of 2013-14

Indices	Pine grobe	Tajang	Nenchalya	Dutta	Mudang tage
Diversity index	2.298	2.398	2.435	2.294	2.099
Evenness index	0.622	0.647	0.671	0.583	0.509
Richness index	3.760	3.892	3.862	3.792	3.607

Table: 8. Village wise diversity, richness and evenness indices of Ostracoda during the rice growing season of 2013-14

Indices	Pine grobe	Tajang	Nenchalya	Dutta	Mudang tage
Diversity index	0.000	0.000	0.000	0.000	0.000
Evenness index	1.000	1.000	1.000	1.000	1.000
Richness index	0.000	0.000	0.000	0.000	0.000

Table: 9. Yields records of rice and fish in rice fields of Ziro

Village	Rice yield ($kgha^{-1}season^{-1}$)	Fish yield ($kgha^{-1}season^{-1}$)
Pine grobe	2000.0-4000.0	350.0-500.0
Tajang	2000.0-3000.0	270.0-480.0
Nenchalya	2000.0-3000.0	260.0-430.0
Dutta	3000.0-4000.0	420.0-500.0
Mudang Tage	3000.0-4000.0	390.0-500.0

Table: 10. Yields records of rice and fish in the rice fields of Ziro,

Village	Rice yield ($kgha^{-1}season^{-1}$)	Fish yield ($kgha^{-1}season^{-1}$)
Pine grobe	2050.0-4000.0	380.0-500.0
Tajang	2000.0-3000.0	320.0-450.0
Nenchalya	2000.0-4000.0	240.0-480.0
Dutta	3050.0-4000.0	410.0-500.0
Mudang Tage	2500.0-4000.0	390.0-500.0

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Diversity of *Eimeria* Schneider, 1875 (Conoidasida: Eucoccidiorida: Eimeriidae) in Broiler chickens of Purulia District, West Bengal, India

Azmal Baidya and Biplob Kumar Modak*

Sidho-Kanho-Birsha University, P.O. & Dist.- Purulia
Pin-723104, West Bengal

Abstract

Eimeria is one of the most important pathogenic parasites in broiler chickens that causes huge economic loss in poultry birds throughout the world including the Purulia district of West Bengal. To study the prevalence of coccidiosis in the broiler chickens of the district, coprological studies were carried out from February 2022 to January 2023. Faecal samples were collected from different poultry farms of the district and examined by the Floatation method (Sheather's solution) followed by microscopic examination of coccidian oocyst and sporocyst. Species were identified by morphometric *Eimeria* is one of the most important pathogenic parasites in broiler chickens that causes huge economic loss in poultry birds throughout the world analysis and standard literature. Out of 254 samples examined, 169 samples were found positive for coccidian species, i.e. the prevalence of coccidiosis in broiler chickens of the Purulia district was 66.53%. Altogether six species of *Eimeria* were recorded of which *Eimeria tenella* was the most prevalent species (40.55%, 103/254), followed by *Eimeria necatrix* (12.20%, 31/254), *Eimeria maxima* (5.51%,14/254), *Eimeria mitis* (3.54%, 09/254), *Eimeria acervulina* (2.75%, 7/254) and *Eimeria brunetti* (1.96%, 5/254). The most common type of mixed infection was found in combination with *E. tenella, E. maxima and E. necatrix* (33.85%, 86/254), followed by *E. tenella, E. maxima* (25.19%, 64/254). Interestingly, in most cases, *E. tenella, E. mxima* and *E. necatrix* were coexisting in various combinations. *E. tenella, E. mxima* and *E. necatrix* were coexist in 33.85%, (86/254) cases, *E. tenella* and *E. necatrix* in 25.19% cases (64/254) and *E. tenella* and *E. maxima* in 15.35% cases (39/254). The present study also revealed that the infection was more prevalent in the rainy season (91.78%) and less in the summer (31.81%). The present communication intends to conclude that coccidiosis is still a major threat to poor poultry bird keepers of the district.

Keywords: Oocyst*, Eimeria*, Sporocyst, Poultry, Prevalence

Introduction

Chickens represent the biggest poultry sector in the world that reared extensively and represent a good, cheap, and healthy protein source for the common people. India ranked 3rd in egg production and 8th in meat production in the world (2021-22 report of The Economic Times news, 31 January 2022). Poultry bird keeping is one of the fewest options for livelihood development of the rural people of any developing country like India. The poultry sector generates more than 3 million employment and it is expected to cross 5 million by 2025 in India (As per data from Central Avian Research Institute). However, rural poultry birds keepers often succumb to huge economic losses due to sudden outbreaks of diseases. Coccidiosis is one such disease which causes loss of millions of dollars every year throughout the globe (Dalloul RA et., al 2006). A study in 2017, indicates 76% and 79.4% of farms from southern and northern India were found to be infected for any species of *Eimeria* (Prakash babu BC *et al.*, 2017). It is a kind of severe gastrointestinal disease of poultry birds caused by several species of protozoan

*Author for correspondence : bkmodak09@gmail.com, Tel. no: +919434543692.
Article Received on: 02.04.2023 Accepted on: 24.04.2023

obligate endoparasitic genera *Eimeria* under the phylum Apicomplexa. Globally seven pathogenic *Eimeria* species infective to chickens are identified *viz. E. tenella, E. necatrix, E. maxima, E. mitis, E. acervulina E. brunetti* and *E. praecox* (Carolina Mesa-Pineda *et al.*, 2021). The most common and highly pathogenic *Eimeria* species in the poultry industry is the *E. tenella* (Ayaz *et al.*, 2003) whereas, *E. praecox* is the least pathogenic (Carolina Mesa-Pineda *et al.*, 2021). Coccidiosis is endemic in most the tropical regions because of favorable ecological conditions for sporulation of coccidian oocyst and its subsequent development and poor management conditions (Blake and Tomley, 2014). The prevalence of coccidiosis in broiler chickens mostly depend upon the age of the chicken (Sharma *et al.*, 2015). Young birds are more prevalent and more readily display to show the symptoms, whereas matured or adult chickens are relatively more resistant (Cervantes *et al.*, 2020). This disease is more severe in broiler chickens where the rate of mortality and morbidity is very high. Dysentery, diarrhoea, and enteritis, which can result in bloody stools in some *Eimeria* species, emaciation, feed conversion that is below average, delayed sexual maturity, drooping wings that cause dehydration, poor development, and low egg and meat quality production are all symptoms of coccidiosis. (Rehman et al ., 2010, Abbas *et al.*, 2017). There is hardly any serious work on the Coccidiosis of poultry birds in Purulia district, West Bengal, where thousands of poor rural people are depending on rearing of chickens as primary or secondary source of their income. The aims of the present study is to find out the prevalence and diversity of Coccidiosis of poultry chickens in the Purulia district.

Materials and Methods

Study area

This present study was conducted in every block of the Purulia district of West Bengal, The geographical location of Purulia district range between 22^{o} and 23.50^{o} N latitudes and 85.75^{o} and 86.65^{o}E east longitudes. The geographical area of the Purulia district is around 6,259 -kilometer square (Fig. 1).

Study period

The present research work was conducted from February 2022 to January 2023 to explore the prevalence of Coccidiosis in poultry chicken of the Purulia district.

Collection of samples

To determine the prevalence of coccidia infection in broiler chickens, a total of 254 pooled faecal samples of poultry were collected from various poultry farms in the current study region. About 3-5 g of each sample were collected in distinct screw-capped vials with proper labeling and brought to the laboratory. The collected faeces samples were evaluated either that day or after being stored in a refrigerator at 4°C for further investigation. The samples of faeces were first thoroughly examined to determine their consistency and the presence of mucous, blood, etc. Standard techniques were used to determine the presence of Eimerian oocysts.

According to the approach described by Soulsby (1982), sucrose solution (also known as Sheather's solution) was used to isolate the coccidia oocysts.

Sporulation of coccidia oocyst

Fecal samples which were positive for coccidia oocysts after the sugar floatation method were mixed with 2.5% potassium dichromate solution in Petri dishes and left at room temperature for sporulation of oocysts. Coccidia species were identified according to their size and morphological features of the oocysts (Saikia *et al.*,2017). The thickness of the oocyst walls, the presence of micropyle, cap, polar granules, size and shape of the sporocysts, the thickness of sporocyst wall, the shape of the Stieda bodies. and sporulation time (Soulsby, 1982) were recorded. Measurements of 25 oocysts of each samples are measured. Measurement of different coccidian oocysts and sporocysts were examined as per the procedure described by Sloss *et al.* (1994).

Systematic accounts of *Eimeria*, Schneider, 1875

Phylum –Apicomplexa Levine, 1970

Class -Conoidasida Levine, 1988

Order-Eucoccidiorida Leger and Duboscq, 1910

Family-Eimeriidae Minchin, 1903

Genus – *Eimeria* Schneider,1875

Results and Discussion

In this present study out of 254 faecal samples, 169 samples were found to be infected with *Eimeria* species and the overall prevalence rate of infection was 66.53% (Table 1)). Season wise data shows that the highest prevalence of Coccidiosis in Poultry chickens in the Purulia district is 91.78% in monsoon and lowest in summer with 31.81% (Fig.3). Month wise data shows that the highest rate of infection occurred in the month of July (96.6%) and the lowest in the month of April (20.0%) (Table 3). The monthly prevalence rate is overall high during the month of July-January, after that it falls sharply and continues up to June.

Considering the measurement of the oocyst and variation of sporulation time, six species of *Eimeria* were identified in broiler chicken of Purulia. Among the six species of the genus *Eimeria,* oocyst of *Eimeria tenella* was most prevalent (40.55%, 103/254) and it is followed by *E. necatrix* (12.20%, 31/254), *E. maxima* (5.51%, 14/254), *E. mitis* (3.54%, 9/254), *E. acervulina* (2.75%, 7/254), and *E. brunetti* (1.96%, 5/254).

Description of oocyst

***Eimeria tenella* Tyzzer, 1929, (Fig. 2A)**

The oocysts are broad and oval in shape. The Oocyst wall is two layered, 1.2 um thick. The outer layer is thick, the inner layer is thinner. Micropyle and micropylar cap are absent. The unsporulated oocyst shows an oval to subspherical sporoblast filling the central portion of the oocyst. Oocystic residuum is absent. The oocyst size ranges from 18.7-22.2 µm in length and 15.3-18.8 µm in width. The sporocysts are broad and elongated and slightly tapering at the anterior portion and the posterior end of the sporocyst is rounded, and broad. The sporocyst ranges from 10.19-11.0 µm in length and 5.9-7.0 µm in width. Anterior end is tapering with a stieda body. Sporocystic residuum is absent. The sporulation time is 24-72 hours, and the prevalence rate of *E.tenella* is 40.55%.

***Eimeria necatrix* Johnson, 1930, (Fig. 2B)**

The oocysts are round and oval in shape and covered by a double-layered wall. The outer wall is thick and light yellow in color while the inner wall is thin and brownish to whitish. Thickness of the oocyst wall is about 1.3um. Micropyle and micropylar cap are absent. The un-sporulated oocyst shows a small spherical sporoblast filling the central portion of the oocyst. The sporulated oocyst shows the presence of clear polar granules at the anterior end and behind the oocyst wall. No oocystic residuum is seen. The oocyst size ranges from 13.1-22.2 µm in length and 11-18.6 µm in width. The sporocysts are mainly comma in shape, measuring about 8.21-13.58 µm in length and 4.90-6.20 µm in width. The posterior portion of the sporocyst is rounded, and broader, anterior end is narrow, tapering with large size stieda body. The sporulation time varied between 16-48 hours. The rate of prevalence of *E. necatrix* is 12.20%..

***Eimeria maxima* Tyzzer, 1929, (Fig. 2C)**

The oocysts of the species collected from the broiler chicken are oval to egg-shaped without micropyle and micropylar cap. The oocyst wall is two layered, and about 1.2 µm thick. The outer wall is thick, and reddish brown while the inner is thin and bluish in colour. The sporulated oocyst has polar granules along the oocyst wall at the anterior end. Oocystic residuum is absent. The sporocysts are elongated, the anterior end is pointed with a clear steida body and the posterior end is broad and rounded. The oocyst measures 21.4-42.8 µm in length and 16.43-29.0 µm in width. Each sporocyst measur about 8.16-12.24 µm in length and 5.0 - 5.2 µm in width. Sporulation time varied from 24-36 hours. The prevalence rate of *E. maxima* is 5.51% in the present study.

***Eimeria mitis* Tyzzer,1929, (Fig. 2D)**

The identified oocysts are spherical to oval in shape and covered with a thin dark brownish-coloured oocyst wall. *E. mitis* has a single oocyst wall, measured about 0.9 µm thick. Micropyle and micropylar cap is absent. The un-sporulated oocyst shows a spherical granular sporoblast with entire portion of the oocyst. The sporulated oocyst shows the clear polar granule near the oocyst wall. Oocystic residuum is absent. The sporocysts are elongated, oval to egg shaped, and show typical arrangement within the oocyst. The oocyst measures 14.4-19.48 µm in length and 13.34-16.90 µm in width. Sporocyst measures about 8.21-12.26 µm in length and 4.7-5.9 µm in width. The posterior end of the sporocyst is rounded, and large, anterior end is narrow and clear with the stieda body. Sporulation time varied from 16- 24 hours. The prevalence rate of *E. mitis* is 3.54%.

***Eimeria acervulina* Tyzzer,1929, (Fig. 2E)**

The oocysts of this species are ellipsoidal in shape. It has no micropyle and micropylar cap in the oocyst. The oocyst wall is about 1.2 µm thick. It is two layered, the outer wall is thick, and light yellow in colour but the inner wall is thin and brown in colour. The un-sporulated oocyst shows an oval spherical sporoblast at the center of the oocyst. A distinct polar granule is visible at the anterior end of the sporulated oocyst. The oocyst length varies from 18.12-26.9 µm in length and 13.2-20.24 µm in width. The sporocysts are typically elongated to pyriform in shape, measuring 10.18-13.24 µm in length and 5.1-6.4 µm in width. The posterior portion of the sporocyst is broader in shape, anterior end is narrow with clear stieda body. The sporulation time is 24-48 hours and the prevalence rate of infections is 2.75%.

Eimeria brunetti **Levine, 1942, (Fig. 2F)**

The oocysts are spherical to oval in shape. It has no micropyle and micropylar cap. The wall of the oocyst is single-layered, 1.3 µm thick, and brown in colour. The un-sporulated oocyst shows a spherical sporoblast presenting a small portion of the oocyst. The sporulated oocyst shows the presence of a clear polar granule at the anterior end near to the oocyst wall. Oocystic residuum is not present. The oocyst length ranges from 19.2-23.4 µm and 13.5-19.4 µm in width. The sporocysts are elongated in shape, and measure about 8.14-13.34 µm in length and 5.0-6.3 µm in width. The posterior end of the sporocyst is round and broader, the anterior end is narrow with clear stieda body. Sporocystic residuum is absent. The sporulation time of *E. brunetti* is varies from 18-24 hours and the prevalence rate of infections is 1.96%.

Comparative characteristics of six Eimeria species, found in poultry chicken of Purulia district, are compiled in Table 2.

The overall prevalence of infection of Coccidiosis in Poultry chickens of the Purulia district is 66.63% and similar kind of observations are recorded by Gari *et al.*, (2008), Olanrewaju and Agbor (2014) in Nigeria. Dinka and Tollosa (2012) in Ethiopia. However Oljira *et al.*, (2012) reported a much lower rate of prevalence (20.57%) from Ambo in Ethiopia.

The present study confirms the persistent occurrence of coccidiosis with seasonal variation in prevalence. Though the incidence rate was recorded as high during the monsoon period but highest in the month of July because of the favourale environmental conditions like high relative humidity (75%), 20°C-30°C degree centigrade temperature, and rainfall of about 600mm. The lowest infection was recorded during summer with the lowest in April, mostly because of extreme weather conditions like very low relative humidity, temperature and rainfall which measured 20-35%, 35°C-40°C and 50 mm respectively. Statistical analysis by two-way ANOVA results (P-value 0.00076) revealed that there is a significant ($p<0.05$) difference in the prevalence of different *Eimeria* species and their infection in different seasons (particularly monsoon to summer and spring) clearly shows that prevalence of infection high in monsoon compared to summer and spring (Table 5). The present investigation finds a strong correlation between the occurrence of coccidiosis and environmental conditions. Similar kinds of observations are also noticed by Haug *et al.*, (2008), Sharma *et al.*, (2013). They also pointed out that high humidity and rainfall favoured the rate of sporulation of coccidian oocysts.

Conclusion

This present study revealed that *E. tenella* was the most prevalent species (40.55%) followed by *E. necatrix* 12.20% . *E. acervulina* and *E. burnetti* were the least prevalent species with a prevalence rate of 2.75% and 1.96% respectively (Table 4). The present study indicates that the highest rate of coccidiosis infection mostly occurred in monsoon (91.78%) and winter (88.15%) and the least infection noticed in spring (35.9%) and summer (31.81%) (Figure 3). Though coccidiosis in poultry is prevalent throughout the year, it varies with the change in climatic conditions like temperature, rainfall, humidity, and habitat stress (poor management) of the Poultry.The findingss of the present study stressed on the regular surveillance of poultry birds for coccidiosis so that the poor poultry bird keeper of the district can be saved from huge economic loss. Disinfection assumes a significant part in diminishing the dispersal of the parasite (Peek HW, 2010), as the most continuous method of transmission of oocysts is through carriers like the movement of staff or instruments among the farms, and the presence of rodents and other insect pests (Cervantes HM *et al.*,2020).

TABLE

Table 1. Prevalence of coccidiosis in Poultry chickens of the Purulia district

Sample examined	Species of coccidia (*Eimeria*) identified	No. of positive samples	Prevalence (%)
254	*Eimeria tenella*Tyzzer, 1929	103	40.55
	*E. necatrix*Johnson, 1930	31	12.20
	*E. maxima*Tyzzer, 1929	14	5.51
	E. mitis Tyzzer, 1929	9	3.54
	*E. acervulina*Tyzzer, 1929	7	2.75
	*E. brunetti*Levine, 1942	5	1.96
Total 254		169	66.53

Table2. Comparative features of six *Eimeria* species in poultry chicken of the Purulia district

Species/features	***Eimeria tenella*Tyzzer, 1929**	***E. necatrix* Johnson, 1930**	***E. maxima* Tyzzer, 1929**	***E. mitis* Tyzzer; 1929**	***E. acervuline,* Tyzzer, 1929**	***E.brunetti* Levine, 1942**
Oocyst shape	oval	oval	egg shaped	spherical	ellipsoid	spherical
Measurement in µm	18.7-22.2×15.3-18.8	13.1-22.4×11-18.6	21.4-42.4×16.43-29	14.4-19.4×13.34-1690	18.12-26.9×13.2-20.44	19.2-23.4×13.5-19.4
Micropyle	absent	absent	absent	absent	absent	absent
Micropylar cap	absent	absent	absent	absent	absent	absent
Polar granules	present	present	present	present	present	present
Sporocyst shape	elongated	pyriform	ovoid	egg shaped	like small banana	elongated
Stieda body	present	present	present	present	present	present
Measurement of sporocyst in µm	10.19-11×5.9-7.0	8.21-13.58×4.90-6.20	8.16-12.24×5-5.2	8.21-12.26×4.71-5.9	10.18-13.4×5.1-6.4	8.14-13.34×5.0-6.3
Sporulation time (hours)	24-72	16-48	24=36	16-24	24-48	18-24
Oocyst residuum	absent	absent	absent	absent	absent	absent

Table 3. Month-wise prevalence of *Eimeria* in chickens of the Purulia district.

Sl No.	Study period	Number of samples examined	No of samples positive	Prevalence (%)
1	February	21	9	42.85
2	March	18	5	27.8
3	April	20	4	20.0
4	May	19	7	36.8
5	June	27	10	37.03
6	July	29	28	96.6
7	August	23	21	91.30
8	September	21	18	85.7
9	October	20	18	90
10	November	20	17	85
11	December	16	14	87.5
12	January	20	18	90
	Total	254	169	66.53%

Table 4. Species (parasite) wise prevalence of infection in Poultry chicken of the Purulia district

Species name	Summer (Infected/examined ×100)	Monsoon (Infected/ examined ×100)	Winter (Infected/ examined ×100)	Spring ((Infected/ examined ×100)	Total prevalence (%)
Eimeria tenella	11/66 (16.7%)	40/73 (54.8%)	46/76 (60.53%))	6/39 (15.4%)	103/254 (40.55%)
E. necatrix	6/66 (9.09%)	12/73 (16.43%)	10/76 (13.16%)	3/39 (7.7%)	31/254 (12.20%)
E. maxima	2/66 (3.03%)	5/73 (6.84%)	6/76 (7.9%)	1/39 (2.6%)	14/254 (5.51%)
E. mitis	0	2/73 (2.73%)	4/76 (5.3%)	3/39 (7.7%)	9/254 (3.54%)
E. acervulina	1/66 (1.51%)	5/73 (6.84%)	0	1/39 (2.6%)	7/254 (2.75%)
E. brunetti	1/66 (1.51%)	3/73 (4.11%)	1/76 (1.31%)	0	5/254 (1.96%)
Total	31.81%	91.78%	88.15%	35.9%	66.53%

Table 5. Showing the Anova result

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Eimeria tenella	4	147.43	36.8575	583.0232
E. necatrix	4	46.38	11.595	15.7575
E. maxima	4	20.37	5.0925	7.134092
E. mitis	4	15.73	3.9325	10.99156
E. acervulina	4	10.95	2.7375	8.616692
E. brunetti	4	6.93	1.7325	2.960692
Summer	6	31.84	5.306667	41.25899
monsoon	6	91.75	15.29167	397.5781
Winter	6	88.2	14.7	526.5485
Spring	6	36	6	30.652

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3620.923	5	724.1846	7.991649	0.000759	2.901295
Columns	526.1862	3	175.3954	1.935554	0.167233	3.287382
Error	1359.265	15	90.61767			
Total	5506.374	23				

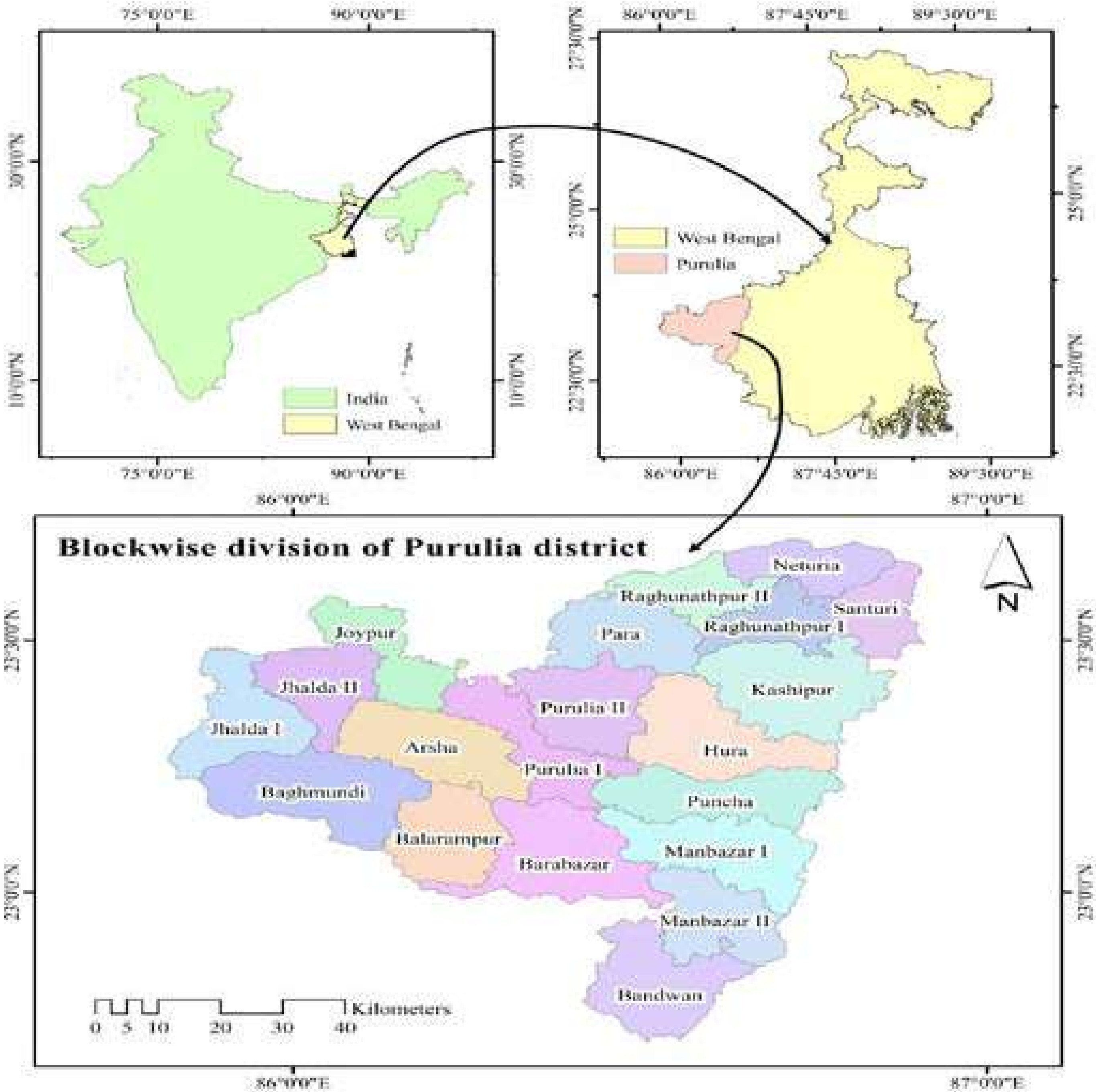

Fig. 1 Map showing the study area.

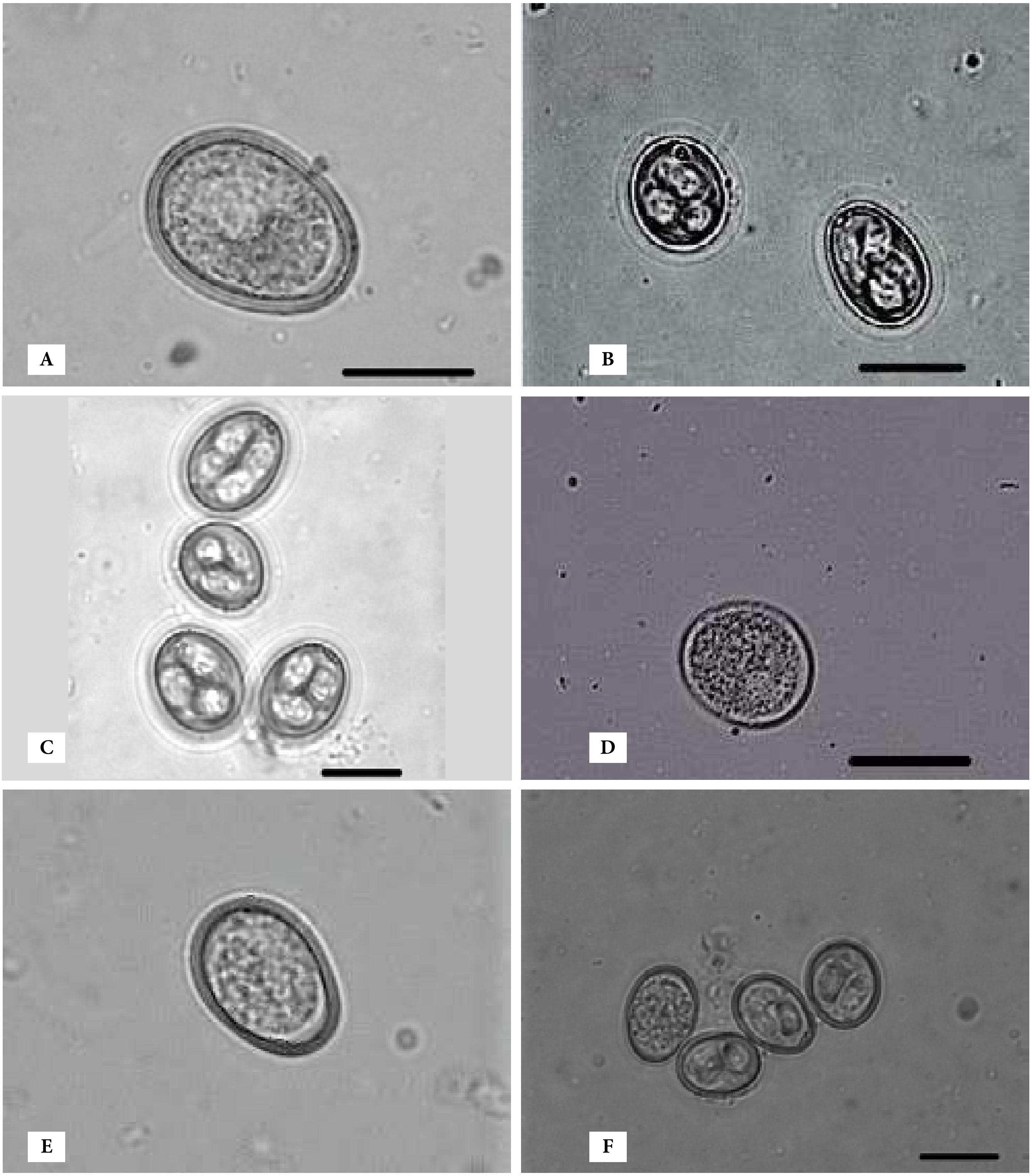

Fig. 2: Species of *Eimeria* found in the Purulia district A. Oocyst of *Eimeria tenella* **B**. Oocyst of *Eimeria necatrix* **C.** Oocyst of *Eimeria maxima* **D.** Oocyst of *Eimeria mitis* **E**. Oocyst of *Eimeria acervulina* **F**. Oocyst of *Eimeria brunetti.*

(Bar = 10 μm)

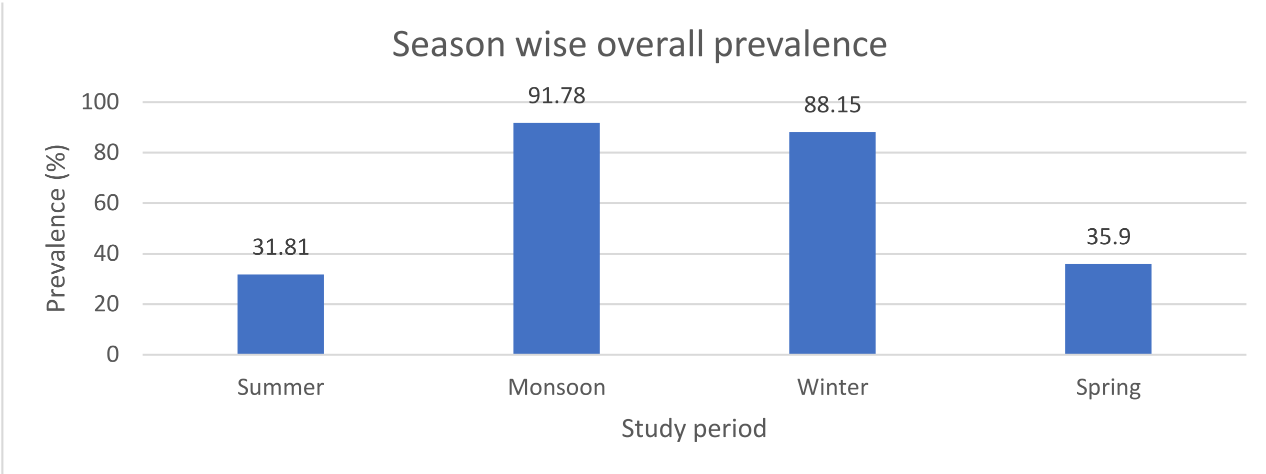

Fig. 3 Seasonal prevalence of coccidiosis in poultry chicken of the Purulia district

Acknowledgement

The first author would like to thank the Department of Zoology of Sidho- Kanho- Birsha University, Purulia for giving permission to do this work. The authors are thankful to Mr Pradyut Bera, JRF, Department of Geography, Sidho-Kanho-Birsha University for providing the study area map and also like to express their sincere gratitude to the veterinary officer of the Purulia district and the poultry farm owners of this district.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Centipede Diversity in Reserved Forests of Southern Kerala: A Preliminary Observation

Rahul Krishnan[1] and G. Prasad[2]*

[1]Research Scholar, Department of Zoology, University of Kerala, India
rahulkrishnanrs@keralauniversity.ac.in
[2]Professor and Head, Department of Zoology, University of Kerala, India
probios1@gmail.com

Abstract

The present study focuses on the southern districts of Kerala, viz., the reserved forests of Thiruvananthapuram, Kollam and Pathanamthitta for the period from May, 2021 to June, 2022. Representatives of three orders belonging to three families, six genera and 14 species have been recorded. The dominant orders reported are *Scolopendromorpha,* followed by *Scutigeromorpha*. Within *Scolopendromorpha*, the genera *Rhysida* and *Digitipes* are the most abundant and enjoy a rich distribution in these areas.

Keywords: Centipedes, *Chilopoda*, *Scolopendromorpha, Scutigeromorpha*

Introduction

The reserved forests of Kerala are home to a vast array of flora and fauna, including the fascinating and diverse group of arthropods known as centipedes. The wide array of soil types with varying degrees of moisture makes perfect habitats for different centipedes (Aswathy *et al., 2017)*. Centipedes are found in almost every corner of the world and have adapted to a wide variety of environments, from deserts to rainforests. In this context, the diversity of centipedes in the reserved forests of Kerala is a topic of great interest and importance. Centipedes are intriguing creatures and play an essential role in maintaining the ecological balance of their respective habitats (Menta and Ramelli, 2020). These arthropods are important predators, feeding on insects and other small invertebrates, and also serve as prey for larger animals such as birds, mammals, and reptiles (Edgecombe and Giribet, 2007). Thus, the study of centipede diversity in the reserved forests of Kerala can help us to better understand the overall biodiversity and ecological dynamics of the region.

The current version of ChiloBase (ChiloBase 2.0, a web-based catalogue of centipedes) accounts for 4114 valid centipede species groups globally from over 5000 published taxonomic references. Vinod Khanna (2008) validated 92 species of Scolopendromorph centipedes in the updated checklist from India. Despite the high diversity of centipedes in the reserved forests of Kerala, there has been lack of studies on their taxonomy, ecology and conservation status. This scarcity is more pronounced in the parts of the Western Ghats that stretch into the southern districts of Kerala. Despite having the largest reserve forest division in Kerala, the district Pathanamthitta is totally unexplored when compared to other districts of Kerala (Sureshan *et al.,*2006). Dhanya and Sureshan (2018) published a checklist of 32 species of Scolopendromorph centipedes from Kerala. This constitutes 35% of the total species recorded from India and 5% of the global record.

Many studies on forest biodiversity have focused on charismatic groups such as mammals, birds, spiders and butterflies, while less attention has been given to understudied taxa such as centipedes. As a result, there is a significant knowledge gap in understanding the diversity, distribution, and ecological role of centipedes in the region (Sureshan *et al.,* 2006). Furthermore, the lack of taxonomic expertise in the region has hindered the identification of many centipede species.

*Author for correspondence
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Methodology

After a pilot survey in selected sites, viz., Ponmudi in Thiruvananthapuram, Thenmala in Kollam and Konni in Pathanamthitta, five random quadrats (10m x 10m each) were laid in each site (Druce *et al.,* 2007). Active sampling methods are adopted to collect the specimens from the selected quadrats seasonally (Pre-monsoon, Monsoon, and Post-Monsoon) from May 2021 to June 2022. The sampling methods include ground collection by flipping rocks and fallen wood, litter sampling, and from vegetation. The captured specimens were brought to the laboratory and fixed using ethyl alcohol. After the microscopic examination using Labomed – Luxeo 6z stereo microscope, the specimens are preserved in 70% ethyl alcohol (Dhanya and Sureshan, 2017).

For the taxonomic identification of Scolopendromorph centipedes, keys by Joshi *et al.,* (2020), Joshi and Edgecombe (2019), Dhanya and Sureshan (2018), Joshi and Edgecombe (2013), Bonato and Minelli (2004), Sureshan *et al.*, (2003), Khanna and Yadav (1997), Yadav (1993), and Würmli (1979) were utilized. The Shannon-Weiner index, dominance index, and Simpson's reciprocal index were used in these areas to compare the alpha diversity across study sites. MS Excel 2016 and Past 4.03 software package were used for the data analysis.

Soil physico-chemical parameters like soil temperature is measured by using a thermometer. For calculating pH, organic carbon and moisture, soil samples from the study sites were brought to the lab. Soil pH is determined by using a digital pH meter, soil organic carbon and moisture content is calculated using standard laboratory procedures.

Results and Discussion

The current study presents the seasonal data of centipede diversity from May 2021 to June 2022. A total of 14 species in six genera, six families and three orders (Table 2) are recorded from the study area during this period. The obtained data indicate the seasonal variation in diversity, as shown in Figure 1 and 2. The highest diversity during the post-monsoon period can be correlated with the optimum soil temperature and active reproduction of centipedes (Lewis, 1972). The highest Shannon-Wiener index value is obtained during the post-monsoon season in all sites (Figure 1) and the minimum in pre-monsoon. Simpson's reciprocal index also shows the same trend (Figure 2). Species like *Cormocephalus dentipes, Digitipes jonesii, Rhysida aspinosa,* and *Rhysida trispinosa* are found throughout the study period and abundant in samples collected. The values of dominance (Figure 3) show a minimum in post-monsoon and high in pre-monsoon. The data substantiate that the post-monsoon season is found to be favourable for centipedes. The post-monsoon data indicates that the highest centipede diversity is found in Thenmala, Kollam (Site 2), followed by Konni, Pathanamthitta (Site 3) (Table 1).

Table 2 shows the physico-chemical properties three sites across three seasons. The vegetations of the study sites include – moist mixed semi-evergreen forest (Site 1 – Ponmudi), West coast semi-evergreen forests (Site 2 – Thenmala), and moist mixed deciduous forest (Site 3 – Konni). The soil temperatures reported in study areas vary across the seasons. The highest temperature was recorded at the site – 2 during the pre-monsoon period and lowest recorded at the site – 3 during monsoon season. The variations in the Shannon Weiner index suggest the influence of temperature on the diversity and showed a positive correlation of $r = 0.98047$ (site 1), $r = 0.25597$ (site 2) and $r = 0.72632$ (site 3). Soil moisture also influences the distribution and diversity of centipedes and followed a positive correlation trend across the seasons ($r = 0.98073$ at site 1, $r = 0.4599$ at site 2, and $r = 0.6072$ at site 3). Hight soil temperature and low moisture content could be the reason behind the low Shannon Weiner index at site – 2 during pre-monsoon period. The soil pH range seems slightly acidic and ranges from 4.3 to 6.49 across the seasons. It showed a significant positive correlation with Shannon diversity index in site 1 and site 3 but insignificant in site 2. In the case of OC (Organic Carbon), site 2 showed a high correlation of $r = 0.9323$, followed by site 1 with $r = 0.4423$ and site 3 with $r = 0.16898$.

Out of nine genera listed in the checklist (Dhanya and Sureshan, 2018) of Scolopendromorph centipedes from Kerala, four genera were found in the present study (Figure 4). The representatives of the genus *Asanada, Scolopendra, Ethmostigmus, Cryptops and Paracryptops are not found. The present study recorded a Scutigeromorph centipede, Thereuopoda longicornis from Thiruvananthapuram. A few specimens of Geophilomorph centipedes belonging to the genus Mecistocephalus were also captured. Scutigeromorpha and Geophilomorpha are the two poorly documented centipede orders with no comprehensive contribution ever done in India. Likewise, m*any species remain undescribed or poorly understood, making it difficult to assess their conservation status or prioritize them for conservation efforts.

Centipedes, like many other organisms, whose diversity and distribution are influenced by the land use patterns. Among the three study sites, Ponmudi (site 1), especially the lower regions contain human settlement. The diversity is not much pronounced in these areas but certain species were found abundant (*Rhysida longipes*, *Digitipes jonesii*). Likewise, extensive monoculture (Teak and Rubber) found in Thenmala (site 2) and Konni (site 3) also show similar trend in diversity. Less disturbed areas with heterogenous habitats showed maximum diversity among study sites. Some species (*Cormocephalus westwoodi, Digitipes chhotanii,* and *Digitipes pruthi)* are exclusively found from these areas. Overall, the lack of centipede diversity studies in the reserved forests of Southern Kerala highlights the need for increased research and conservation efforts for these important arthropods. Such efforts could lead to a better understanding of the role of centipedes in the forest ecosystem and help to ensure their conservation for future generations.

Table 1 – Post-monsoon data of the study areas

	Site 1	**Site 2**	**Site 3**
Shannon-Wiener Index	1.908	2.276	2.15
Dominance	0.1719	0.1105	0.1255
Evenness	0.749	0.8852	0.8588

Site 1 – Ponmudi, Thiruvananthapuram

Site 2 – Thenmala, Kollam

Site 3 – Konni, Pathanamthitta.

Table 2 – List of species found in the present study

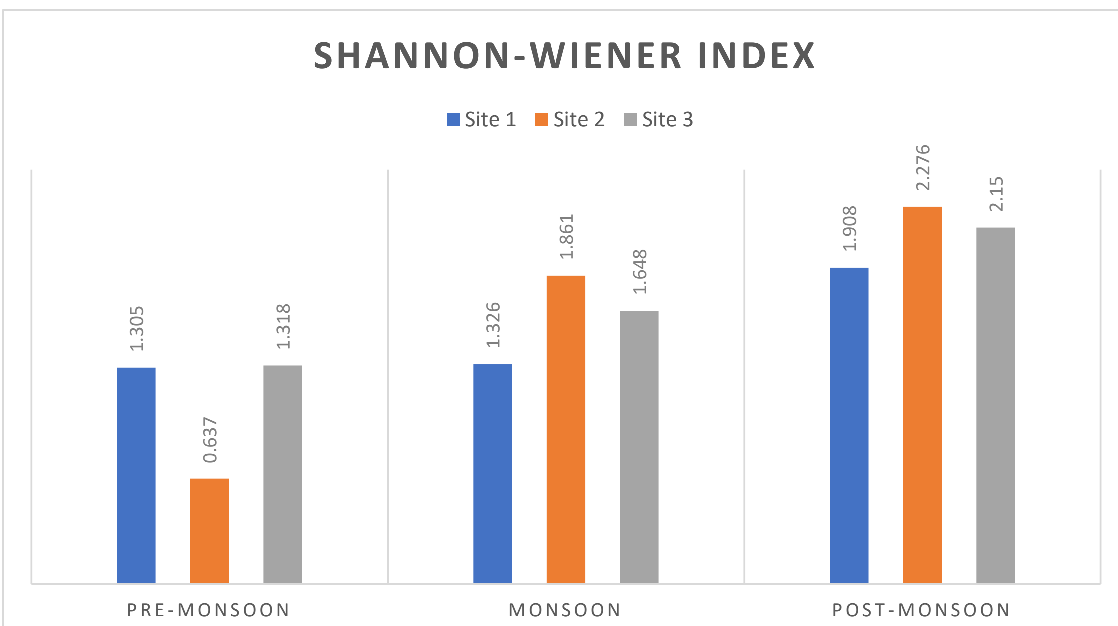
Order – *Scolopendromorpha*	
1	*Cormocephalus dentipes*
2	*Cormocephalus westwoodi*
3	*Digitipes barnabasi*
4	*Digitipes chhotanii*
5	*Digitipes coonoorensis*
6	*Digitipes jonesii*
7	*Digitipes pruthi*
8	*Otostigmus gravelyi*
9	*Rhysida aspinosa*
10	*Rhysida longipes*
11	*Rhysida pazhuthara*
12	*Rhysida trispinosa*
Order – *Scutigeromorpha*	
13	*Thereuopoda longicornis*
Order – *Geophilomorpha*	
14	*Mecistocephalus sp.*

Table 3 – Mean Shannon Diversity index and soil physico-chemical properties of three sites across three seasons.

Sites	Season	Shannon Index	Temperature	pH	OC %	SM %
Site 1	PrM	1.305	26^0 C	5.77	3.8	4.89
Site 1	M	1.326	23^0 C	4.3	2.73	30.34
Site 1	PsM	1.908	$24.5\,^0$ C	4.97	2.22	16.27
Site 2	PrM	0.6365	27.5^0 C	6.49	3.13	1.35
Site 2	M	1.861	22.7^0 C	4.52	2.77	37.61
Site 2	PsM	2.276	23.5^0 C	5.23	3.21	20.96
Site 3	PrM	1.318	26.4^0 C	5.51	2.26	2.73
Site 3	M	1.648	21.8^0 C	4.62	2.8	27.11
Site 3	PsM	2.15	24^0 C	4.95	3.12	19.47

Site 1 – Ponmudi, Thiruvananthapuram; **Site 2** – Thenmala, Kollam; **Site 3** – Konni, Pathanamthitta. **PrM** – pre-monsoon; **M** – monsoon; **PsM** – post-monsoon; **OC** – organic carbon; **SM** – soil moisture.

Figure 1 – Seasonal variations of Shannon-Wiener index across Site 1, Site 2 and Site 3

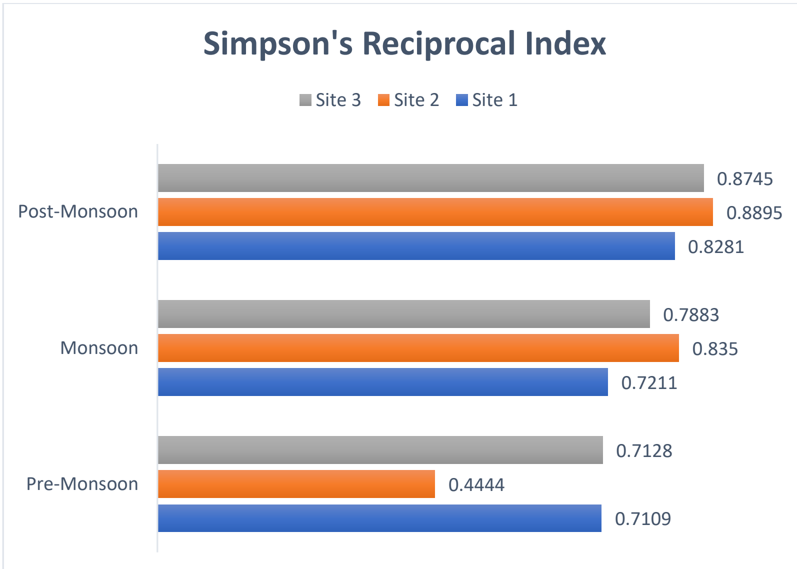


Site 1 – Ponmudi, Thiruvananthapuram

Site 2 – Thenmala, Kollam

Site 3 – Konni, Pathanamthitta.

Figure 2 – Seasonal variations of Simpson's Reciprocal index across Site 1, Site 2 and Site 3

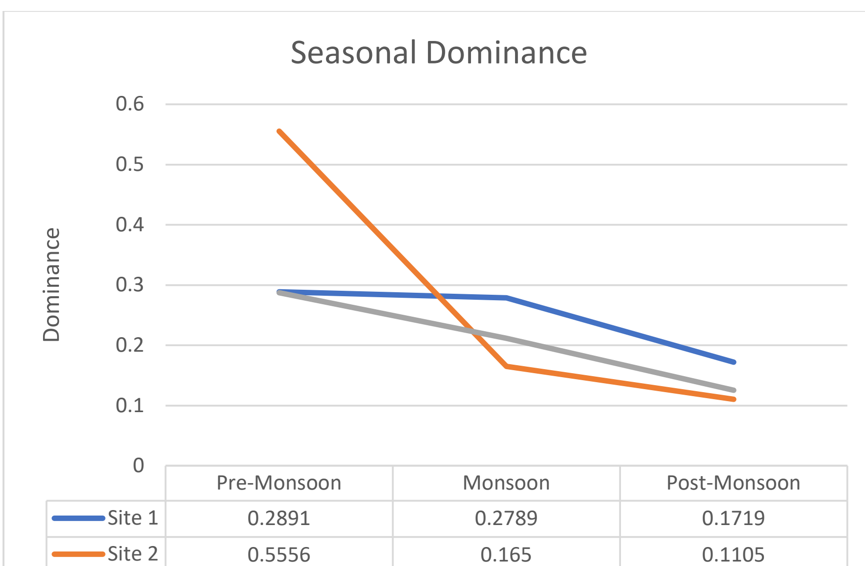


Site 1 – Ponmudi, Thiruvananthapuram

Site 2 – Thenmala, Kollam

Site 3 – Konni, Pathanamthitta.

Figure 3 – Seasonal variations of Dominance across Site 1, Site 2, and Site 3

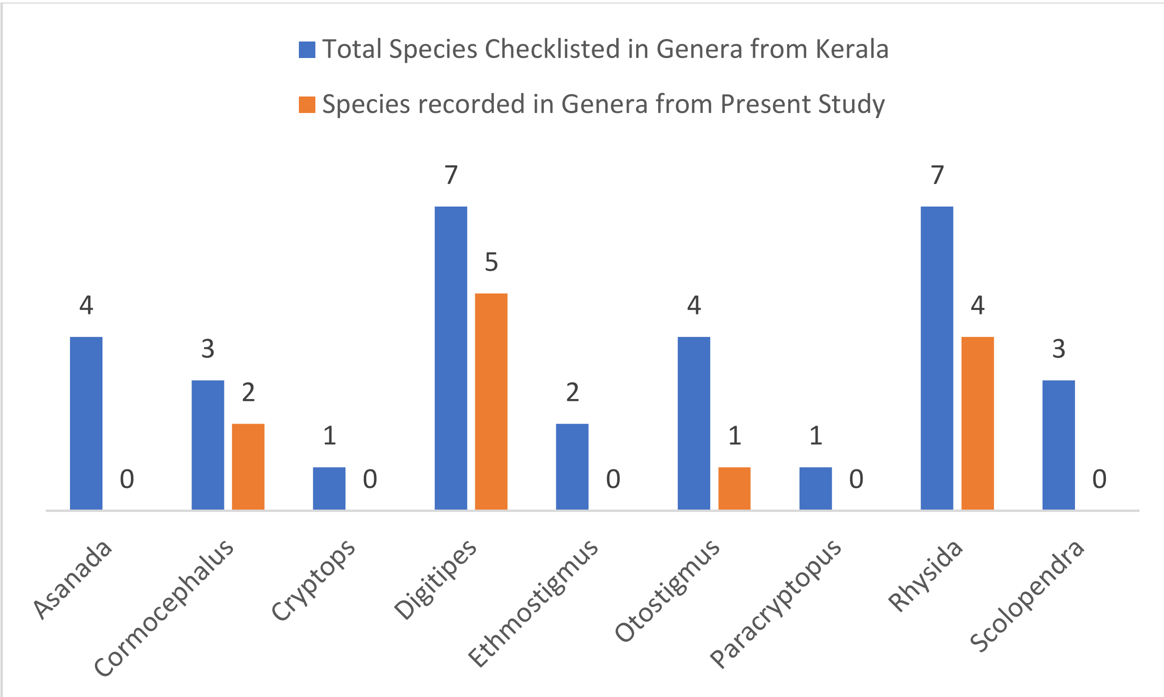


Site 1 – Ponmudi, Thiruvananthapuram

Site 2 – Thenmala, Kollam

Site 3 – Konni, Pathanamthitta.

Figure 4 – Comparison of total Genera (Scolopendromorpha) checklisted in Kerala with present study records.



Acknowledgement

Authors are grateful to Dr Gregory D. Edgecombe, Natural History Museum, London; Dr Jahnavi Joshi, Centre for Cellular and Molecular Biology CSIR, Hyderabad, Telangana, India for the immense help in the identification and for providing valuable resources. Authors also extend sincere gratitude to UGC for providing the funds (JRF Fellowship) for conducting the research. The fieldwork assistance by P. Nandu, S. Anaswara, and A. Muhammed is gratefully acknowledged.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Diversity and spatial distribution of molluscs along the salinity gradient in Ashtamudi Lake Ramsar site, Kerala, India

Chinnu Vishwanathan* and Biju Kumar, A.
Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram - 695581

Abstract

Study of the diversity and spatial distribution of molluscs along salinity gradient in Ashtamudi Lake recorded the presence of 83 species with one polyplacophoran, 41 gastropods, 37 bivalves and four cephalopods. The species diversity in various salinity zones was in the order: saline zone- 80 species > estuarine zone- 28 species > freshwater zone- 14 species. The report includes three species new to the west coast of India: *Assiminea woodmasoniana* G. Nevill, 1880, *Rugalucina vietnamica* (Zorina, 1978) and *Platevindex martensi* (Plate, 1893). Species: such as *Chiton granoradiatus* Leloup, 1937; *Clithon sowerbianum* (Récluz, 1843); *Littoraria pallescens* (Philippi, 1846); *Acteocina decorata* (Pilsbry, 1904); *Alaona ala* (Hanley, 1845) and *Serratina siamensis* (E. von Martens, 1860) are new to Kerala. The paper analyses the alpha and beta diversity of molluscs in the Ashtamudi Lake, Kerala.

Keywords: Ashtamudi, Salinity, Estuary, Gastropods, Bivalves, Diversity index

Introduction

Estuaries are a unique class of transient, highly dynamic, productive aquatic habitats that act as the ecotone between terrestrial, fresh water and marine ecosystems (Shetye, 2011). Being semi-enclosed water bodies, the sea water entering the estuaries from one side is diluted by the fresh water from the other side, making these estuaries sites of spatial and temporal fluctuations in variables like salinity and community structure (Elliott and McLusky, 2002). The major environmental parameter determining the diversity and abundance of different organisms in the estuaries is water salinity, which varies along the longitudinal profile, transverse profile, depth, tides, and seasonally (Chertoprud *et al.*, 2013).

Macrobenthic fauna comprises a substantial portion of the estuarine biomass (Bailey-Brock *et al.,* 2002) and molluscs constitute the major component of the estuarine macrobenthic communities. Estuarine molluscs inhabit different feeding niches and are excellent ecological indicators (Asuquo and Anyanwu, 2018). Since they are highly sensitive to the changes in their natural environment, they are ideal organisms for studying the relationship between species distribution and variables like salinity (Montagna and Kalke, 1995). Studies on estuarine molluscs of India began with the works of Stoliczka (1869), followed by contributions from Preston (1916), Desai and Krishnankutty (1967), Rao *et al.* (1983), Bhat and Neelakantan (1984), Nair *et al.* (1984), Mandal and Nandi (1989), Mohapatra (2001, 2008), Laxmilatha *et al.* (2006), Dey (2008), Dev Roy *et al.* (2009), Venkatesan *et al.* (2010), Behera and Nayak (2013), Vanmali and Jadhav (2015) and Tudu *et al.* (2018). Distribution of molluscs along the salinity gradient in Indian estuaries was studied by Gopal and Chauhan (2006), Roy and Nandi (2012), Roy *et al.* (2013), Jayachandran *et al.* (2019) and Rehitha *et al.* (2022).

The present study analyses the diversity and spatial distribution of molluscs in Ashtamudi Lake, Kerala along its salinity gradient. Studies on molluscs of the Ashtamudi estuary have been initiated by Divakaran *et al.* (1981), Nair *et al.* (1984), Velayudhan *et al.* (1998) Kripa and Mohammed Salih (1999), Raghunathan (2007), Vimalraj *et al.* (2014),

*Author for correspondence : chinnu@keralauniversity.ac.in
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Venkatesan *et al.* (2015), Arathi *et al.* (2018), and Ravinesh *et al.* (2021), however none of these works have considered the effect of salinity gradient on the distribution of molluscan species in Ashtamudi Lake.

Materials and Methods

Ashtamudi Lake in Kollam district of Kerala, India (8°59 N 76°36 E) is the deepest and the second largest backwater system in Kerala, having an area of 61.4 km^2 and a maximum depth of 6.4 meters at the conflux where the lake merges with the Arabian Sea (Anoop *et al.*, 2008; Chinnadurai *et al.*, 2016). Ashtamudi Lake was designated as a Ramsar site in November 2002. The Kallada River, a mountainous river from the Western Ghats discharges into the Ashtamudi Lake (Jennerjahn *et al.*, 2008). The study was conducted in the Ashtamudi estuary from January 2022 to January 2023. Six sampling sites were selected randomly based on increasing salinity from Koivila where the Kallada River joins the lake, to Neendakara Barmouth, where the estuary discharges into the Arabian Sea (Figure1). The sampling sites were divided into three distinct salinity zones based on the salinity gradient, namely the freshwater zone (salinity of 5 ppt - 14 ppt), estuarine zone (salinity, 15 ppt - 24 ppt) and saline zone (salinity of 25 ppt - 34 ppt). Koivila and Peringalam were taken as the freshwater zone, Ashtamudi and Tholukadavu as the estuarine zone and Dalavapuram and Neendakara Barmouth as the saline zone (Figure 1). The salinity of the water at each site was estimated using hand-held Refractometer and standard methods of APHA (2017). The specimens were collected by direct search in low tide, hand picking, hand lift netting and grab sampling. A Van veen grab sampler collected sediment up to 20 cm depth of roughly 0.1m^2 area. The quadrat method was also employed with 10 m ×10 m grid using 1×1 m^2 quadrats. The sediment collected during grab sampling was washed with lake water on the field, and the molluscan species were separated using sieves of varying mesh sizes. The fresh specimens of polyplacophorans, gastropods, bivalves and cephalopods were cleaned, washed, photographed and preserved in 70% ethanol. The empty shells of gastropods and bivalves were preserved dry (Geiger *et al.*, 2007; Edward *et al.*, 2022; Ravinesh and Biju Kumar, 2022). The collected specimens were identified with the help of taxonomic publications (Oliver, 1992; Bosch *et al.*, 1995; Subba Rao, 2003, 2017; Robin, 2008; Huber, 2010, 2015; Eichhorst, 2016; Goulding *et al.*, 2021; Edward *et al.*, 2022). All scientific names were finalized following the website World Register of Marine Species (http://www.marinespecies.org). Statistical analyses were done using PAST 4.3 and SPSS Statistics 24.

Results and Discussion

The present study recorded 83 molluscan species classified under four classes (Polyplacophora, Gastropoda, Bivalvia and Cephalopoda), seven subclasses, 20 orders, 44 families and 72 genera. Class Gastropoda has the highest diversity with 41 species, followed by Bivalvia (37 species), Cephalopoda (four species) and Polyplacophora (one species) (Table 1). Earlier, 119 molluscan species classified under three classes have been reported from the Ashtamudi estuary (Ravinesh *et al.* 2021).

Species like *Assiminea woodmasoniana* G. Nevill, 1880, *Rugalucina vietnamica* (Zorina, 1978) and *Platevindex martensi* (Plate, 1893) are recorded from the lake and are first observation records to the West Coast of India also (Table 1, Figure 2). Species like *Chiton granoradiatus* Leloup, 1937, *Clithon sowerbianum* (Récluz, 1843), *Littoraria pallescens* (Philippi, 1846), *Acteocina decorata* (Pilsbry, 1904), *Alaona ala* (Hanley, 1845) and *Serratina siamensis* (E. von Martens, 1860) are also recorded from the lake and happens to be first time from Kerala (Table 1, Figure 2).

Based on the salinity gradient in Ashtamudi Lake, the molluscan species diversity was highest in the saline zone, with 80 species comprising of one polyplacophoran, 39 gastropods, 36 bivalves and four cephalopods. The estuarine zone reported 28 species (16 gastropods and 12 bivalves), and the freshwater zone with 14 species (nine gastropods and five bivalves), respectively. Roy and Nandi (2012) documented 48 molluscan species along the salinity gradient of Hugli- Matla Estuary with 39 gastropods and nine bivalves. The alien mussel, *Mytella strigata* (Hanley, 1843) has been established successfully in all the three salinity zones in Ashtamudi Lake. Studies by Yuan *et al.* (2010) shows wide range salinity tolerance exhibited by *Mytella strigata* (salinity ranging from 2 ppt - 40 ppt). A total of 11 species, represented by seven gastropods and four bivalves were recorded commonly from all three zones indicating that these species show a wider range of tolerance to salinity. Species like *Telescopium telescopium* (Linnaeus, 1758), *Melampus lividus* (Deshayes, 1830), *Cassidula nucleus* (Gmelin, 1791), *Pythia plicata* (Férussac, 1821) were recorded from the saline zone. These species are exclusively mangrove-associated species and they were collected live from mangrove patches adjoining the Neendakara Barmouth region.

For analysing the alpha diversity of the three zones, diversity indices like Shannon-Weiner diversity index, Margalef-richness index, Simpson- dominance index and Pielou's evenness index were calculated (Table 2). Shannon- Weiner index showed the highest value of 3.221 in the saline zone, followed by the estuarine zone (2.58) and the freshwater zone (2.083). According to Bath *et al.* (1999), the high diversity of molluscs is correlated with an increase in salinity. The Margalef species richness values were 5.732 for the saline zone, 3.095 for the estuarine zone and 1.705 for the freshwater zone. The Simpson-dominance index recorded a high value of 0.945 in the saline zone, accompanied by 0.895 in the estuarine zone and 0.86 at the freshwater zone. Pielou's evenness index showed a high value of 0.729 in the freshwater zone, indicating more even distribution of species and comparatively less values of 0.628 in the estuarine zone and 0.596 in the saline zone, indicating less even distribution of species as the saline zone is dominated only by the euryhaline species.

For beta diversity, the Whittaker diversity index was computed (Table 3), and it documented the lowest value of 0.365 between the saline and estuarine zone, indicating a high level of similarity between these two zones. Among freshwater and estuarine zones, the beta diversity value was 0.375 and the highest beta diversity value of 0.660 was reported between freshwater and saline zones, indicating the least level of similarity shared by the freshwater zone and saline zone. The dendrogram (hierarchical clustering- group average linkage) of the molluscan families assemblages is shown in Figure 3. The results shows that families like Chitonidae, Trochidae, Chilodontaidae, Planaxidae, Rostellariidae, Turritellidae, Pisaniidae, Conidae, Turridae, Haminoeidae, Pinnidae, Anomiidae, Ungulinidae, Cardiidae, Sepiolidae, Sepiidae and Loliginidae are clustered separately. This may be because species in these families are reported only from the saline zone.

The present survey was carried out for a short period covering only six random sites. Extensive studies covering more sites for a longer period are necessary to understand better the spatial distribution of molluscs along the salinity gradient and the β diversity index of Ashtamudi Lake. Considering the lake as an Ramsar site, its protection and conservation is imperative especially on the alien species of molluscs as well as pollution point of view.

Table 1: List of molluscs recorded from the three salinity zones in the Ashtamudi estuary

Sl.No	Classification/Name of species	Salinity Zones		
		Freshwater Zone	Estuarine Zone	Saline Zone
1	**CLASS: POLYPLACOPHORA** **FAMILY: CHITONIDAE** *Chiton granoradiatus* Leloup, 1937	-	-	+
2	**CLASS: GASTROPODA** **FAMILY: TROCHIDAE** *Umbonium vestiarium* (Linnaeus, 1758)	-	-	+
3	**FAMILY: CHILODONTAIDAE** *Euchelus asper* (Gmelin, 1791)	-	-	+
4	**FAMILY: NERITIDAE** *Clithon oualaniense* (Lesson, 1831)	+	+	+
5	*Clithon sowerbianum* (Récluz, 1843)	+	+	+
6	*Neripteron violaceum* (Gmelin, 1791)	+	+	+
7	*Nerita albicilla* Linnaeus, 1758	-	-	+

Sl.No	Classification/Name of species	Salinity Zones		
		Freshwater Zone	Estuarine Zone	Saline Zone
8	**FAMILY: PHENACOLEPADIDAE** *Plesiothyreus cinnamomeus* (A. Gould, 1846)	+	+	+
9	**FAMILY: PACHYCHILIDAE** *Faunus ater* (Linnaeus, 1758)	+	-	-
10	**FAMILY: PLANAXIDAE** *Planaxis sulcatus* (Born, 1778)	-	-	+
11	**FAMILY: POTAMIDIDAE** *Pirenella cingulata* (Gmelin, 1791)	+	+	+
12	*Telescopium telescopium* (Linnaeus, 1758)	-	-	+
13	**FAMILY: CALYPTRAEIDAE** *Desmaulus extinctorium* (Lamarck, 1822)	-	-	+
14	*Ergaea walshi* (Reeve, 1859)	-	+	+
15	**FAMILY: LITTORINIDAE** *Littoraria pallescens* (Philippi, 1846)	+	+	+
16	*Littoraria undulata* (Gray, 1839)	-	-	+
17	**FAMILY: ROSTELLARIIDAE** *Tibia curta* (G. B. Sowerby II, 1842)	-	-	+
18	**FAMILY: TURRITELLIDAE** *Turritella acutangula* (Linnaeus, 1758)	-	-	+
19	**FAMILY: NATICIDAE** *Eunaticina papilla* (Gmelin, 1791)	-	-	+
20	*Notocochlis gualteriana* (Récluz, 1844)	-	-	+
21	*Paratectonatica tigrina* (Röding, 1798)	-	-	+
22	**FAMILY: ASSIMINEIDAE** *Assiminea woodmasoniana* G. Nevill, 1880	+	+	+
23	**FAMILY: BURSIDAE** *Bufonaria crumena* (Lamarck, 1816)	-	+	+
24	*Bufonaria echinata* (Link, 1807)	-	+	+
25	**FAMILY: BABYLONIIDAE** *Babylonia spirata* (Linnaeus, 1758)	-	-	+
26	*Babylonia zeylanica* (Bruguière, 1789)	-	-	+

Sl.No	Classification/Name of species	Salinity Zones		
		Freshwater Zone	Estuarine Zone	Saline Zone
27	**FAMILY: NASSARIIDAE** *Nassodonta insignis* H. Adams, 1867	+	-	-
28	*Nassarius jacksonianus* (Quoy & Gaimard, 1833)	-	+	+
29	**FAMILY: PISANIIDAE** *Cantharus tranquebaricus* (Gmelin, 1791)	-	-	+
30	**FAMILY: MURICIDAE** *Indothais blanfordi* (Melvill, 1893)	-	+	+
31	*Indothais lacera* (Born, 1778)	-	-	+
32	*Murex pecten* Lightfoot, 1786	-	-	+
33	**FAMILY: CONIDAE** *Conus inscriptus* Reeve, 1843	-	-	+
34	**FAMILY: CLAVATULIDAE** *Turricula javana* (Linnaeus, 1767)	-	+	+
35	*Turricula tornata* (Dillwyn, 1817)	-	+	+
36	**FAMILY: TURRIDAE** *Unedogemmula indica (*Röding, 1798)	-	-	+
37	**FAMILY: TORNATINIDAE** *Acteocina decorata* (Pilsbry, 1904)	-	+	+
38	**FAMILY: HAMINOEIDAE** *Haminoea pemphis* (Philippi, 1847)	-	-	+
39	**FAMILY: ELLOBIIDAE** *Melampus lividus* (Deshayes, 1830)	-	-	+
40	*Cassidula nucleus* (Gmelin, 1791)	-	-	+
41	*Pythia plicata* (*Férussac, 1821)*	-	-	+
42	**FAMILY: ONCHIDIIDAE** *Platevindex martensi* (Plate, 1893)	-	+	+
43	**CLASS: BIVALVIA** **FAMILY: MYTILIDAE** *Arcuatula senhousia* (Benson, 1842)	-	-	+
44	*Brachidontes pharaonis* (P. Fischer, 1870)	-	-	+
45	*Byssogerdius striatulus* (Hanley, 1843)	-	-	+
46	*Modiolus modulaides* (Ro¨ding, 1798)	-	-	+

Sl.No	Classification/Name of species	Salinity Zones		
		Freshwater Zone	Estuarine Zone	Saline Zone
47	*Mytella strigata* (Hanley, 1843)	+	+	+
48	*Perna perna* (Linnaeus, 1758)	-	-	+
49	*Perna viridis* (Linnaeus, 1758)	-	-	+
50	**FAMILY: ARCIDAE** *Anadara inaequivalvis* (Bruguie`re, 1789)	-	-	+
51	*Anadara indica* (Gmelin, 1791)	-	+	+
52	*Didimacar tenebrica* (Reeve, 1844)	-	-	+
53	*Tegillarca aequilatera* (Dunker, 1868)	-	-	+
54	**FAMILY: PINNIDAE** *Pinna bicolor* Gmelin, 1791	-	-	+
55	**FAMILY: ISOGNOMONIDAE** *Isognomon isognomum* (Linnaeus, 1758)	-	+	+
56	**FAMILY: OSTREIDAE** *Magallana bilineata* (Röding, 1798)	+	+	+
57	*Saccostrea cuccullata* (Born, 1778)	+	+	+
58	**FAMILY: ANOMIIDAE** *Anomia sp.*	-	-	+
59	**FAMILY: LUCINIDAE** *Euanodontia ovum* (Reeve, 1850)	-	-	+
60	*Rugalucina vietnamica* (Zorina, 1978)	-	-	+
61	**FAMILY: UNGULINIDAE** *Felaniella cuneata* (Spengler, 1798)	-	-	+
62	*Diplodonta sp.*	-	-	+
63	**FAMILY: CARDIIDAE** *Vepricardium coronatum* (Schröter, 1786)	-	-	+
64	**FAMILY: CYRENIDAE** *Villorita cyprinoides* (Gray, 1825)	+	+	-
65	**FAMILY: PSAMMOBIIDAE** *Hiatula diphos* (Linnaeus, 1771)	-	-	+
66	*Gari elongata* (Lamarck, 1818)	-	-	+
67	**FAMILY: TELLINIDAE** *Alaona ala* (Hanley, 1845)	-	+	+

Sl.No	Classification/Name of species	Salinity Zones		
		Freshwater Zone	Estuarine Zone	Saline Zone
68	*Jitlada philippinarum* (Hanley, 1844)	-	-	+
69	*Nitidotellina unifasciata* (G. B. Sowerby II, 1867)	-	-	+
70	*Serratina siamensis* (E. von Martens, 1860)	-	+	+
71	**FAMILY: MACTRIDAE** *Standella pellucida* (Gmelin, 1791)	-	+	+
72	**FAMILY: VENERIDAE** *Anomalodiscus squamosus* (Linnaeus, 1758)	-	+	+
73	*Dosinia labiosa* Römer, 1862	-	-	+
74	*Marcia opima* (Gmelin, 1791)	-	-	+
75	*Marcia recens* (Holten, 1802)	-	+	+
76	*Meretrix aurora* (Hornell, 1917)	-	-	+
77	*Meretrix casta* (Gmelin, 1791)	-	-	+
78	*Timoclea cochinensis* (G. B. Sowerby II, 1853)	-	-	+
79	**FAMILY: PHOLADIDAE** *Martesia nairi* (Turner & Santhakumaran, 1989)	+	+	+
80	**CLASS: CEPHALOPODA** **FAMILY: SEPIOLIDAE** *Euprymna berryi* Sasaki, 1929	-	-	+
81	**FAMILY: SEPIIDAE** *Sepiella inermis* (Van Hasselt, 1835)	-	-	+
82	**FAMILY: LOLIGINIDAE** *Uroteuthis (Photololigo) duvaucelii* (d'Orbigny, 1835)	-	-	+
83	*Uroteuthis (Photololigo) singhalensis* (Ortmann, 1891)	-	-	+

Table 2: α diversity indices of the three salinity zones.

Biodiversity Indices	Freshwater zone	Estuarine zone	Saline zone
Shannon- Weiner Index	2.083	2.58	3.221
Margalef Richness Index	1.705	3.095	5.732
Simpson Dominance Index	0.86	0.895	0.945
Pielou's Evenness Index	0.729	0.628	0.596

Table 3: β diversity of the molluscan species between the three salinity zones.

Whittaker beta diversity index			
	Freshwater zone	Estuarine zone	Saline zone
Freshwater zone	0		
Estuarine zone	0.375	0	
Saline zone	0.660	0.365	0

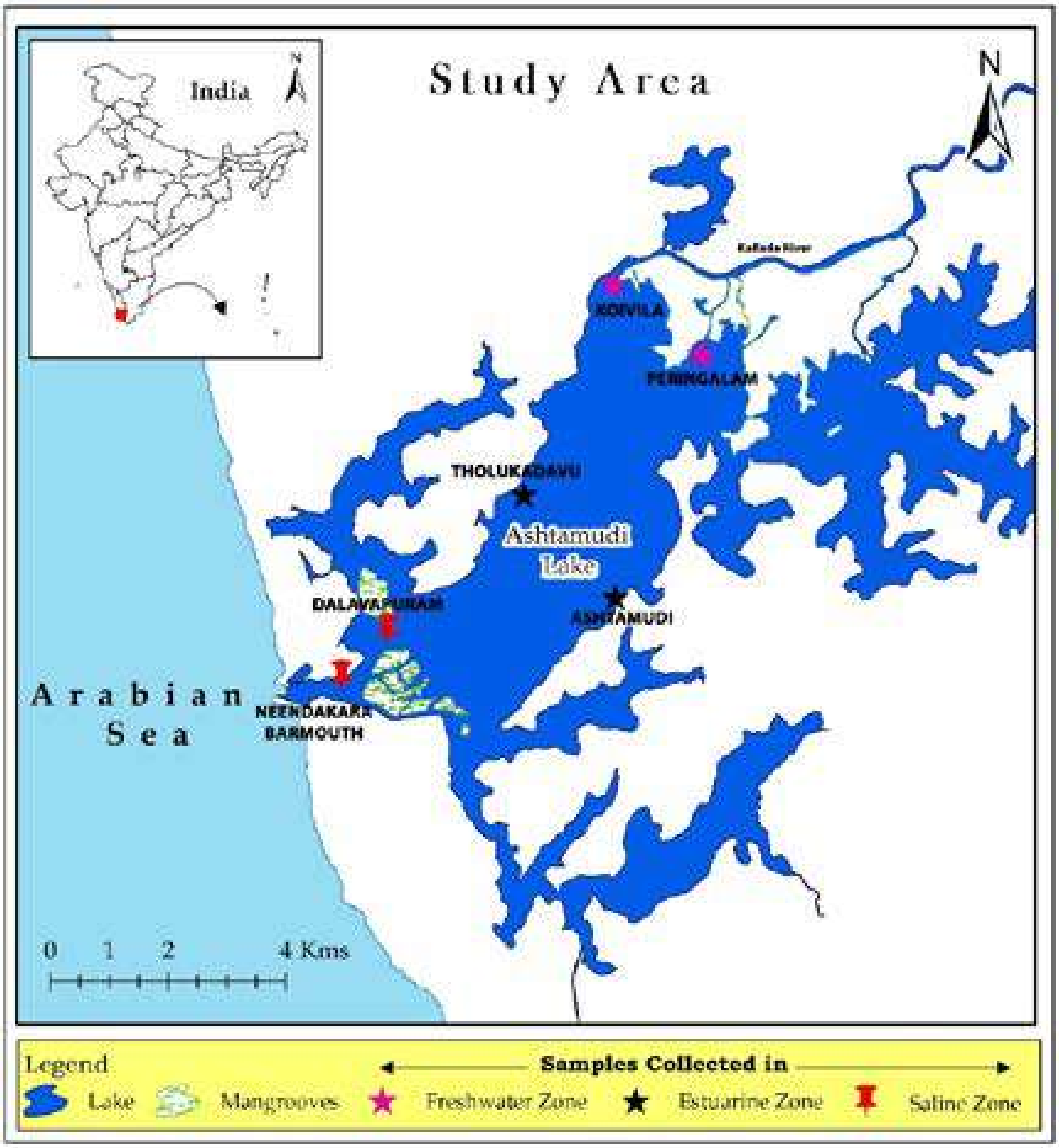

Figure 1: Map of Ashtamudi Lake showing the study sites.

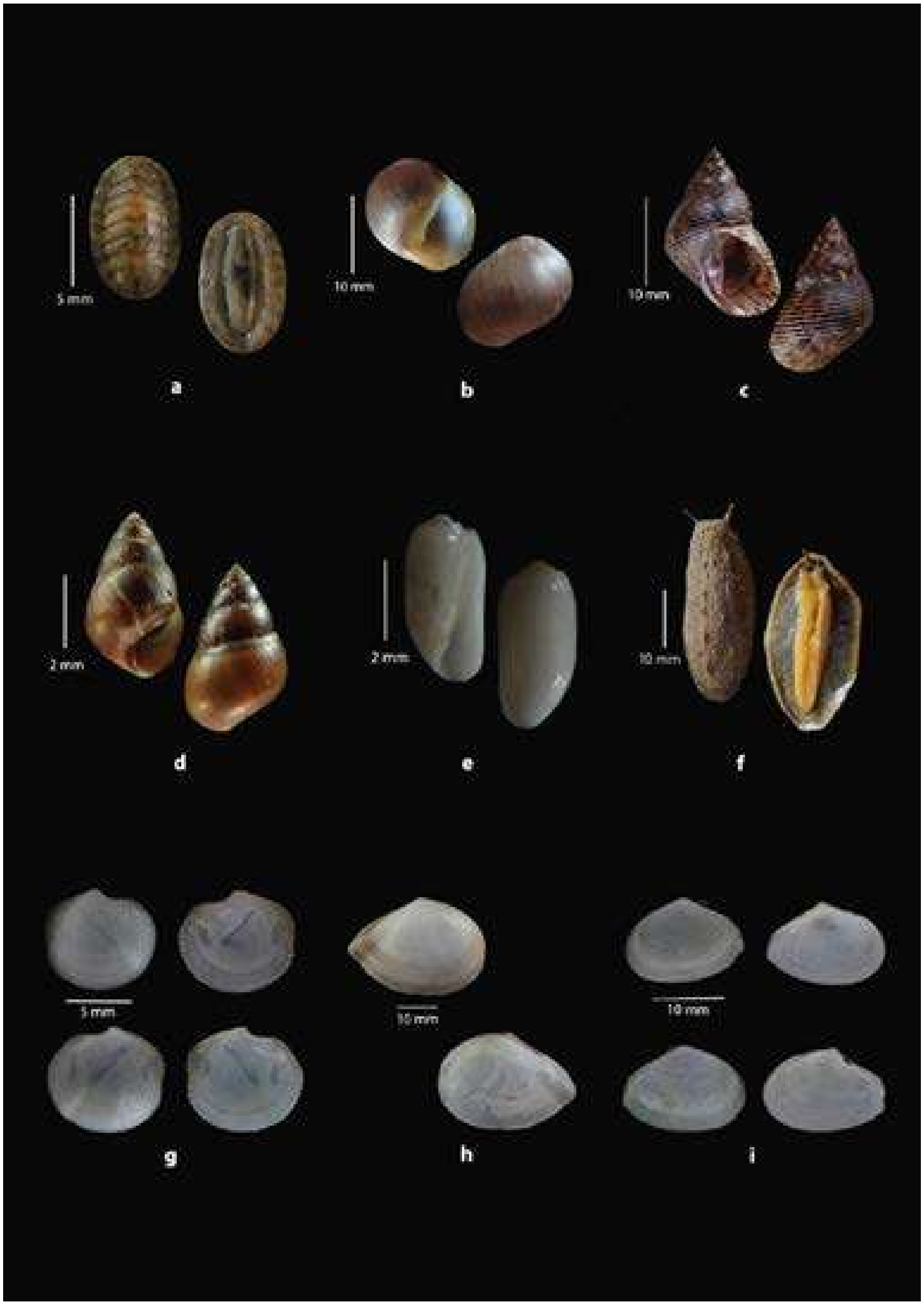

Figure 2: **a** *Chiton granoradiatus* Leloup, 1937; **b** *Clithon sowerbianum* (Récluz, 1843); **c** *Littoraria pallescens* (Philippi, 1846); **d** *Assiminea woodmasoniana* G. Nevill, 1880; **e** *Acteocina decorata* (Pilsbry, 1904); **f** *Platevindex martensi* (Plate, 1893); **g** *Rugalucina vietnamica* (Zorina, 1978); **h** *Alaona ala* (Hanley, 1845); **i** *Serratina siamensis* (Martens, 1860) (Photographs by: Chinnu Vishwanathan).

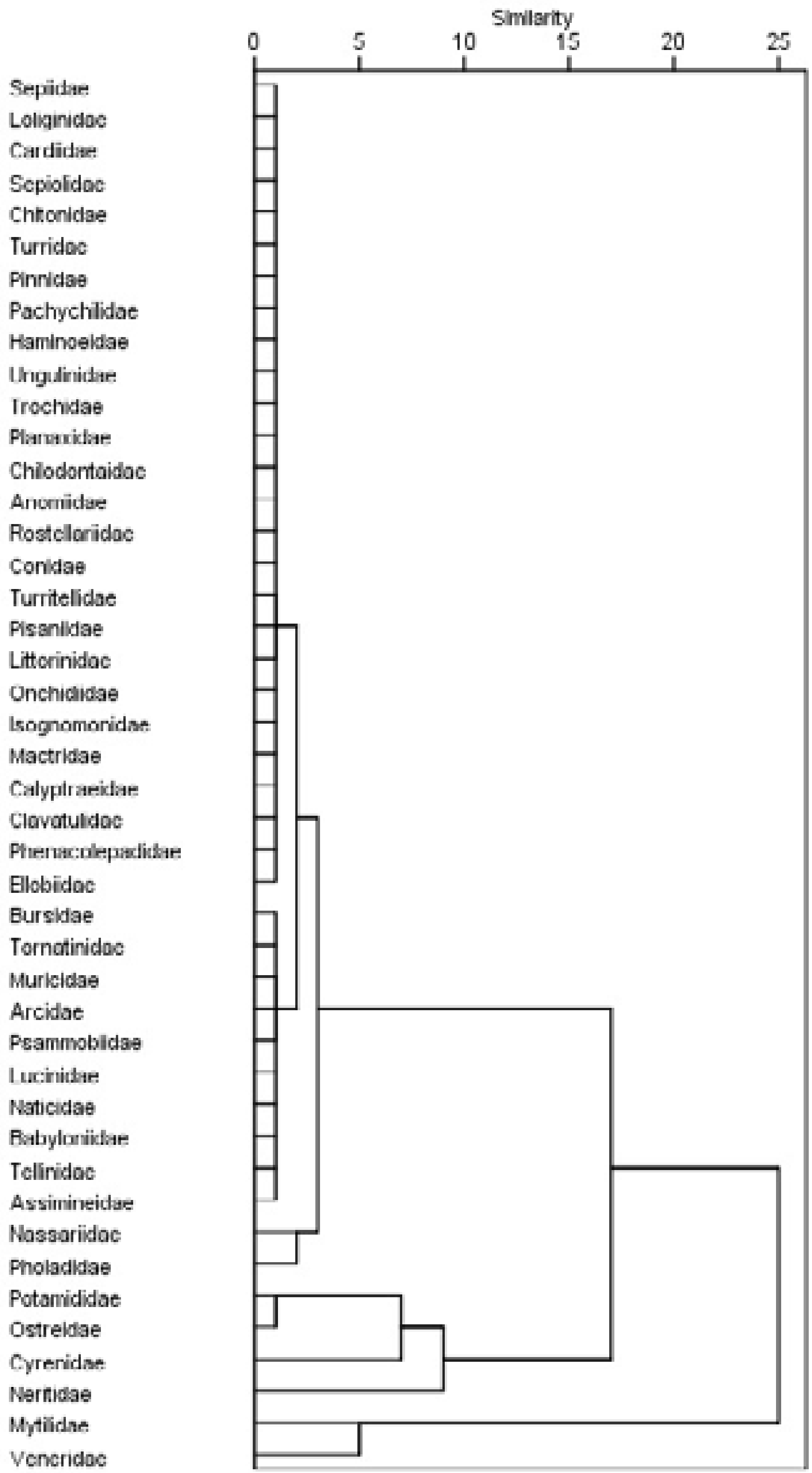

Figure 3: Dendrogram of hierarchical clustering (group average linkage) of the molluscan families in Ashtamudi Lake.

Acknowledgements

The authors are grateful to the Department of Aquatic Biology and Fisheries, University of Kerala, for providing all the facilities and Chinnu Vishwanathan is thankful to University Grants Commission for providing Joint CSIR-UGC Senior Research Fellowship for carrying out the study.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Diversity of Mollusca (Gastropoda) Along Intertidal Rocky Shores of Thiruvananthapuram District, Kerala Coast

Preetha Karnaver[1*]., Ajin Madhavan[2]., Ravinesh R[3]., Reshmi, R[4]. Biju Kumar. A[5] and Hari Kumar., B[6]

[1]*Department of Zoology, Christian College,Chengannur, Alappuzha 689122, Kerala, India*
**Email-: karnaver1@gmail.com*
[2]*Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Cochin – 682016, Kerala, India.*
[3]*Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Atal Bhavan, LNG Road, Puthuvypu, Ochanthuruthu P.O, Kochi-682508*
[4]*Department of Zoology, NSS College, Pandalam, Pathanamthitta 689501, Kerala, India*
[5]*Department of Aquatic Biology & Fisheries, University of Kerala, Thiruvananthapuram 695581, Kerala,*
[6] *KNM NSS ayurveda hospital, Vallamkulam, Pathanamthitta, Kerala, India*

Abstract

An assessment of intertidal rocky shore biodiversity of gastropods along Mulloor, Kovalam and Vizhinjam sites of Thiruvananthapuram district Kerala coast is done during three different seasons during 2020- 2022, and identified 108 species across 6 subclasses, 9 orders, 20 super families, 27 families and 61 genera. Neogastropoda was the most species- rich order (50 species) followed by orders Littoriimorpha (30 species), Trochida (7 species), Cycloneritida (7 species), Lepettellida (5 species), Patellogastropoa (2 species), Cephalaspidea (2 species) and Seguenziida (1 species). Family Muricidae was having maximum species diversity (18 species) followed by family Conidae (17 species). Among the 108 species observed in the study, 50 were commonly occurring, whereas 22 were uncommon and 36 were rare. *Littorara undulata* was the most abundant species observed during the study. A site - wise comparison of the three study sites revealed that Vizhinjam (84 species) was having maximum species diversity followed by Mulloor (82 species) and Kovalam (61 species). An assessment of diversity indices such as Shannon-Wiener index (H) Simpson Dominance Index (D), Evenness index (E) gave significant values indicating very high diversity of gastropods along the study sites. The present study provides information on the gastropod resources of the selected study area, which forms the baseline data for future ecological studies.

Keywords: Biodiversity, Mollusca, Gastropoda, Intertidal rocky, species.

Introduction

Rocky intertidal zone provides wide variety of marine species, serves as a feeding and breeding ground for many organisms, and helps to protect the coastline from erosion. (Miller 2004). Rocky shore organisms are adapted to tolerate the extreme conditions of this environment, such as desiccation, temperature changes, wave actions and tidal fluctuations, which results in a unique and harsh habitat for many marine organisms (Nair and Thampy, 1980; Smith

*Author for correspondence : diptera.zsi@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

2013; Eglantine *et al.*, 2014; Marshall *et al* 2013; Underwood and Chapman 2013). Rocky shore is highly heterogenous and genetically diverse environment (Araújo *et al.*, 2005) that offers a wide array of ecosystem services like fresh air, clean and recycled water, protection, food source, sites of recreational activities, high productivity etc. (Branch *et al.*, 2008). Apart from being rich biodiversity sites, they are ideal laboratories for studying ecological and biological processes, providing food and feeding grounds for many rare and threatened species and promoting the stabilisation of inshore sediments (Benedetti, 2001).

Rock pools form an ideal microhabitat for settling diverse flora and fauna (Tikader, 1986; Cruz et al 2014). Phylum Mollusca, the second largest in the animal kingdom next to Arthropoda in terms of the number of species, form one of the major and biodiverse marine invertebrate taxa (Bouchet and Strong, 2010). Gastropoda forms the most species rich and diverse class in the phylum Mollusca (Pechenik 2016). Many edible species of Gastropods are abundantly found in intertidal regions of rocky shores (Prasanna and Ramesh, 2018). Gastropods are ecologically and economically important for the coastal area and their existence influences the microecological condition of an ecosystem (Ramanibai and Govindan, 2018., Puryono and Suryanti, 2019). Rocky shore biodiversity studies from Indian coasts are very less except a few related to the ecology and distribution of individual species or on algal and invertebrate communities (Krishnaswamy, 1957, Rao and Sreeramulu, 1970, Ravinesh and Bijukumar 2013, Baiju *et al.*, 2023). The recent diversity study associated with gastropod communities along Kerala coast include those of Sary *et al.*, (2013, 2014), Ravinesh and Biju Kumar (2013), Anu *et al.*, (2017), Ravinesh *et al.*, (2022) and Baiju *et al.*, (2023). The objective of the present study is to identify the marine gastropods along intertidal rocky shores of the Thiruvananthapuram district and to determine the composition of the gastropod community based on most represented family. The study also aims at comparing the diversity indices of gastropods along the study area.

Material and Methods

The intertidal rocky patches of three closely located regions of Thiruvananthapuram district – Mulloor (8°29'30.9"N 76°53'55.5"E), Kovalam (8°24'02.0"N 76°58'18.1"E) and Vizhinjam (8°22'34.4"N 76°59'37.0"E) **(Fig: 1)** were chosen as the study sites. Monthly regular collections were taken during 2021- 2022 by direct hand picking and Snorkelling (with the help of professional divers). Photographs were taken using Olympus TG-5 and Nikkon D90 digital cameras. The identification of the shells up to species level was done following revision papers, manuals and publications (Röckel et al, 1995; Rao, 2003; Apte, 1998, 2012, 2014; Robin, 2008; Rao, 2003; Franklin and Laladhas, 2014; Edward *et al*, 2022) and online databases.

The identified shells were carefully placed in separate bottles with labels indicating the name of species, family, order, location, date of collection and name of the collector. The numbers of shells of each species obtained from each site were also recorded for calculating the diversity indices. Diversity indices such as Shannon-Wiener index (H) Simpson Dominance Index (D), Evenness index (E) were calculated using the software Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer *et al.*, 2001). The scheme of classification followed was that of Bouchet *et al.* (2017).

Results and Discussion

Rocky shores are the most dynamic, productive and harshest ecosystems (Worm and Lotze, 2006; Tomanek and Helmuth, 2002) and of late artificial sea walls are also reported to support biodiversity (Biju Kumar and Ravinesh, 2011). The present study revealed the presence of a total of 108 species of gastropods belonging to 6 Subclasses, 8 orders, 20 super families, 27 families and 61 genera (Table I, Fig: 2)

Order Neogastropoda harboured the highest number of species (50) categorised under nine families and twenty five genera; almost 46 % of the species collected was from this species-rich order. Neogastropods are carnivorous and prefer diversity in dietary and eating behaviours compared to other classes of Gastropoda (Taufik *et al.*, 2017). The availability of preferred food sources depending on the type of molluscs is an important factor that influences the density of a particular species (Islami 2012). Order Littorinimorpha stood next in species diversity represented by thirty species coming under six families and seventeen genera contributing to 28% of the total diversity. Orders Trochida (6%) was represented by seven species belonging to four families and four genera. Order Cycloneritida (6%) was also represented by a single genus with seven species coming under a single family, while order Lepetellida (5%) was represented by two families comprising of five genera and five species. Order Caenogastropoda(4%) harboured four species coming under three families and four genera. Order Patellogastropoda (2%) was represented by two species coming under two genera and two families. Order Seguenziida(1%) had the least representation with a single species under the family Chilodontidae. The order Cephalaspidea (2%) was also represented by two species each belonging to two different genera coming under a single family. An analysis of the species diversity in each family revealed that Muricidae harboured the highest number of species (18) followed by Conidae (17 species) and Cypraeidae (16). Familiy Neritidae was represented by seven species followed by families Littorinidae (5), Turbinidae (4) and Fissurellidae (4). Families Trochidae, Calyptraeidae, Cymatiidae and Columbellidae were represented by three species each whereas families Planaxidae, Bursidae, Mitridae, and Haminoeidae were represented by two species each. Eoacmaeidae, Nacellidae, Haliotidae, Chilodontidae, Cerithiidae, Epitoniidae, Zebinidae, Fasciolariidae, Raphitomidae and Acteonidae however, exhibited the least species diversity with only one species each. According to Abbot (1991), gastropod families Neritidae and Littorinidae are the most commonly found across wide ecological zones.

A categorisation of species into common, rare and uncommon based on the number of specimens obtained showed that 50 species (46%) were of common occurrence, 22 species were uncommon (20.37%) and 36 species were rare (33.33%) **(Fig: 3).** *Littoraria undulata* belonging to the family Littorinidae was the most abundant species (3133) observed in the study along with *Trochus radiatus* (2959), *Anachis terpsichore* (2364), *Nerita albicilla* (1512) and *Clypidina notata* (1157). Periwinkles belonging to littorinid family; often occur at high densities along rocky shores globally (Davies and Williams, 1998). They are adapted to retreat into crevices and attach to the substrate to avoid dislodgement due to strong wave action (Katie *et al.*, 2014). A comparison of species diversity among the three study sites revealed that Vizhinjam (84 species) stood high in species diversity followed by Mulloor (82 species) and Kovalam (61 species) **(Fig. 4)**.

An analysis of various diversity indices showed that Evenness Index was highest at Mulloor (41.79) followed by Vizhinjam (29.64) and Kovalam (28.57). Simpsons diversity index showed a value of 0.93 across the three sites, indicating very high diversity. Assessment of Shannon index also indicated very high diversity (3.0485) along the selected study sites.

Out of the 108 species recorded, six species were recorded for the first time from the Kerala coast and thirteen species were new records to west coast of India (Plates 1 to 3). Variations in temperature, steepness of shores, tidal range, amount of protection, wave frequency and electrical conductivity also regulate the kind and number of biotas associated with rocky habitats; (Tikader *et al.*, 1986; D'Souza *et al.*, 2022). Anthropogenic pressures due to sewage dumping, urbanization, tourism, recreational activities runoffs and shell collectors can pose a serious threat to the existing diversity of rocky habitats (Prasanna and Ramesh, 2018). Rocky shores provide a variety of food sources for marine organisms, including algae, plankton, and small invertebrates. This supports a diverse food web, with many species relying on other species for food.

Rocky shores are providing wide variety of food sources for marine organisms, including algae, plankton, and small invertebrates. This supports a diverse food web, with many species relying on other species for food. The study areas diversity of algae, sponges, crustaceans, and echinoderms and Ascidians (Ravinesh and Biju Kumar 2013, Anu *et al.*, 2017) and the overall, the combination of physical diversity, food availability, connectivity, adaptation, and environmental stability makes rocky shores a highly diverse in these regions. The rich gastropod diversity of the rocky patches along the Thiruvananthapuram coastline throws light into the potential for in- depth taxonomic studies. The varying physicochemical parameters prevailing in the ecosystem coupled with high productivity can be the reason for the highly diverse species patterns observed in the study.

APPENDIX – Tables and Figures

Table 1—Gastropod Biodiversity associated with the intertidal rocky shores of Mulloor, Kovalam and Vizhinjam + Present; - Absent

No	Classification	Mulloor	Kovalam	Vizhinjam	Abundance	Remarks
1	Class: Gastropoda Subclass: Patellogastropoda Order Patellogastropoda Superfamily: Lottioidea Family: Eoacmaeidae ***Eoacmaea ceylanica* (E. A. Smith, 1911)**	+	+	+	**Common**	**New to west Coast of India.**
2	Super family: Patelloidea Family: Nacellidae ***Cellana radiata* (Born, 1778)**	+	+	+	**Common**	
3	Subclass: Vetigastropoda Order: Lepettellida Superfamily: Fissurelloidea Family: Fissurellidae ***Diodora singaporensis* (Reeve,1850)**	+	+	+	**Common**	
4	***Emarginula obovata* (A. Adams, 1852)**	+	-	+	**uncommon**	First record in west coast
5	***Scutus unguis* (Linnaeus, 1758)**	+	+	+	**Common**	First record to South west coast of India
6	***Clypidina notata* (Linnaeus, 1785)**	+	+	+	**Common**	
7	Superfamily: Haliotoidea Family: Haliotidae ***Haliotis varia* Linnaeus, 1758**	+	+	+	**Common**	
8	Order: Seguenziida Superfamily: Seguenzioidea Family: Chilodontidae ***Euchelus asper* (Gmelin, 1791)**	+	+	+	**Common**	
9	Order: Trochida Superfamily: Trochoidea Family: Trochidae ***Clanculus microdon* A. Adams, 1853**	+	+	+	**Common**	First record in Kerala
10	***Trochus maculatus* Linnaeus, 1758**	+	-	+	**uncommon**	
11	***Trochus radiatus* Gmelin, 1791**	+	+	+	**Common**	

No	Classification	Mulloor	Kovalam	Vizhinjam	Abundance	Remarks
12	Family: Turbinidae ***Astralium semicostatum* (Kiener, 1850)**	+	-	+	**uncommon**	First record in west coast
13	***Turbo argyrostomus* Linnaeus, 1758**	+	-	+	**uncommon**	
14	***Turbo bruneus* (Röding, 1798)**	+	-	+	**uncommon**	
15	***Turbo intercostalis* Menke, 1846**	+	-	+	**uncommon**	
16	Subclass: Neritimorpha Order: Cycloneritida Superfamily: Neritoidea Family: Neritidae ***Nerita albicilla* Linnaeus, 1758**	+	+	+	**Common**	
17	***Nerita litterata* Gmelin, 1791**	+	+	+	**Common**	
18	***Nerita maura* Récluz, 1842**	+	+	+	**uncommon**	
19	***Nerita nigrita* Röding, 1798**	-	-	+	**uncommon**	
20	***Nerita oryzarum* Récluz, 1841**	+	+	-	**uncommon**	
21	***Nerita plicata* Linnaeus, 1758**	+	+	+	**Common**	
22	***Nerita polita* Linnaeus, 1758**	+	+	+	**Common**	
23	Subclass: Caenogastropoda Order: Caenogastropoda Superfamily: Cerithioidea Family: Cerithiidae ***Rhinoclavis sinensis* (Gmelin, 1791)**	-	+	+	**Common**	
24	Family: Planaxidae ***Planaxis sulcatus* (Born, 1778)**	+	+	+	**Common**	
25	***Supplanaxis niger* Quoy & Gaimard, 1833**	+	+	+	**Common**	
26	Superfamily: Epitonoidea Family: Epitonidae ***Acrilla acuminata* (G. B. Sowerby II, 1844)**	+	-	-	**Rare**	New to Kerala
27	Order: Littorinimorpha Superfamily: Littorinoidea Family: Littorinidae ***Echinolittorina leucosticta* (Philippi, 1847)**	+	+	+	**Common**	
28	***Echinolittorina malaccana* (Philippi, 1847)**	+	+	+	**Common**	

No	Classification	Mulloor	Kovalam	Vizhinjam	Abundance	Remarks
29	***Echinolittorina vidua* (Gould, 1859)**	+	+	+	**Common**	
30	***Littoraria undulata* (Gray, 1839)**	+	+	+	**Common**	
31	***Littoraria intermedia* (Philippi, 1846)**	-	+	+	**Common**	
32	Superfamily: Rissooidea Family: Zebinidae ***Stosicia annulata* (Dunker, 1859)**	-	_	+	**Rare**	
33	Superfamily: Calyptraeoidea Family: Calyptraeidae ***Desmaulus edgarianus* (Melvill, 1898)**	+	-	+	**Common**	
34	***Desmaulus extinctorium* (Lamarck, 1822**	+	+	+	**Common**	
35	***Ergaea walshi* (Reeve, 1859)**	+	+	+	**Common**	
36	Order: Littorinimorpha Superfamily: Cypraeoidea Family: Cypraeidae ***Naria helvola* (Linnaeus, 1758**)	+	-	+	**Rare**	First record in west coast
37	***Naria lamarckii* (J. E. Gray, 1825)**	-	-	+	**Rare**	
38	***Naria ocellata* (Linnaeus, 1758)**	+	+	+	**Common**	
39	***Erronea caurica dracaena* (Born, 1778)**	+	-	-	**Rare**	First record in Kerala
40	***Erronea errones* (Linnaeus, 1758)**	+	-	-	**Rare**	
41	***Palmadusta asellus (Linnaeus, 1758)***	+	+	+	**Common**	
42	***Palmadusta clandestina* (Linnaeus, 1767)**	+	+	+	**Common**	First record in west coast
43	***Palmadusta lentiginosa* (J.E. Gray, 1825)**	-	+	+	**Common**	New to Kerala
44	***Lyncina carneola* (Linnaeus, 1758)**	-	-	+	**Rare**	
45	***Lyncina vitellus* (Linnaeus, 1758)**	+	+	+	**unommon**	
46	***Mauritia arabica asiatica* F.A. Schilder & M. Schilder, 1939**	+	+	+	**Common**	
47	***Mauritia mauritiana* (Linnaeus, 1758**)	_	-	+	**Rare**	First record in Kerala
48	***Monetaria annulus* (Linnaeus, 1758)**	+	-	+	**Uncommon**	
49	***Monetaria caputserpentis* (Linnaeus, 1758)**	+	-	+	**Common**	
50	***Monetaria moneta* (Linnaeus, 1758)**	+	+	+	**Common**	

No	Classification	Mulloor	Kovalam	Vizhinjam	Abundance	Remarks
51	***Staphylaea limacina interstincta* (W. Wood, 1828)**	-	+	-	**Rare**	
52	Superfamily: Tonnoidea Family: Bursidae ***Dulcerana granularis* (Röding, 1798)**	+	+	+	**Common**	
53	***Tutufa bubo* (Linnaeus, 1758)**	-	+	-	**Rare**	
54	Family: Cymatiidae ***Gyrineum natator* (Röding, 1798)**	+	+	+	**Common**	
55	***Lotoria Perryi (W. K Emerson and Old, 1963))***	+	+	+	**Common**	
56	***Monoplex parthenopeus* (Salis-Marschlins, 1793)**	+	-	-	**Rare**	
57	Order: Neogastropoda Super family: Buccinoidea Family: Columbellidae ***Anachis terpsichore* (G. B. Sowerby II, 1822)**	+	+	+	**Common**	
58	***Pardalinops testudinaria* (Link, 1807)**	+	+	+	**Common**	
59	***Pyrene flava* (Bruguière, 1789)**	+	+	+	**Common**	
60	Family: Pisaniidae ***Cantharus melanostoma* (Sowerby I, 1825)**	+	+	+	**Common**	
61	***Cantharus spiralis* Gray, 1839**	+	+	+	**Common**	
62	***Engina lineata* (Reeve,1846)**	+	+	+	**Common**	
63	***Engina zea* Melvill, 1893**	+	+	+	**Common**	
64	***Pollia undosa* (Linnaeus, 1758)**	+	+	+	**Common**	
65	Family: Fasciolariidae ***Filifusus ferrugineus* (Lamarck, 1822)**	+	+	+	**Common**	New to west coast of India
66	Superfamily: Muricoidea Family: Muricidae ***Chicoreus brunneus* (Link, 1807)**	-	-	+	**Rare**	
67	***Chicoreus ramosus* (Linnaeus, 1758)**	-	-	+	**Rare**	
68	***Chicoreus virgineus* (Röding, 1798)**	-	-	+	**Rare**	
69	***Haustellum langleitae* Houart, 1993**	+	+	+	**Common**	New to West Coast of India

No	Classification	Mulloor	Kovalam	Vizhinjam	Abundance	Remarks
70	***Mipus gyratus* (Hinds, 1844)**	+	-	+	**Uncommon**	New to West Coast of India
71	***Drupella margariticola* (Broderip, 1833)**	+	+	+	**Common**	
72	***Ergalatax contracta* (Reeve, 1846)**	+	+	+	**Common**	
73	***Lataxiena solenosteiroides* Houart, Fraussen & Barbier, 2013**	-	+	+	**Common**	
74	***Maculotriton serriale* (Deshayes in Laborde, 1833)**	+	-	+	**Uncommon**	
75	***Muricodrupa anaxares* (Kiener,1835)**	+	+	-	**Uncommon**	First record in Kerala
76	***Pascula muricata* (Reeve, 1846)**	+	-	+	**Uncommon**	
77	***Pascula ochrostoma* (Blainville, 1832)**	+	-	+	**Uncommon**	First record in west coast
78	***Tenguella granulata* (Duclos, 1832)**	+	-	+	**Uncommon**	
79	***Indothais blanfordi* (Melvill,1893)**	+	-	+	**Uncommon**	
80	***Indothais sacellum* (Gmelin, 1791)**	-	-	+	**Rare**	
81	***Mancinella alouina* (Röding, 1798)**	-	+	-	**Rare**	
82	***Purpura bufo* Lamarck, 1822**	+	+	+	**Common**	
83	***Purpura panama* (Röding, 1798)**	+	+	+	**Common**	
84	***Semiricinula tissoti* (Petit de la Saussaye, 1852)**	+	+	+	**Common**	
85	Superfamily: Mitroidea Family: Mitridae ***Pseudonebularia chrysalis* (Reeve, 1844)**	-	+	-	**Rare**	
86	***Pseudonebularia proscissa* (Reeve, 1844)**	-	-	+	**Rare**	
87	Superfamily: Conoidea Family: Conidae ***Conus achatinus* Gmelin, 1791**	-	-	+	**Rare**	
88	***Conus biliosus* (Röding, 1798)**	+	-	-	**Rare**	
89	***Conus bizona Coomans,* Moolenbeek & Wils, 1981**	+	-	-	**Rare**	
90	***Conus catus* Hwass in Bruguière, 1792**	+	-	-	**Rare**	
91	***Conus ceylanensis* Hwass in Bruguière, 1792**	-	-	+	**Rare**	

No	Classification	Mulloor	Kovalam	Vizhinjam	Abundance	Remarks
92	***Conus chaldaeus* (Roding,1798)**	+	-	-	**Rare**	
93	***Conus coronatus* Gmelin, 1791**	+	-	-	**Rare**	
94	***Conus ebraeus* Linnaeus, 1758**	-	+	-	**Rare**	
95	***Conus flavidus* Lamarck, 1810**	+	-	+	**Rare**	
96	***Conus glans* Hwass in Bruguière, 1792**	+	-	-	**Rare**	
97	***Conus juliaallaryae* (T. Cossignani, 2013)**	_	-	+	**Rare**	
98	***Conus lividus* Hwass in Bruguière, 1792**	-	+	+	**Uncommon**	
99	***Conus miles* Linnaeus, 1758**	+	+	-	**Uncommon**	
100	***Conus parvatus* Walls, 1979**	-	+	+	**Uncommon**	
101	***Conus rattus* Hwass in Bruguière, 1792**	+	-	+	**Uncommon**	
102	***Conus tessulatus* Born, 1778**	+	-	-	**Rare**	
103	***Conus zonatus* Hwass in Bruguière, 1792**	-	-	+	**Rare**	
104	Family: Clathurellidae ***Lienardia koyamai* Bozzetti, 2007**	+	-	-	**Rare**	New record to west coast of India
105	Family: Raphitomidae ***Pseudodaphnella barnardi* (Brazier, 1876)**	-	-	+	**Rare**	New record to west coast of India
106	Subclass: Heterobranchia Superfamily: Acteonoidea Family: Acteonidae ***Pupa solidula* (Linnaeus, 1758)**	+	-	-	**Rare**	New record to west coast of India
107	Order: Cephalaspidea Superfamily: Haminoeoidea Family: Haminoeidae ***Haloa aptei* (Bharate, Oskars, Narayana, Ravinesh, Biju Kumar & Malaquias, 2018)**	-	-	+	**Rare**	
108	***Lamprohaminoea cymbalum* (Quoy & Gaimard, 1833)**	+	-	-	**Rare**	

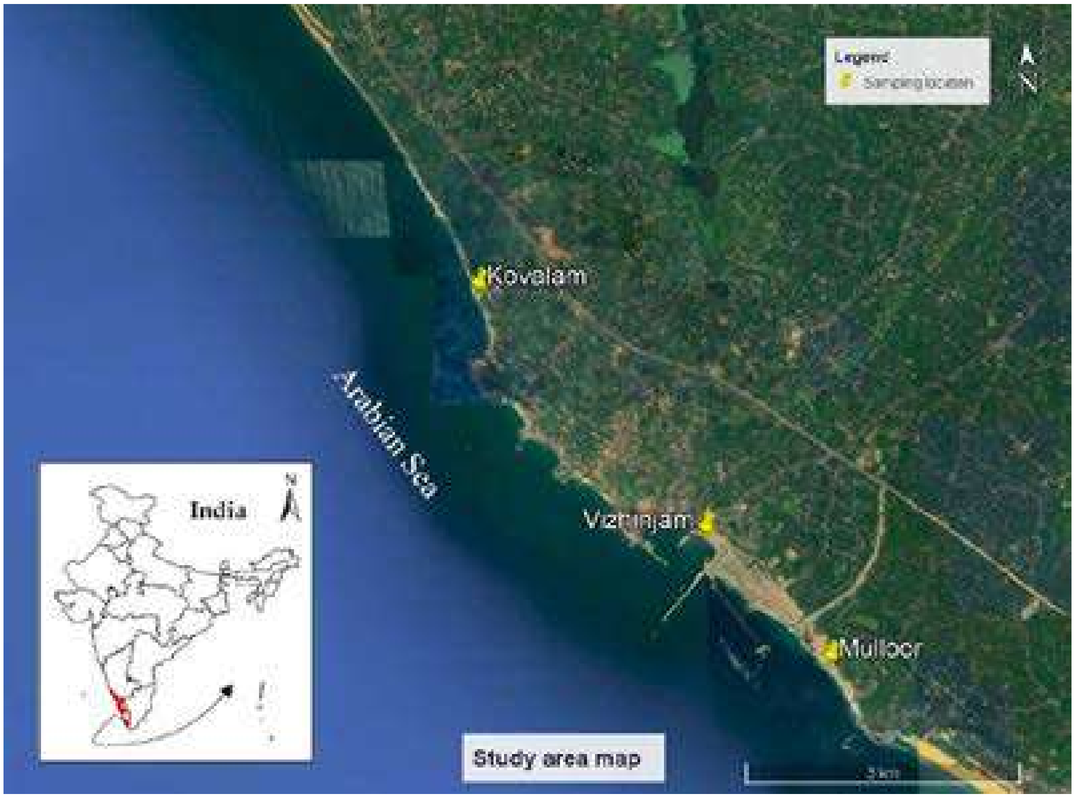


Fig 1: Map showing the study sites

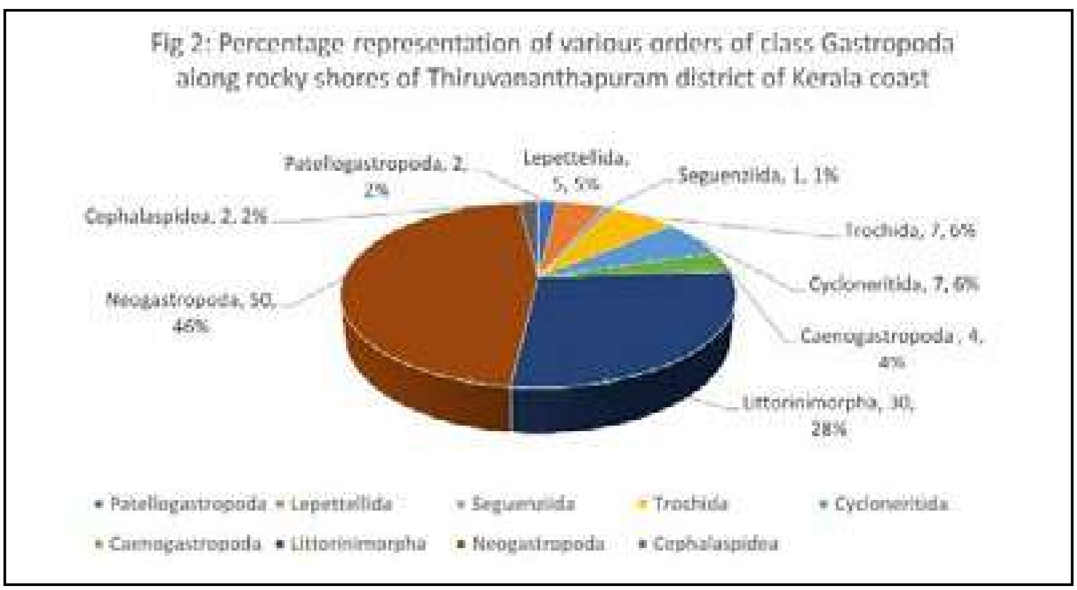


Fig 2: Percentage representation of various orders of class Gastropoda along rocky shores of Thiruvananthapuram district of Kerala coast

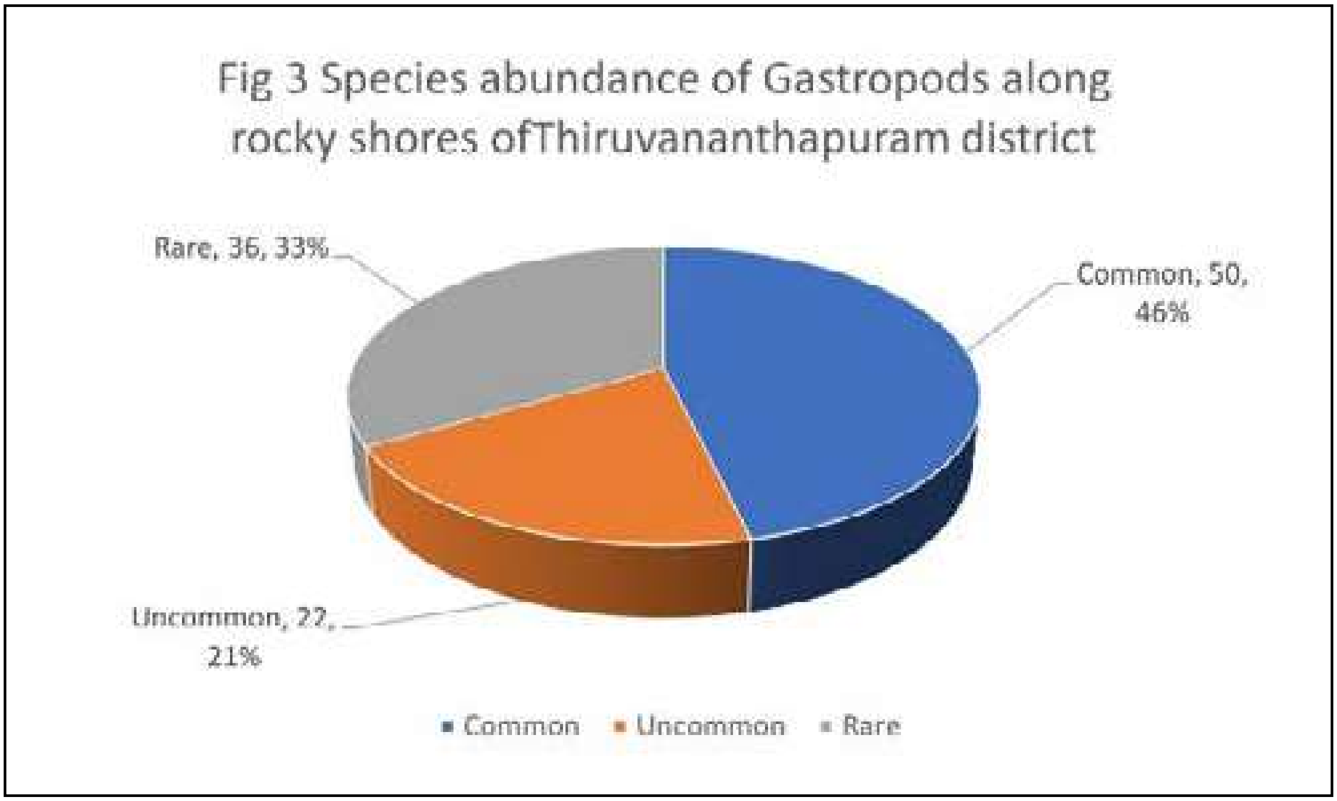


Fig 3: Species abundance of gastropods along rocky shores of Thiruvananthapuram district

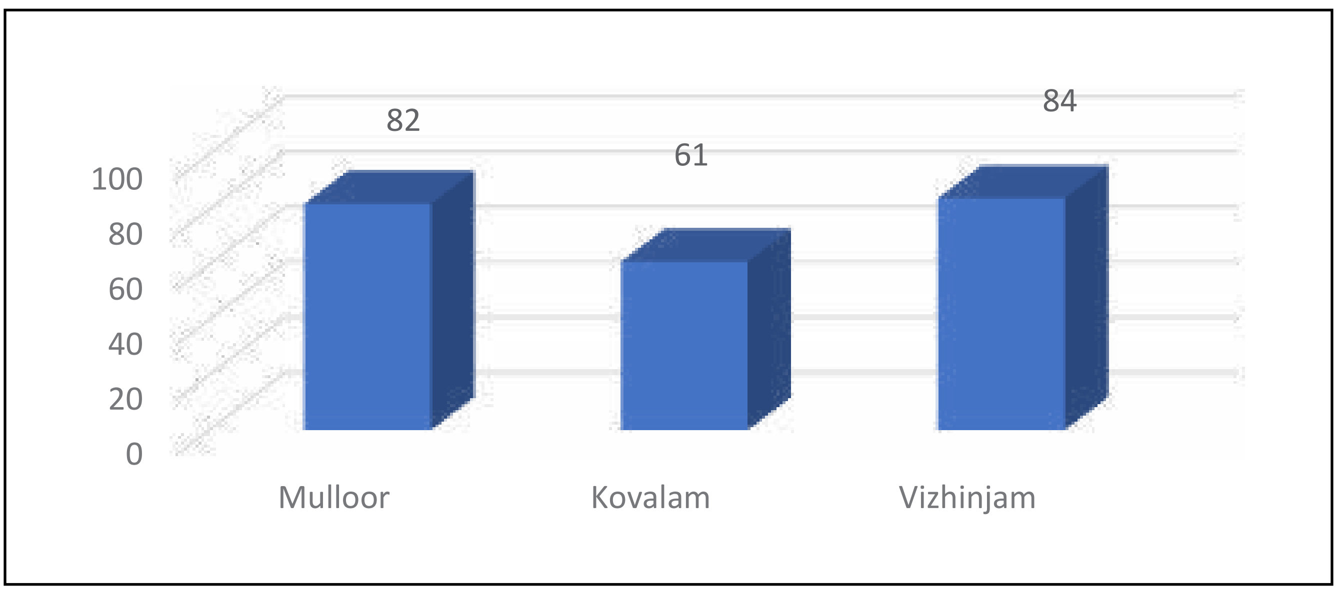


Fig 4: Site wise comparison of Gastropod diversity

New reports from the study –

Plate 1

Plate 2

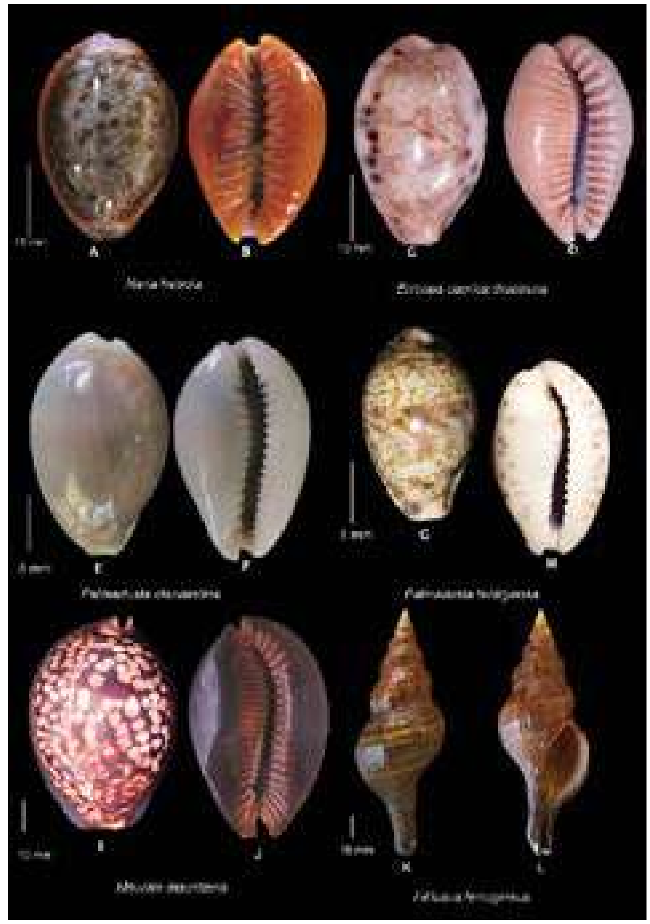
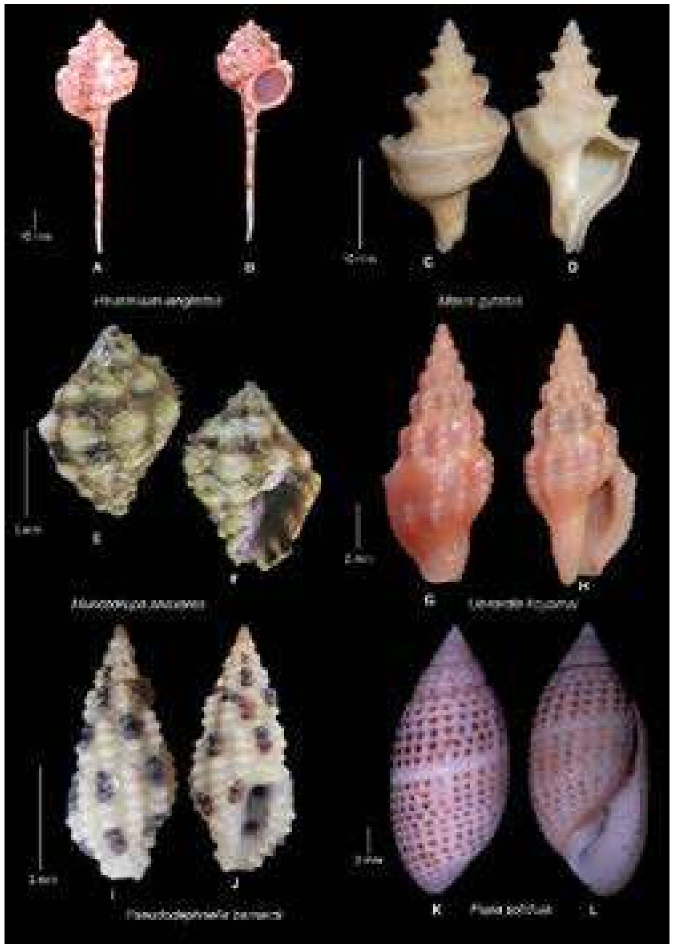


Plate 3



Acknowledgements

The authors thank the Department of aquatic Biology and Fisheries, University of Kerala, Karyavattam, Thiruvananthapuram for the facilities and encouragement.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Ant Diversity in Forested and Human Disturbed varying elevational habitats of Shendurney Wildlife Sanctuary, Western Ghats, India with Landscape Analysis using QGIS.

Merin Elizabeth George[1*], G Prasad[2]

[1]*PhD Scholar, Department of Zoology, University of Kerala, India. Email: megkattimattom@gmail.com*
[2]*Professor and Head, Department of Zoology, University of Kerala, India. Email: probios1@gmail.com*

Abstract

Shendurney Wildlife Sanctuary is located at Agasthyamalai Hills of Southern Western Ghats, Southern India. Despite being in a biodiversity hotspot, there has been no study of ants from this region to date which makes it difficult to monitor any need for conservation efforts. The present study aims to make a comparison between the Forested and Disturbed Habitats of the Sanctuary. The study was done from March 2021 to February 2022 spanning four seasons. Two Forested and two disturbed habitats were selected in two elevations (500m and 1100 m). Three 20x20 m quadrats were selected in each habitat. The ants were collected using standard protocol. The diversity of the sites was analysed and compared to understand the impact of disturbance on ant assemblages. From all sites, soil samples were collected. The samples were analysed for pH, Organic Carbon, Moisture, and Temperature. It was noticed that forested regions had a better diversity and lesser dominance compared to Disturbed Habitats. In addition, landscape pattern was analysed using QGIS to understand the landscape pattern and disturbance.

Keywords: Ants, Shendurney Wildlife Sanctuary, Landscape Analysis, Formicidae

Introduction

Habitat disturbance is a significant threat to biodiversity as it changes interspecific interactions, alters species composition, and wreaks havoc in the balance of competitive interactions. Discovering habitat disturbance at an early stage is crucial as it can help ensure it is stopped before it reaches an unmitigable stage. Hence the need for indicator species whose diversity changes can be used to detect these disturbances early. Ants are excellent indicator species owing to their high abundance, sensitivity to disturbance, ease of sampling, well-known taxonomy, widespread distribution, and ease of collection. Ants have been used for estimating habitat disturbance and the effectiveness of restoration measures taken in different habitats like copper mines (Diehl *et al.*, 2004), sites with arsenic content (Ribas *et al.*, 2012), logged areas (Kalif *et al.*, 2001), grasslands (Fagan *et al.*, 2010), mine sites (Majer, 1983) and fragmented forests (Coelho and Santos, 2009). The use of ants as indicators was first done in the 1980s. (Majer, 1983). The use of ants as indicator species, although being done internationally (Castracani *et al.*, 2010; Fagan *et al.*, 2010; Gomez *et al.*, 2003; Hoffmann and Andersen, 2003; Majer *et al.*, 2007), is used very less in India (Barve and Davidar, 2008; Marathe, 2016). There is an increasing need for a country like India, with its numerous biodiversity hotspots, to use invertebrates, especially ants, in the environment management.

The present study compares two sites in two elevations. Each elevation has one forested and one disturbed site. The study aims to understand the difference in diversity between these two sites and, therefore, the effect of disturbance on ant assemblages. Additionally, landuse pattern analysis of Shendurney Wildlife Sanctuary has been done.

*Author for correspondence : megkattimattom@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Materials and Methods

The collection was done in Shendurney Wildlife Sanctuary, Kollam, Kerala. The sanctuary is located between 76º 59' 30⁰ and 77º 16' 30⁰ East Longitude and 8º 44 ' and 9º14' North Latitude, spanning 171 sq. km for a period of one year from March 2021 to February 2022, spanning four seasons. Two sites were selected each at low and mid-elevation (500m and 1100 m), one with forested and another with disturbed habitat. The forested area had West coast tropical semi-evergreen, while the disturbed habitats have Rubber Plantation. Each site was divided into three quadrats of 20 x 20 m. Ants were collected using Ants of Leaf Litter (ALL) Protocol (Agosti *et al.*, 2000). Pitfalls traps, handpicking, litter sifting, and inverted umbrella method were used.

Litter was collected from the quadrats from 1x1 m^2 plots in the quadrats, and ants were collected. The ants collected were preserved in 70% alcohol immediately after collection. The collection and preservation were done using methods given by Agosti *et al.,* (2000). They were viewed with a stereozoom microscope. The keys used were by Bingham (1903), Bolton (1994), and other latest keys and publications, including Bharati *et al.,* (2016). A label indicating the scientific name, the site and the month of the collection was attached to the specimens deposited in the museum of the Department of Zoology, University of Kerala. Photographic records of the specimens were taken for future reference. The checklist of all the species was prepared. The diversity indices (Shannon-Wiener diversity index, Shannon Evenness Index and Dominance index) from the four different habitats were calculated using the statistical software PAST, 2005. The functional groups were classified on the basis of classifications provided by Anderson (2000) and Bharti *et al.*, (2013).The rest of the statistical analysis was done using different packages in R studio (R Core Team, 2000). The Species accumulation curves were plotted using iNEXT package (Hsieh *et al.*, 2016). NMDS and PCA were done using *vegan* package (Oksanen *et al.*, 2008).

Landscape Analysis

The Landsat 8 images were downloaded from USGS Website and landscape analysis of Shedurney Wildlife Sanctuary, Kollam, Kerala, was done using QGIS 3.28 Tisler version software.

Results and Discussion

A total of 67 species of ants were collected from four sites. (Table 2). The richest genus was *Crematogaster* (nine species). Formicinae, Myrmicinae, Ponerinae, Dolichoderinae and Pseudomyrmicinae subfamilies were observed. The diversity indices (Table 1) show that Forested regions of high elevation had the highest diversity, least dominance and least evenness. The Rubber Plantation site in low elevation had the least diversity, highest dominance and highest evenness. The low diversity in disturbed habitat shows that disturbance indeed has a negative effect on ants. All values were found to be significant at 5% level.

The species accumulation curves (Fig 1) have the rubber plantations with curves reaching an asymptote, whereas the forested regions still have more species to be discovered when richness is compared, but Shannon and Simpson diversity seems to have reached an asymptote showing that the collection is complete.

The Functional group abundance is shown in Fig 2. Evergreen site seems to have all the functional groups. The plantation in the low elevation has the least number of functional groups. Specialist groups were only observed in the High elevation forest region. The functional group abundance shows that disturbed sites are preferred by opportunists as these sites have fewer competing species. King *et al.*,(1998) has shown that opportunists take over an ecosystem in the presence of disturbance and Specialist ants are found only in forested regions as their niche habitats are present in forest regions.

NMDS (Fig. 3) graph showed that more common ants like *Camponotus sp.* and invasive ants like *Nylanderia sp.* were found more in disturbed sites. PCA (Fig. 4) accounts for 86.81 of the variation in the graph. pH and Temperature have a higher influence on the diversity. Moisture levels did not show significance and hence was not used for further analysis. Disturbed sites recorded higher temperature than forested sites and Forest sites have a higher pH than disturbed sites. Invasive species are associated with disturbed habitats, and this indicates that the levels of disturbance are high. Temperature effects ants immensely as they prefer an increase in temperature up to certain levels after which the diversity declines (Parr and Bishop, 2022). Landscape Analysis (Fig 5.) shows the areas which are disturbed and this increasing disturbance highlights the need for restoration measures. The ant diversity also reflects these disturbance levels.

Species richness, in general, decreases with habitat disturbance. Severely converted sites have been found to reduce species and genus level richness and alter functional group composition. (Burbidge and Majer, 1992). In addition, it has been shown that native vegetation when converted to monoculture plantations also reduced ant diversity (Giliomee, 1985). Ant species richness differs in monocultures and forests (Cerda´ *et al.*, 2009). In the current study as well, disturbed monoculture rubber plantations have lower diversity than the forested regions.

The need for ecosystem conservation is rising with the increased human needs for land and other resources. It is vital that anthropogenic activities do not taint the pristine forests lest the ecological balance is upset. Sustainable development is key for a future preserving the planet's diversity. Use of ants as indicators ensures that changes made by disturbance are found early, and restoration measures can be taken earlier, and therefore more effectively. The need for a good bioindicator is even more pronounced in a country like India with numerous biodiversity hotspots and endemic species. The need to conserve rare species is on the rise with the increasing destructive anthropogenic activities. The present study highlights the growing need for more work on ant diversity to measure the changes in ant assemblages and consequently, the rate of habitat loss.

Tables and Figures

Table 1

Indices	FH	F	D	DH
Taxa_S	48	32	10	14
Shannon_H	3.003	2.668	1.893	2.181
Dominance_D	0.07074	0.09979	0.1867	0.1441
Evenness_e^H/S	0.4198	0.4505	0.6636	0.6327

Table 1. Diversity indices. FH – Forest High Elevation, F – Forest Low elevation, D – Disturbed Low elevation, DH – Disturbed High elevation

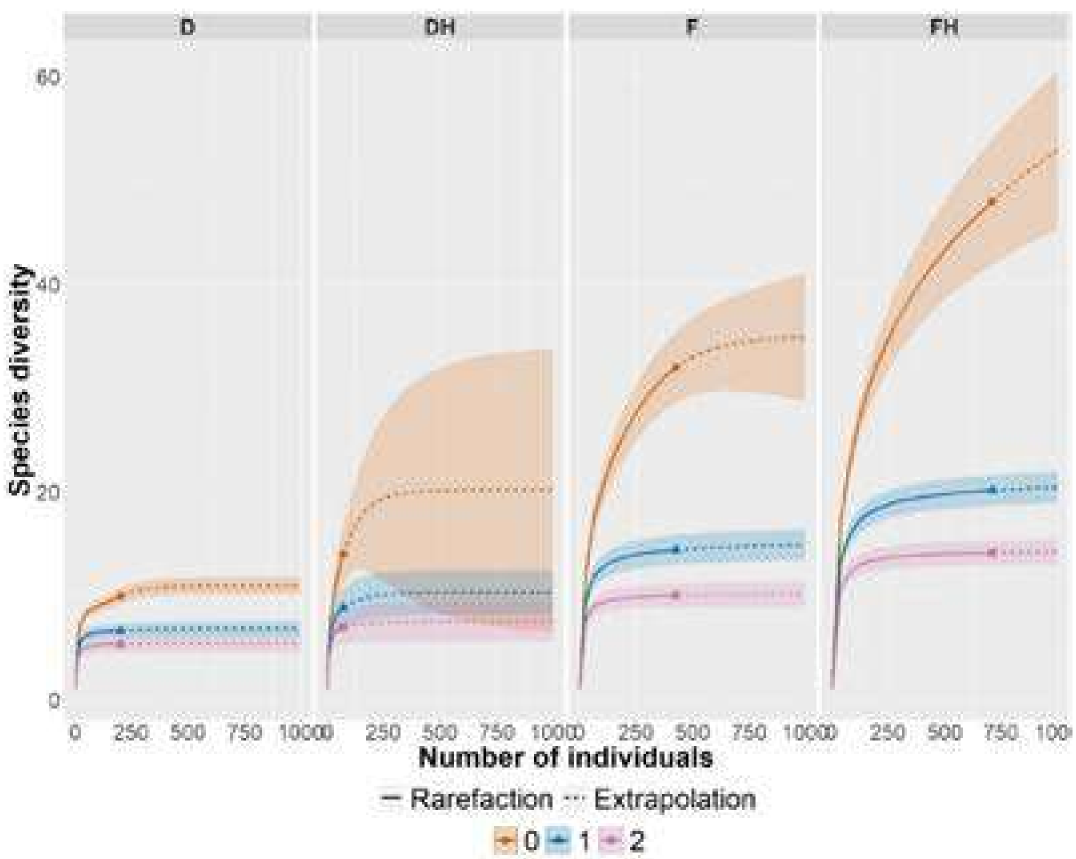

Fig 1. Species Accumulation Curve. 0 - Richness, 1 - Shannon diversity, 2 - Simpson diversity

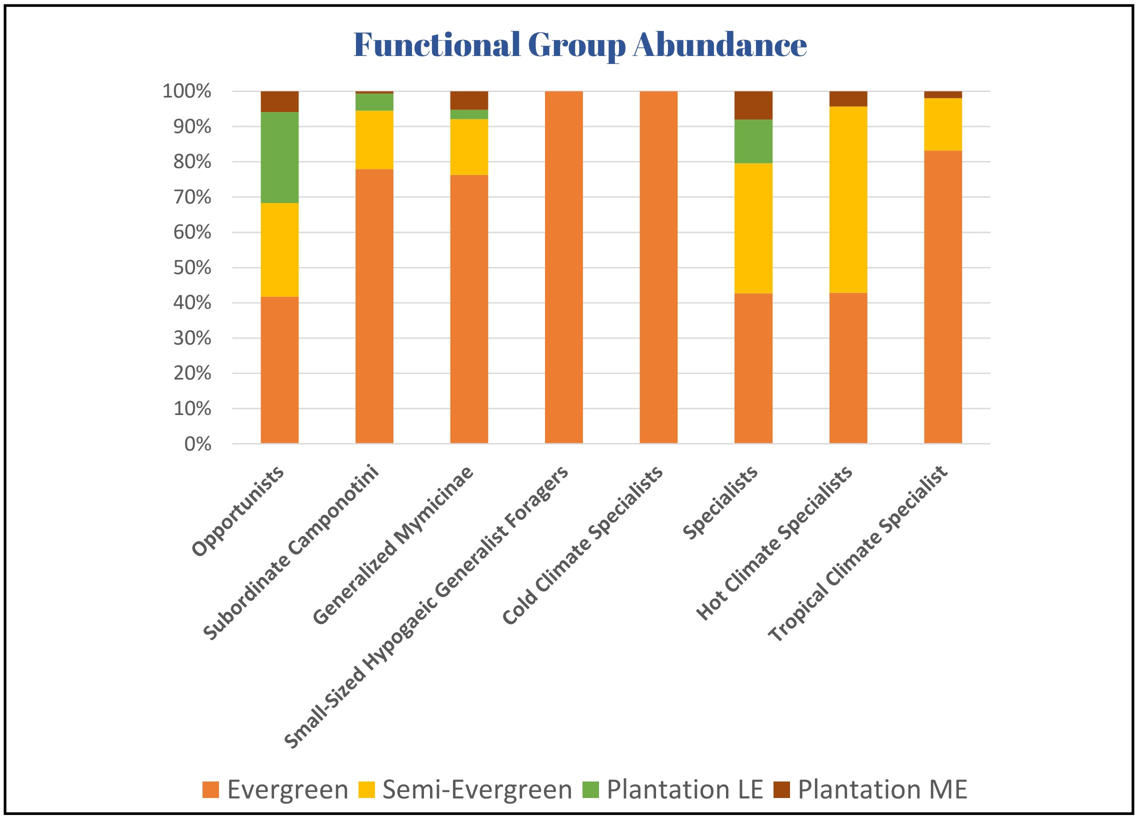

Fig 2. Functional group abundance

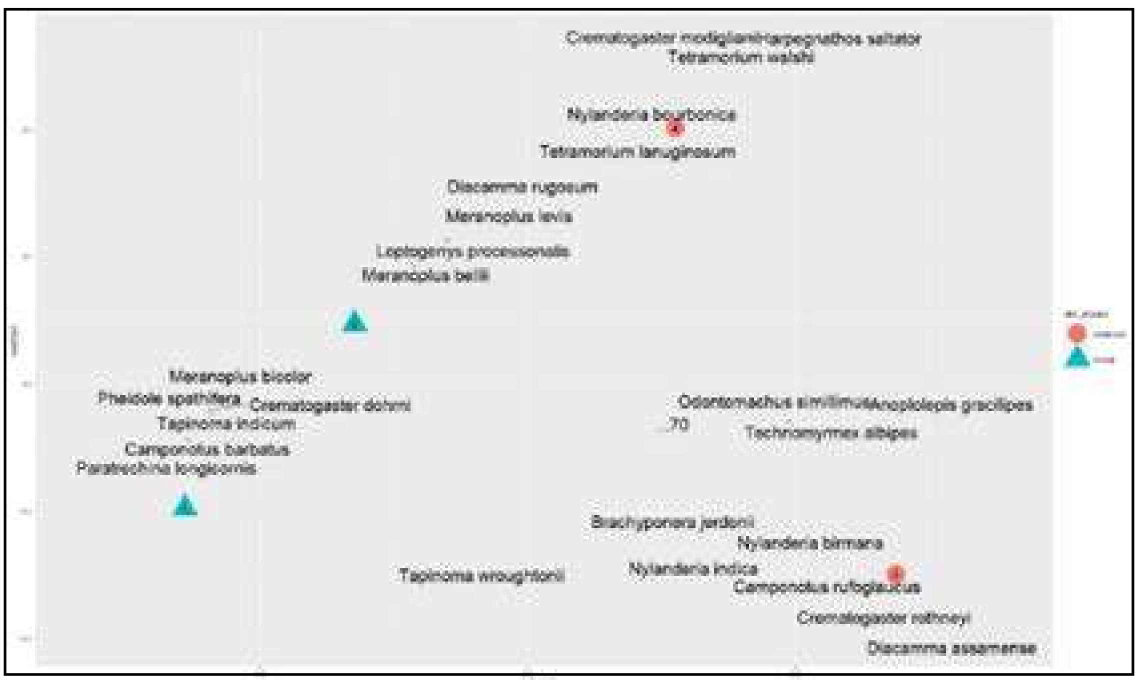

Fig 3. NMDS showing association between ant species and sites.

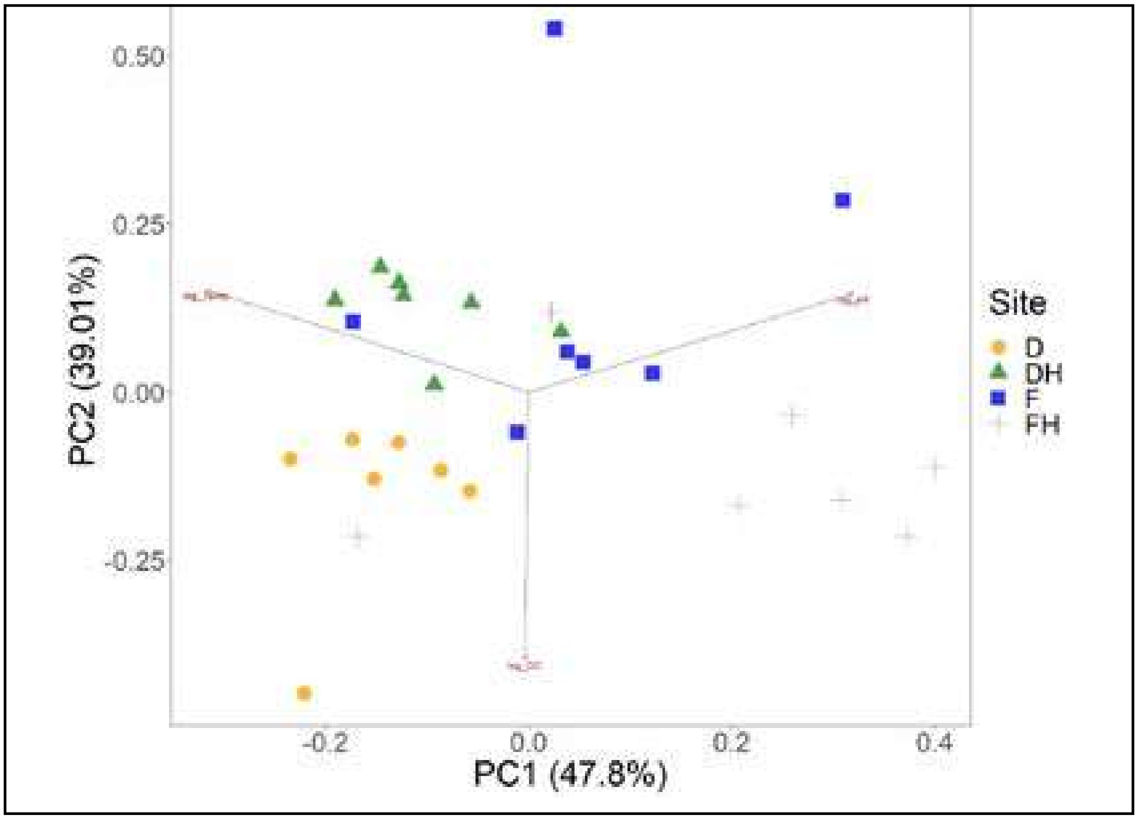

Fig 4. PCA of abiotic factors

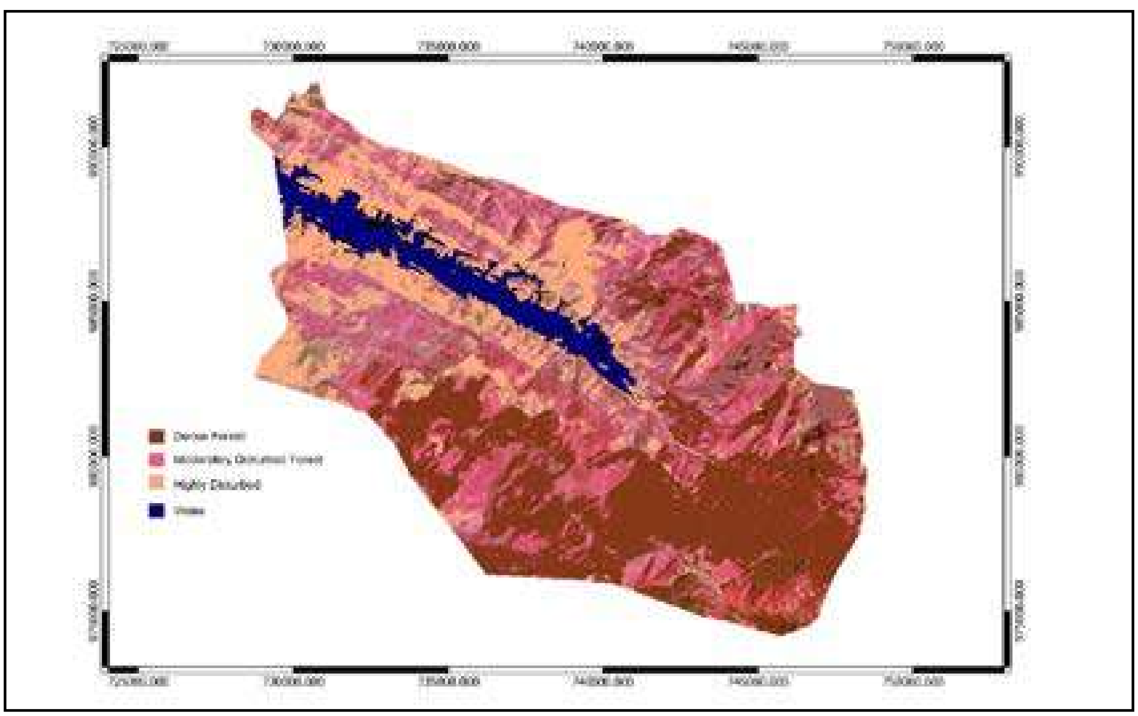

Fig 5. Landscape Patterns in Shendurney Wildlife Sanctuary

Table 2

Subfamily	Species	Functional Group
Dolichoderinae	*Dolichoderus taprobane*	TCS
	Tapinoma indicum	OPP
	*Tapinoma melanocephalum**	OPP
	Tapinoma wroughtonii	OPP
	Technomyrmex albipes	OPP
	Technomyrmex vitiensis	OPP
Formicinae	*Anoplolepis gracilipes**	OPP
	Camponotus barbatus	SC
	Camponotus confucii	SC
	Camponotus oblongus	SC
	Camponotus parius	SC
	Camponotus rufoglaucus	SC
	Camponotus sericeus	SC
	Camponotus thoracicus	SC
	Lepisiota fergusoni	OPP
	*Lepisiota opaca**	OPP
	Nylanderia birmana	OPP
	Nylanderia bourbonica	OPP
	Nylanderia indica	OPP
	Nylanderia smythiesi	OPP
	Nylanderia taylori	OPP
	Nylanderia yerburyi	OPP
	Oecophylla smaragdina	TCS
	*Paratrechina longicornis**	SC
	Plagolepis jerdonii	CRY
	Polyrhachis aculeata	SC
	Polyrhachis proxima	SC
	Prenolepis naoroji	CCS

Subfamily	Species	Functional Group
Myrmicinae	*Carebara affinis*	SSHF
	Cataulacus taprobane	TCS
	Crematogaster dohrni	GM
	Crematogaster biroi	GM
	Crematogaster ebenina	GM
	Crematogaster modigliani	GM
	Crematogaster rothneyi	GM
	Crematogaster rogenhoferi	GM
	Crematogaster subnuda	GM
	Crematogaster walshi	GM
	Crematogaster wroughtonii	GM
	Meranoplus bellii	HCS
	Meranoplus bicolor	HCS
	Meranoplus levis	HCS
	Monomorium abberans	GM
	Monomorium dichroum	OPP
	*Monomorium floricola**	OPP
	Monomorium latinode	OPP
	Monomorium minutum	OPP
	Pheidole constancinae	GM
	Pheidole spathifera	GM
	Pheidole wroughtoni	GM
	Recurvidris recurvispinosa	CRY
	*Solenopsis geminata**	OPP
	Tetramorium fergusoni	OPP
	*Tetramorium lanuginosum**	OPP
	*Tetramorium pacificum**	OPP
	Tetramorium petiolatum	OPP
	Tetramorium walshi	OPP
	Trichomyrmex mayri	GM

Subfamily	Species	Functional Group
Ponerinae	*Brachyponera jerdonii*	SP
	Diacamma assamense	OPP
	Diacamma rugosum	OPP
	Diacamma rugosum sculptum	OPP
	Harpegnathos saltator	SP
	Leptogenys birmana	SP
	Leptogenys processonalis	SP
	Odontomachus simillimus	SP
Pseudomyrmicinae	*Tetraponera rufonigra*	TCS

Table 2. *Checklist of Ants. * - Invasive species, CRY – Cryptic Species, CCS – Cold Climate Specialists, GM – Generalized Myrmicinae, HCS – Hot Climate Specialists, OPP – Opportunists, SC – Subordinate Camponotini, SP = Specialist Predators, TCS – Tropical Climate Specialist,*

Acknowledgements

We express our gratitude to Kerala Forests and Wildlife Department for providing the permission (No. KFDHQ – 3492/2019 – CWW/WL10) to collect specimens in Shendurney Wildlife Sanctuary, Kollam, Kerala. We would also like to thank University of Kerala for providing the funds for this research. In addition, Ebin Thomas, Asima A, Rahul Krishnan R S, and Mohammad Suhail are thanked by the authors for their assistance during the field surveys. We would also like to thank Nishi Babu for her continued support during the preparation of this paper. In addition, we would like to thank the anonymous reviewer for their suggestions.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Diversity and Taxonomical Identification of Marine Zooplankton from Digha adjacent Coastal Waters

Purbita Bhattacharyya[1,2], K. Anbarasu[1], S. Balakrishnan[2,*]

[1]*Department of Marine Biotechnology, Bharathidasan University, Tiruchirappalli – 620 024, Tamil Nadu, India*

[2]*Zoological Survey of India, Marine Aquarium and Regional Centre, Digha – 721 428, West Bengal, India*

E. mail: marugalbalu82@gmail.com

Abstract

Zooplankton is significant organisms in the food chain as predators of phytoplankton, the photosynthetic oxygen-producing aquatic plants; thus, they protect the ecosystem from eutrophication. Zooplankton are diversified and widely distributed throughout the lotic and lentic water bodies. The marine zooplankton community includes many different species of animals, ranging in size from microscopic protozoans to animals of several meters in dimension with buoyancy capacity. In this article, we describe the distribution, diversity, and taxonomic identification of marine zooplankton as evaluated by collecting species from the Digha adjacent coastal area (21.6222ºN; 087.5066ºE), West Bengal, India. Generally, almost all zooplankton species have their own specific depth range, but some of those also exhibit nocturnal migration, which helps in conserving energy, as well as beneficial for themselves, by prevent mortality by visual predators. Zooplankton, as the intermediate link between producer (phytoplankton) and consumer (secondary and tertiary) in the trophic chain, plays pivotal roles in the energy and matter transport processes, the cycling of elements, and their vertical flux in marine environments. This community is highly diverse in terms of their size, number, taxonomy, trophic structure, geographical distribution, tolerance to different environmental variables, etc. These are also considered some of the most important bio-indicators and linkages in shaping the extent and pace of climate change. During the survey, a small plankton local net was used to collect zooplankton. Totally, nine genera with ten different species, such as *Euterpina acutifrons, Oithona brevicornis brevicornis, Paracalanus parvus parvus, Paracalanus aculeatus aculeatus, Microsetella norvegica, Nannocalanus minor, Undinula vulgaris, Canthocalanus pauper, Eucalanus elongatus elongatus* and *Subeucalanus crassus* have been identified and characterized. The survey is a current report of the above species diversity, occurrence, distribution, and characteristics in these coastal areas during this period. We hope it is significant data for further analysis, such as the breeding of fish and crustaceans.

Keywords: Zooplankton, Diversity, Taxonomy, Digha, West Bengal.

Introduction

Zooplankton is a microscopic or macroscopic group of aquatic organisms that float in the water at different zones at the mercy of wind and water flow. Zooplankton are the predators of phytoplankton, the photosynthetic oxygen-producing aquatic plant, thus they control the ecosystem and bloom of phytoplankton. Zooplankton are diversified and widely distributed throughout riverine, coastal, and marine aquatic bodies (Laakmann *et al.*, 2020). The marine

*Author for correspondence : marugalbalu82@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

zooplankton community includes many different species of animals, ranging in size from microscopic protozoans to animals several meters in dimension. In this review of the literature, the distribution, diversity, and taxonomical identification of marine zooplankton are evaluated by collecting species from the Digha-adjacent coastal area, West Bengal. Generally, almost all zooplankton species have their own specific depth range, but some of those also exhibit nocturnal migration and help conserve energy, which is beneficial for them, and prevents mortality by visual predators (Carol *et al.*, 1997). Zooplankton, as the intermediate link between producer (phytoplankton) and consumer (secondary and tertiary) levels in the trophic chain, plays pivotal roles in the energy and matter transport processes, the cycling of elements, and their vertical flux in the marine environment. This community is highly diverse in terms of their size, taxonomy, trophic structure, geographical distribution, tolerance to different environmental variables, etc. These are also considered to be one of the most important linkages in shaping the extent and pace of climate change.

Primary and secondary consumers, the zooplankton community constitutes about one-tenth of the total marine biomass on which the whole class of fishery depends. Owing to its multi-dimensional economic and ecological utility, zooplankton is a core subject of research in all marine biological investigations. Zooplankton studies along the Odisha coast, in general, remained meager and were limited to the Chilika Lake (Devasundaram, 1954; Patnaik, 1973; Naik *et al.*, 2008), Hooghly estuary (Sarkar *et al.*, 1986), Rushikulya estuary (Gouda and Panigrahy, 1995), Bahuda estuary (Mishra and Panigrahy, 1996), Burhabalanga estuary (Ramaiah *et al.*, 1996), Mahanadi estuary (Srichandan *et al.*, 2013), Gopalpur Port (Sahu *et al.*, 2012), Gopalpur Creek (Sahu *et al.*, 2013), Rushikulya estuary (Sahu *et al.*, 2010, Baliarsingh *et al.*, 2013, Srichandan *et al.*, 2015). According to Issarapon zooplankton communities in the Bay of Bengal consisted of 205 species, 119 genera, and 44 taxa (Jitlang *et al.*, 2007). The only study on zooplankton distribution in coastal waters along the Odisha coast was that of Sahu *et al.* (2010) and Srichandan *et al.* (2014). Moharana and Patra (2013) have reported the abundance of 12 species of protozoa, eight species of Rotifera, six species of Cladoceran, and four species of Copepoda, including different genera. A total of twenty different *Tintinnid* species have been recorded by Dash, Behera *et al.* (2017). Horizontal and vertical distribution and abundance of Zooplankton around the Swatch-of-No-Ground of Northern Bay of Bengal, authored by Nurany *et al.* (2021). So far, little attention has been paid to the study of the diversity of plankton. Other sources of information are also limited to stray records or accounts in expedition reports at the Digha coast.

Materials and Methods

Sampling Study Site

Digha coast is located in the Purba Medinipur district of West Bengal, India. It's stretched from the mouth of the Subarnarekha River to Old Digha, up to Digha Mohana. The total length of the study area is around 9-10 km including Digha Mohana, Old Digha, New Digha, Talsari delta located in Jaleswar district of Odisha State, India (Figure 1).

Figure 1. Map showing the study sites Digha along West Bengal.

Water samples analysis

Water samples were collected in sterilized plastic bottles and placed in ice-packed container which later transported to the Laboratory for analysis. Water parameters like temperature (°C), Dissolved Oxygen (DO), Hydrogen-ion concentration (pH) and Salinity (ppt), were determined and recorded right at the sampling stations. All parameters were determined in accordance with the standard methods (AOAC, 2000; APHA, 2005). The seawater temperatures were measured by mercury thermometer with an accuracy of 0.1°C. Salinity of surface seawater was measured by Refractometer Model [HI 98319, Hannah] while the pH was measured using water proof pH meter [HI 98108] and DO was estimated by Winkler's method (Strickland and Parsons, 1972).

Collection, Preservation and Identification

Surveys were conducted in different adjacent coastal areas of Digha, West Bengal. Surface samplings of zooplankton were made at monthly intervals by horizontal small local towing of a plankton net (0.35m diameter) made up of bolting silk (Cloth No. 10; mesh size 158µm) for a number of bucket water filters in the net for several times. The collected samples were preserved in 5% neutralized formalin and used for qualitative analysis. A known quantity of water (1000 lit) was filtered through a bag net of the same mesh size, and the numerical zooplankton analysis was carried out using a binocular microscope. Photographs were taken with the help of a binocular microscope for taxonomic identification. Zooplankton species was measured following standard by Kasturirangan (1963); Wimpenny (1966); Newell and Newell (1977); Smith (1977); Sarkar *et al.* (1986); Perumal *et al.* (1998); and Conway *et al.* (2003).

Results

Seawater temperatures recorded at two different sites ranged from 30.7 to 31.0°C. The minimum seawater temperature was observed at the hospital beach, and the maximum was registered at Udaipur Beach. The observed salinity values ranged between 31.0 and 31.6 ppt, with the higher salinity (31.6 ppt) at Hospital Beach and the lowest at Udaipur Beach. Hydrogen ion concentration (pH) ranged from 7.92 to 8.3, with the maximum at Udaipur beach and the minimum at Hospital beach, respectively. The dissolved oxygen (DO) concentration varied between 6.1 – 6.4 mg/l registering a maximum at Hospital Beach and minimum values at Udaipur Beach (Figure 2). Totally ten species belonging to nine genera, six families, and three orders were recorded in the present investigation (Table 1). In the present observation, zooplankton distribution can be divided into three distinct categories based on the period of existence at the Digha coast. Zooplankton species such as *Euterpina acutifrons, Oithona brevicornis brevicornis, Paracalanus parvus parvus, Paracalanus aculeatus aculeatus, Microsetella norvegica, Nannocalanus minor, Undinula vulgaris, Canthocalanus pauper, Eucalanus elongatus elongatus, Subeucalanus crassus* and *Oithona brevicornis brevicornis* have been reported (Figure 3).

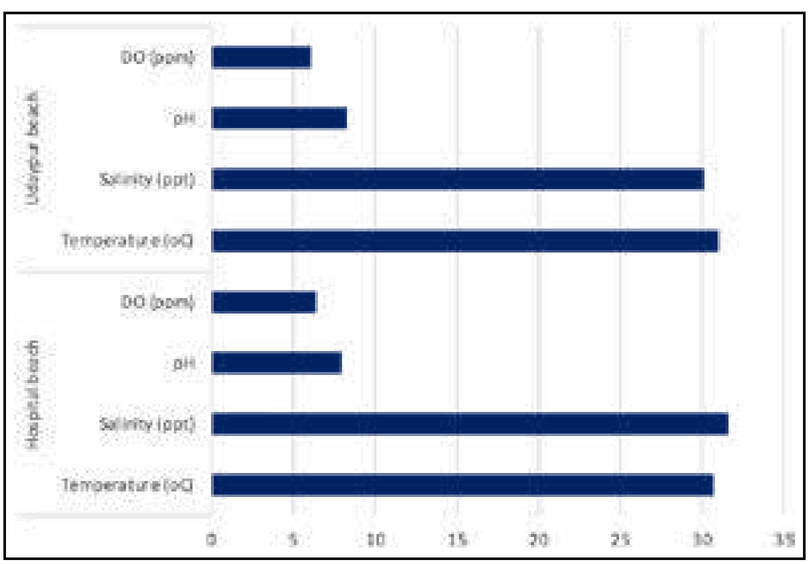


Figure 2. Water quality parameters analysis in Digha adjacent areas.

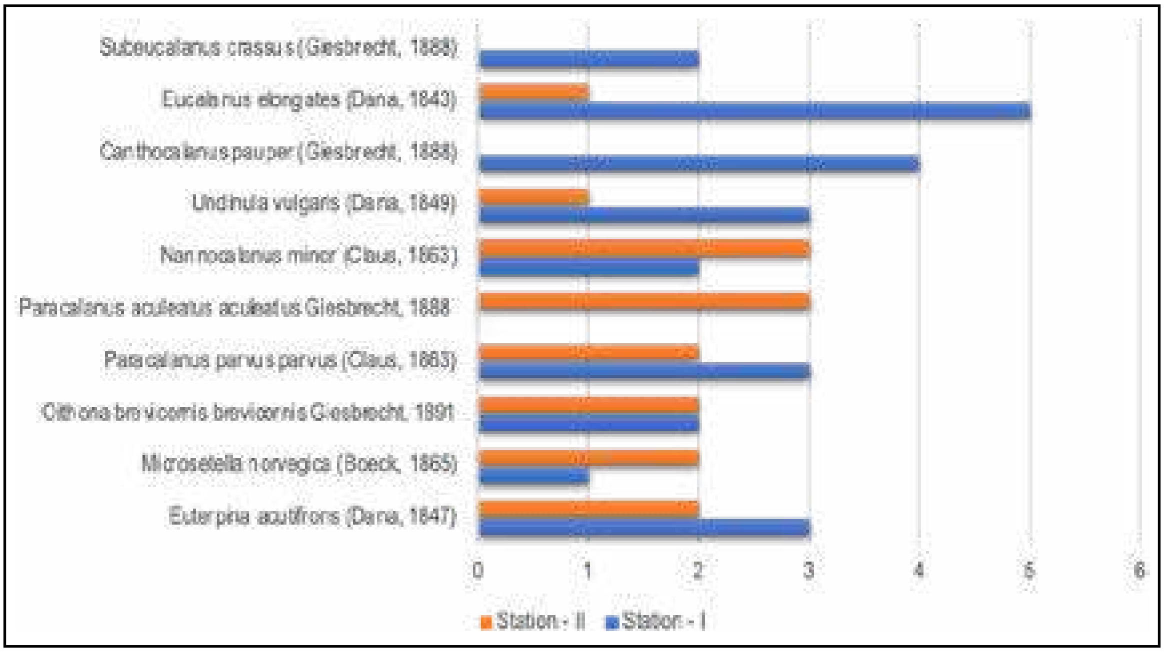


Figure 3. Relative proportion of species wise distribution from two different sites.

Table 1. List of zooplankton species identified from the study.

S. No.	Order	Family	Species	No. of Example	
				S1	**S2**
01.	Harpacticoida	Paracalanidae	*Euterpina acutifrons* (Dana, 1847)	03	02
02.	Harpacticoida	Paracalanidae	*Microsetella norvegica* (Boeck, 1865)	01	02
03.	Cyclopoida	Oithonidae	*Oithona brevicornis brevicornis* Giesbrecht, 1891	02	02
04.	Calanoida	Calanidae	*Paracalanus parvus parvus* (Claus, 1863)	03	02
05.	Calanoida	Calanidae	*Paracalanus aculeatus aculeatus* Giesbrecht, 1888	00	03
06	Calanoida	Calanidae	*Nannocalanus minor (*Claus, 1863*)*	02	03
07.	Calanoida	Calanidae	*Undinula vulgaris* (Dana, 1849)	03	01
08.	Calanoida	Calanidae	*Canthocalanus pauper* (Giesbrecht, 1888)	04	00
09.	Calanoida	Eucalanidae	*Eucalanus elongates* (Dana, 1843)	05	01
10.	Calanoida	Subeucalanidae	*Subeucalanus crassus* (Giesbrecht, 1888)	02	00
				25	**16**

Note: S1. Hospital beach; S2. Udaypur beach

The dominant species in the families were Calanidae (5 spp.), Paracalanidae (2 spp.), Eucalanidae, and Subeucalanidae (1 sp.). The maximum number of species identified belongs to Calanidae (5 spp.) followed by Paracalanidae (2 spp.), Eucalanidae, and Subeucalanidae (1 sp.) (Figure 4). The dominant species in the order were Calanoida (70%), Harpacticoida (20%) and Cyclopoida (10%) (Figure 5).

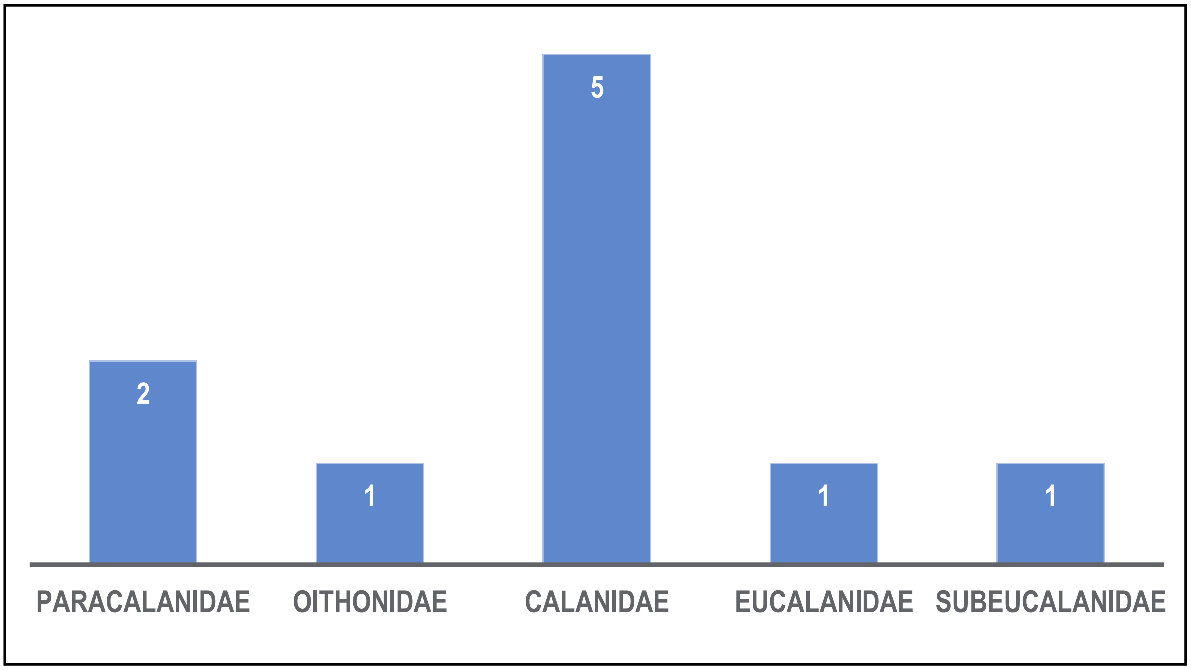


Figure 4. Relative proportion of species composition in the major families of zooplankton.

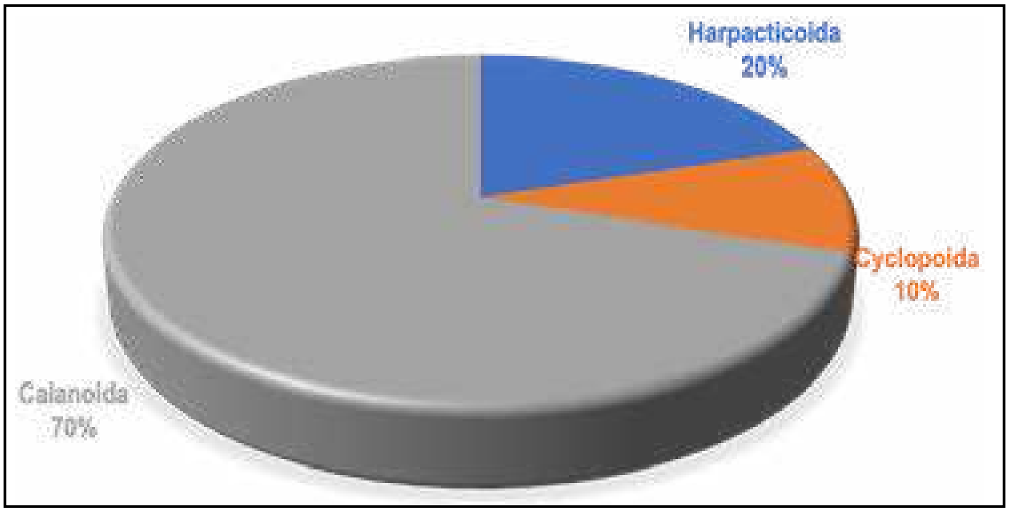


Figure 5. Relative proportion of species composition in the major orders of zooplankton.

Systematic analysis:

***Euterpina acutifrons* (Dana, 1847)**

Phylum : Arthropoda von Siebold, 1848

Subphylum : Crustacea Brünnich, 1772

Class : Hexanauplia Oakley, Wolfe, Lindgren & Zaharof, 2013

Subclass : Copepoda Milne Edwards, 1840

Infraclass : Neocopepoda Huys & Boxshall, 1991

Superorder : Podoplea Giesbrecht, 1882

Order : Harpacticoida Sars G.O., 1903

Family : Tachidiidae Sars G.O., 1909

Genus : *Euterpina* Norman, 1903

Species : *Euterpina acutifrons* (Dana, 1847) (Figure 5).

Characters: Body onion-shaped, length of body greatly abbreviated, 5th legs rudimentary, more or less fused, unlike in the two sexes; length of female 0.35 to 0.5 mm, of male 0.3 to 0.4 m.

Habitat: Marine, tropical, neritic.

Distribution: Indo-west Pacific, West Bengal, Odisha, Kerala coast.

***Microsetella norvegica* (Boeck, 1865)**

Family : Ectinosomatidae Sars G.O., 1903

Genus : *Microsetella* Brady & Robertson, 1873

Species : *Microsetella norvegica* (Boeck, 1865) (Figure 5).

Characters: Body slender and laterally compressed. The urosome is as wide as metasome. Caudal rami setae nearly long as body length and divergent.

Habitat: Bathy-pelagic, epipelagic.

Distribution: Found in Hooghly estuary of West Bengal, Odisha, South-east coast of India, Southern Kerala.

***Oithona brevicornis brevicornis* Giesbrecht, 1891**

Order : Cyclopoida Burmeister, 1834

Suborder : Oithonida Khodami, Mercado-Salas, Tang & Matrinez Arbizu, 2019

Family : Oithonidae Dana, 1853

Genus : *Oithona* Baird, 1843

Species : *Oithona brevicornis brevicornis* Giesbrecht, 1891 (Figure 5).

Characters: Rostrum is much longer and narrower, comparatively small in size that other cyclopoids. Body has thoracic segments; the forehead is rounded dorsally. The caudal rami have 3x the width. Caudal setae are plumbed and the antennules have segments that differ in male and female.

Habitat: Marine, Subtidal, Intertidal, Euryhaline

Distribution: Indian to Atlantic Ocean, tropical and temperate Pacific Ocean, Hooghly estuary of West Bengal, Odisha.

***Paracalanus parvus parvus* (Claus, 1863)**

Order : Calanoida Sars G.O., 1903

Family : Paracalanidae Giesbrecht, 1893

Genus : *Paracalanus* Boeck, 1865

Species : *Paracalanus parvus parvus* (Claus, 1863) (Figure 5).

Characters: Female *P. parvus parvus* size ranging from 0.6-1.3 mm and the male is between 0.5 and 1.4 mm.

Habitat: Marine, Eastern Mediterranean waters.

Distribution: Indo-Pacific Ocean and northeast Atlantic Ocean, Odisha, Hooghly estuary of West Bengal and Kerala coast.

***Paracalanus aculeatus aculeatus* Giesbrecht, 1888**

Characters: Cephalic region is oval shaped, short and have 4 segments. Thoracic region is uniformly segmented. Antennas are shorter than body length.

Habitat: Marine

Distribution: Indo-Pacific Ocean. Widely distributed in Odisha and North - western coast of Bay of Bengal and West Bengal coast of India.

***Nannocalanus minor* (Claus, 1863)** (Figure 5).

Family : Calanidae Dana, 1849

Genus : *Nannocalanus* Sars G.O., 1925

Characters: Body is bilaterally symmetrical, length ranging from 1.8-2.45mm.

Habitat: Marine, pelagic.

Distribution: Indo-west Pacific and Atlantic Ocean, also found in West Bengal and Odisha coast of India.

***Undinula vulgaris* (Dana, 1849)**

Genus : *Undinula* Scott A., 1909

Species : *Undinula vulgaris* (Dana, 1849) (Figure 5).

Characters: Short cylindrical body,

Habitat: Marine pelagic.

Distribution: Western Indian Ocean, North-western Bay of Bengal, West Bengal and Odisha coast.

***Canthocalanus pauper* (Giesbrecht, 1888)**

Genus : *Canthocalanus* Scott A., 1909

Species : *Canthocalanus pauper* (Giesbrecht, 1888) (Figure 5).

Characters: Cephalic region segmented into 5 parts, Thoracic region is segmented into 6 parts,

Habitat: Tropical, Marine

Distribution: India, Nothern-western coast of Bay of Bengal, West Bengal and Odisha.

***Eucalanus elongatus elongatus* (Dana, 1848)** (Figure 5).

Family : Eucalanidae Giesbrecht, 1893

Genus : *Eucalanus* Dana, 1852-1853

Characters: Elongated slender body, Antenna is longer than body length. Presence of 5 segments in Cephalic region. Thoracic region also segmented in 5 parts.

Habitat: Marine pelagic and Tropical.

Distribution: Widely distributed in the Bay of Bengal coast of West Bengal and Odisha.

***Subeucalanus crassus* (Giesbrecht, 1888)** (Figure 5).

Family : Subeucalanidae Giesbrecht, 1893

Genus : *Subeucalanus* Geletin, 1976

Characters: Cephalic region is sub-elongated and the thoracic part is short (only 3 segments). Antenna are much longer than body length. Have 21-24 segments in the antenna.

Habitat: Marine subtropical and Pelagic

Distribution: Northwest Pacific: China, India, West Bengal, Odisha.

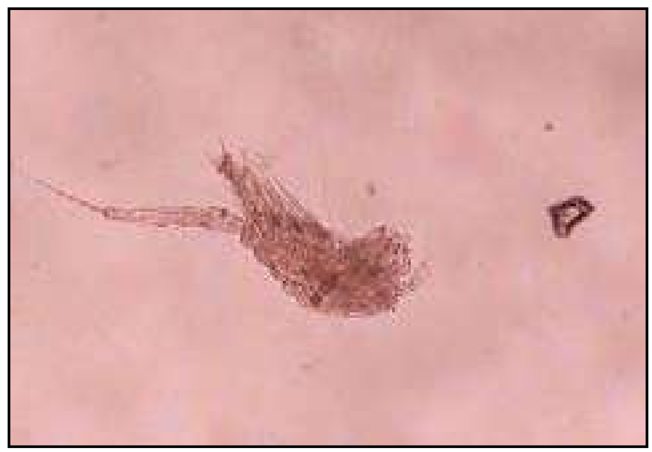
Discussion

Zooplankton shows a higher standing crop on the west coast of India than on the east coast. The International Indian Ocean Expedition Plankton Atlas (Prasad and Singh, 1980) contains maps of the total zooplankton biomass in the Arabian Sea and the total zooplankton biomass in the Indian Ocean (Moharana and Patra, 2013). Total zooplankton biomass and the constituent species under the major taxa in relation to hydrographic conditions in the Hooghly estuarine complex were studied around Sagar Island from March 1979 to February 1981 (Sarkar *et al.*, 1986). The temperature difference is a main factor influencing the abundance of zooplankton in coastal as well as estuarine bodies of water. During the study, the salinity of the study area was found to be moderate to high (30-32ppt), according to Jayalakshmi *et al.* (2017), can be a result of a higher rate of evaporation. In the present study, the dissolved oxygen remained 6-6.4 mg/l which was under the optimum range. Total zooplankton biomass was higher in winter than in summer, and there was no significant relation between tintinnid cell number and total zooplankton biomass. It may mainly be due to the optimum temperature, light, pH, water current etc. This supports the findings of Manna *et al.* (2008) that copepods play the dominant role in total zooplankton biomass in the coastal water of Digha, and therefore, total zooplankton density is not a determinant of tintinnid distribution (Dash *et al.*, 2017). In the present study, the copepods are the most dominant zooplankton groups, which will support the captive larval feeding of marine fishes as reported by Davis, Derbes and Head (2018). Similar kinds of observations about the dominance of copepods in the total density were reported by Perumal *et al.* (2009), Fernandes and Ramaiah (2009), Jagadeesan *et al.* (2013), Jayaraj *et al.* (2014), and Jemi Job and Hatha (2018). The occurrence of higher values of copepods among the other zooplankton on the Odisha coast corroborates many earlier findings (Wellershaus, 1974; Sarkar *et al.*, 1984; Nagarajaiah and Gupta, 1985; Nair *et al.*, 1984; Padmavati and Goswami, 1996; Mishra and Panigrahy, 1999; Karuppasamy and Perumal, 2000; Qasim, 2005; Madhu *et al.*, 2007; Koppelmann and Weikert, 2000). In the present study, zooplankton were found to be represented by the families Calanidae (5 spp.), Paracalanidae (2 spp.), Eucalanidae, and Subeucalanidae (1 sp.). The maximum number of species identified belongs to Calanidae (5 spp.) followed by Paracalanidae (2 spp.), Eucalanidae, and Subeucalanidae (1 sp.). The dominant species in the order were Calanoida (70%), Harpacticoida (20%), and Cyclopoida (10%). The findings have generated baseline information regarding zooplankton species diversity and taxonomy in the coastal waters of Digha, West Bengal.

Euterpina acutifrons (Dana, 1847)

Paracalanus parvus parvus (Claus, 1863)

Paracalanus aculeatus aculeatus Giesbrecht, 1888



Oithona brevicornis brevicornis Giesbrecht, 1891

Microsetella norvegica (Boeck, 1865)

Nannocalanus minor (Claus, 1863)

Undinula vulgaris (Dana, 1849)

Canthocalanus pauper (Giesbrecht, 1888)

Subeucalanus crassus (Giesbrecht, 1888)

Eucalanus elongatus elongatus (Dana, 1848)

Figure 5. List of zooplankton species were identified.

Acknowledgements

I wish to express our sincere gratitude and thanks to the Director, Zoological Survey of India, Hqs, Kolkata, for his help and guidance throughout this study. I also wish to express my thanks to the Head of the Department, Department of Marine Biotechnology, Bharathidasan University, Tiruchirappalli - 620 024, Tamil Nadu, India, for the initiation of the project and his constant sharing of ideas during the survey work.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Bumble bee, *Bombus haemorrhoidalis* Smith, 1852 (Apoidea: Hymenoptera)- a significant Pollinator and Bio-indicator species of the lower Shiwalik ranges in the Western Himalayan states of India

Shivani Sharma[1,2,3], Gaurav Sharma[1,4] and Namita Joshi [2]

[1]Zoological Survey of India (MoEFCC), Northern Regional Centre, Dehradun-248195, Uttarakhand, India.
[2]Department of Environmental Sciences, Kanya Gurukula Campus, Gurukula Kangri Vishwavidyalaya, Haridwar-249404, Uttarakhand, India.
emails: [3]shiva.skt.03@gmail.com, [4]drgaurav.sharma@gov.in

Abstract

This study has been carried out to find out the role of the bumble bee, *Bombus haemorrhoidalis* as a significant pollinator and Bio-indicator species in the ecosystems of the lower Shiwalik ranges in the Western Himalayan states of India during 2019-22. The *Bombus haemorrhoidalis* was the only dominant species of the genus *Bombus* ranging in the selected study area. This species was recorded as very active and pollinating in the winter period during harsh environmental conditions. The *B. haemorrhoidalis* has a great role in pollinating the flowers of *Solanum melongena, Cajanus cajan*, *Cucumis sativus, Cucurbita maxima* in agricultural fields and *Ocimum tenuiflorum*, *Helianthus annus* in cultivated gardens *Mesosphaerum suaveolens*, *Vitex negundo*, *Eremostachys superba, Justicia adhatoda, Impatiens glandulifera*, *Tecoma stans*, and *Lantana camara etc* in wild in the study area.

Keywords: Bumble bee, *Bombus haemorrhoidalis*, Hymenoptera, Pollinator, Western-Himalaya, India.

Introduction

The Western Himalayas is one of the most diverse ecosystems in the world. The rich bio-diversity of this mountainous region provides suitable habitats for bumble bees. There are about 250 species of bumble bees reported around the world, out of which 48 species so far reported from India (Saini *et al.,* 2015). The bumble bees belongs to the high land and distributed mostly in temperate regions in the world as they are cold-adapted species (Williams, 1991). Bumble bees are the important bio-indicators of the Himalayan ecosystem as they indicate the health of an ecosystem and the presence of specific components in the habitats. These bees are distinct by their black and yellow body hairs present in the bands over the abdomen, the hindlegs of female bees are modified into corbicula surrounded by the hair to collect pollen. Their long proboscis and fuzzy body make them more efficient pollinators and they also visited more numbers of flowers per minute as compared to honey bees. They follow unique buzzy foraging behavior to pollinate flowers, as they produce very distinctive vibrational sounds that extract pollen from the anther of the flower. With their hairy body and legs, they transfer pollen to the stigma of the flower and fertilise the flowering plants. These insects pollinate wild, agricultural and horticultural plants which are not pollinated by honey bees (Wahengbam *et al.,* 2019). *B. haemorrhoidalis* is an active pollinator in western Himalayan ecosystems, its distribution range starts from 500-1800m. This species is observed as the most significant pollinator to maintain the germplasm of many floral species in the mountain regions, due to the presence of very limited pollinators of other faunal groups in the winter season. These distinct characteristics make them efficient pollinators in the Himalayan ecosystem.

*Author for correspondence :
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Material and Methods

Study Area

The present study was conducted in the selected 20 localities of the Lower Shiwalik ranges in the Western Himalayan States of India (10 selected localities each in Himachal Pradesh and Uttarakhand). The field collection has been done by sweep net sampling method between the altitude of 565-1224m during different seasons of 2019-22. The vegetation in the Shivalik foothills is dominated by Sub-tropical coniferous and broad-leaf forests. The samplings were conducted in the different localities of the study area to assess the presence of *B. haemorrhoidalis* and its floral resources present in the different habitats such as agricultural, barren horticultural lands and grasslands.

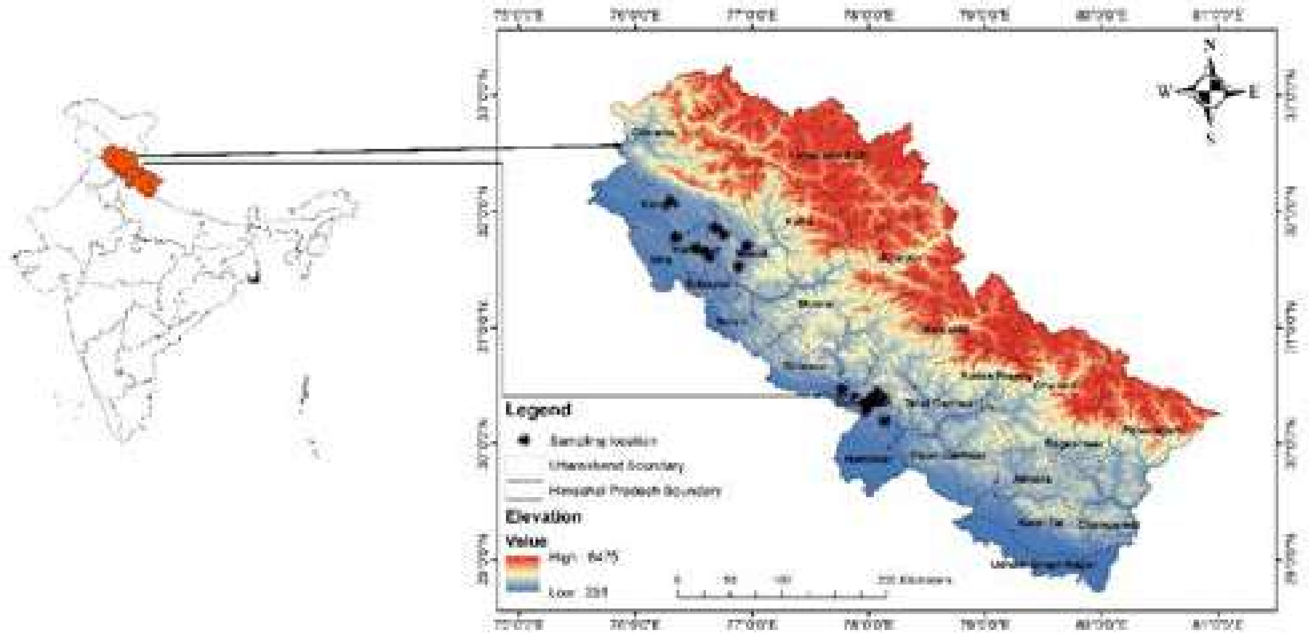

Figure 1. Map showing the study area for sampling of Bumblebee specimens from Shiwalik ranges in Himachal Pradesh and Uttarakhand states.

Sampling Methodology

The bumble bee's specimens were collected and recorded pollinating different flowering plants throughout the year 2019-22 in different localities of the study area. The survey has been conducted between the altitude of 565-1224m during different seasons, *i.e.* pre-monsoon (January–June), monsoon (July–September), and post-monsoon (October–January) from 8am-5pm in pre-monsoon and monsoon periods and from 8am-4pm in the post-monsoon periods due to short light hours. The collection has been done by using the sweep net of nylon. Specimens were killed in jars after capturing which were charged with ethyl-acetate fumes. Insect mounting has been done with the insect stretcher and with different size of entomological pins (sizes 1, 2, and 3) after mounting an artificially incubated chamber with a yellow light bulb was used for 2-3 days to dry the stretched specimens in discontinuous light hours. Then these processed specimens were transferred to fumigated entomological boxes. For the genitalia dissection male abdomen segments were dipped inside KOH solution for 24 hours and with the help of forceps genitalia pulls out and wasted solution was discarded. All the specimens of the bumble bee were examined under a Luxeo 4Z stereomicroscope and digitally photographed using Nikon digital camera D7500. For the identification, keys given in Bingham, 1897; Williams, 1991; Michener, 2007; Saini *et al.,* 2015 were followed and the identification of floral plants was made using the keys by Pusalkar and Srivastava, 2018.

Results & Discussion

Systematic Account

Order HYMENOPTERA

Superfamily APOIDEA

Family APIDAE

Subfamily APINAE

Tribe Bombini

Genus *Bombus* Latreille, 1802

Species *haemorrhoidalis* Smith, 1852

Bombus orientalis Smith, 1854

Bombus buccinatoris Smith, 1879

Orientalibombus haemorrhoidalis semialbopleuralis Tkalcu, 1974

Orientalibombus haemorrhoidalis cinnameus Tkalcu, 1989

Orientalibombus montivolans semivicinus Tkalcu, 1991

B. haemorrhoidalis hive has three different casts, male (drone), female (worker) and single queen, queen is the one who lays the fertile eggs in the colony and maintains its population. Adults in the hive feed on nectar and larvae feeds on a mixture of pollen and honey to get energy (Williams, 1991). *B. haemorrhoidalis* is an important bio-indicator, it indicates the health of the ecosystem and diversity of the ecosystem as it is a specific pollinator to specific flowers (**Table 1).** The bumble bee species have long tongue length and they can easily reach the stigma of a flower with a long corolla, while short tongue bee has to bite the corolla of a flower to reach the stigma. Hence, long-tongue pollinators can not be replaced by honey bees (Free and Williams, 1973; Rasmont, 1988). This species was the only dominant species of genus *Bombus* ranging between this altitude in the study area. It has great efficiency to survive in extreme cold conditions and also can fly at high wind speed. As the temperature decreases in the winter season, this species has been recorded as one of those species which remains active and pollinates in the late winter period during the harsh environmental conditions. It was reported foraging in the dawn and dusk hours; their peak activities were reported from 8am-10am and 4pm-6pm and they were found least active during the afternoon. The maximum species richness of this species was reported in the Post-Monsoon period. The Bumble bee population is declining worldwide due to integrated-agricultural practices such as the use of pesticides, fungicides, herbicides; habitat degradation; habitat fragmentation; forest fire; outbreaks of invasive species and climate changes (Goulson *et al.,* 2008 and Tamburini *et al.,* 2021). The increase in hot wave frequency can predict the local extinction of bumble bee species (Soroye *et al.,* 2020). The conservation of bumble bees will help us in the sustaining of natural resources and it is also important for ecosystem functioning or food security. As it is an important bio-indicator species it indicates the health and presence of specific floral components in an ecosystem. So this indicator species will help in conserving all the species within that region. The evaluation of indicator species within a particular biogeographic region can provide information about the status of declining species within communities and can also give information about conservation strategies for complete communities (Birkhofer *et al.,* 2018). Therefore, more earnest efforts are required for the conservation of this species, their habitats and floral resources to conserve the entire ecosystem in any geographical area.

Table 1: Nectar plants of *B. haemorrhoidalis* recorded in the study area (Foraging ecology).

Sl. No.	Botanical name	Common name	Blooming period	Wild/Cultivated/Invasive
Family: Acanthaceae				
1.	*Justicia adhatoda* L.	Basuti	Throughout year	Wild
Family: Asteraceae				
2.	*Dahlia coccinea* Cav.	Dahlia	June-November	Cultivated
3.	*Tithonia rotundifolia* (Mill.)	Red sunflower	November- December	Cultivated
4.	*Helianthus annuus* L.	Common- Sunflower	June-October	Cultivated
5.	*Cirsium arvense* (L.)	Field thistle	March- April	Wild

Sl. No.	Botanical name	Common name	Blooming period	Wild/Cultivated/Invasive
Family: Balsaminaceae				
6.	*Impatiens glandulifera* Royle	Himalayan balsam	September-December	Wild
Family: Bignoniaceae				
7.	*Tecoma stans* (L.)	Yellow trumpet	Throughout year	Cultivated
Family: Convolvulaceae				
8.	Ipomoea purpurea (L.)	Morning-glory	October- December	Wild
Family: Cucurbitaceae				
9.	*Cucurbita maxima* Duchesne	Pumpkin	November-December	Cultivated
10.	*Cucumis sativus* L.	Cucumber	June- August	Cultivated
Family: Lamiaceae				
11.	*Vitex negundo* L.	Chaste tree	September–December	Wild
12.	*Mesosphaerum suaveolens* (L.)	Pignut	September–December	Wild
13.	*Eremostachys superba* (Van Mooli)	Golden Himalayan Spike	March-April	Wild and Cultivated
Family: Leguminaceae				
14.	*Glycine max* (L.)	Soyabean	April-June	Cultivated
15.	*Trifolium resupinatum L.*	Persian clover	November- March	Cultivated
Family: Solanaceae				
16.	*Solanum melongena* (L.)	Brinjal	June–October	Cultivated
Family: Verbenaceae				
17.	*Lantana camara* L.	Lantana	Throughout year	Invasive
Family:Malvaceae				
18.	*Hibiscus mutabilis* L.	Cotton- rose	October- January	Cultivated

Figure 2. Floral resources of *B. haemorrhoidalis* in western Himalayas, India.

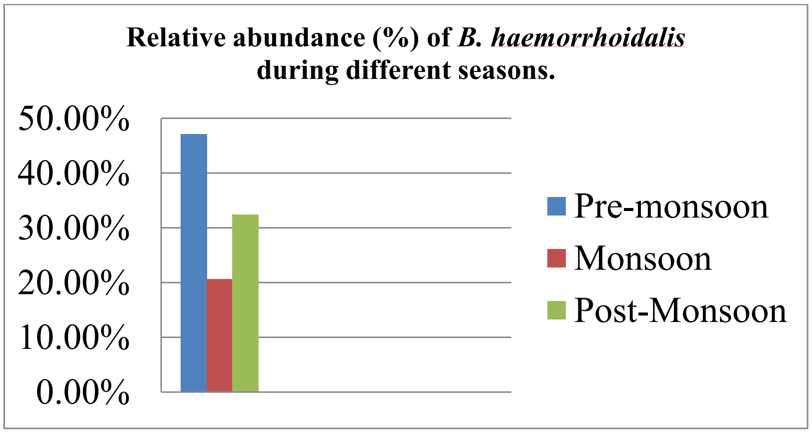

Figure 3. Relative abundance (%) of *B. haemorrhoidalis* during different seasons.

Figure 4. A. Queen B. Drone ( ) C. Worker ( )

Figure 5. Male genitalia of *B. haemorrhoidalis*

Acknowledgements

The authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India, Kolkata, for providing the necessary facilities and support. The help rendered by Dr. *Rifat* H. *Raina*, Scientist-E, Desert Regional Centre, Zoological Survey of India, Jodhpur for providing the current update on the bumble bees is duly acknowledged.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Spiders (Arachnida: Araneae) of the Shendurney Wildlife Sanctuary, Kerala, India

Puthoor Pattammal Sudhin & Souvik Sen*

Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore
Kolkata – 700053, West Bengal, India.
Email: sensouvik07@gmail.com.

Abstract

The spider fauna of the Shendurney Wildlife Sanctuary of Kerala is documented based on the present collections and published records. A total of 79 species of spiders belonging to 53 genera and 16 families are recognized from the sanctuary. Among these spiders, 24 species are endemic to India, and two species, *Clubiona melanosticta* Thorell, 1890, and *Oxyopes mirabilis* Zhang, Yang & Zhu, 2005, are new records to India and South Asia as well. Most of the species of spiders (63%) belong to the families Araneidae and Salticidae. Analysis of guild structure recognized six feeding guilds, with orb-weavers being the most common, followed by stalkers and ambushers.

Keywords: Araneae, checklist, new records, guilds, endemic, Western Ghats, protected area

Introduction

Spiders are among the most successful groups of animals on earth, and they inhabit almost all terrestrial ecosystems and are especially diverse in the tropical and subtropical regions of the world (Foelix, 2011). They play important roles in several ecosystems as primary predators and prey for a diverse range of organisms (Nyffeler, 1999). They are also valuable in evaluating the total species richness and health of terrestrial ecosystems (Norris, 1999), and they respond differently to natural conditions and human disturbances (Pearce and Venier, 2006). Several of these qualities make spiders an interesting group for studying biodiversity and assessing natural ecosystems.

Spiders are important members of the forest community, which play a vital role in the forest food chain and contribute significantly to the biodiversity. Their abundance and diversity in forest ecosystems are important factors for future conservation and management efforts. The present study is carried out in the Shendurney Wildlife Sanctuary, a protected area of Kerala in the Western Ghats. It is one of the richest areas of biodiversity in the Western Ghats, bestowed with rare and endangered species of both flora and fauna. The diversity and distribution of spiders in this area are poorly known as compared to the other protected areas of the Western Ghats. Asima *et al.* (2021, 2022), Sen & Sureshan (2022), and Sudhin *et al.* (2022) described some new species of spiders from this region. Asima and Prasad (2022), recently reported 38 araneid spiders from the sanctuary. No other work on spiders have been carried out in this sanctuary till date. Therefore, extensive surveys and studies are required to find out the true diversity of spiders occurring in the Shendurney Wildlife Sanctuary. In the present study, an updated checklist of the spiders of the Shendurney Wildlife Sanctuary is provided based on the present collections and published records.

*Author for correspondence :
Article Received on: 21.04.2023

Accepted on: 24.05.2023

Material and methods

Study area: The Shendurney Wildlife Sanctuary, situated in the Kollam district of Kerala, falls within the Agasthyamalai Biosphere Reserve of the Western Ghats. The sanctuary (8°44' to 9°14' N N latitude and 76°59' to 77°16' E longitude) covers an area of 171 km^2 (Aditya *et al.* 2018; Bilyaminu *et al.* 2021). The sanctuary has substantial natural vegetation, ranging from the southern secondary moist mixed deciduous forest to the southern subtropical hill forest (Narayanankutty *et al.* 2014). The elevation in the sanctuary varies from 800 to 1920 m above MSL, with a general slope towards the west (Aditya *et al.* 2018).

Methods: Collection of spiders was carried out in the different locations of the sanctuary from April 2019 to March 2022. Spiders were collected using standard sampling techniques such as vegetation beating, ground hand collection, aerial hand collection, and sweep netting (Sebastian and Peter, 2009). Collected specimens were preserved in 70% alcohol. Specimens were later examined in detail using a Leica M205A stereomicroscope. Images were acquired by using a Leica DFC4500 digital camera attached to the Leica M205A stereomicroscope equipped with Leica Application Suite (LAS), version 4.1.2. Identification was made with the help of relevant literature available in the World Spider Catalog (2023). Description of the length of leg segments is as follows: total length [femur, patella, tibia, metatarsus (except palp) and tarsus]. The studied spiders were deposited in the National Zoological Collections of the Zoological Survey of India (NZC-ZSI), Kolkata, West Bengal, and the Western Ghat Regional Centre (ZSI/WGRC), Kozhikode, Kerala.

Abbreviations used in the text and figures: ALE = anterior lateral eye, AME = anterior median eye, PLE = posterior lateral eye, PME = posterior median eye.

Figure 1. Map of the Shendurney Wildlife Sanctuary, Kerala.

Results

The study resulted in the recognition of 79 species of spiders belonging to 53 genera and 16 families (Tables 1 & 2). Among the collected spiders, 24 species are endemic to India (Table 2). Araneidae was the most diverse family (35 species, 44.3%) of the sanctuary followed by Salticidae (15 species,19%) and Oxyopidae (5 species, 6.3%) (Table 1). The remaining spider families contributed less than five species (Table 1). The families with the highest number of genera were the Araneidae (17 genera) and Salticidae (14 genera), and the rest of the families represent less than four genera (Table 1).

Spiders from the sanctuary were classified into the following guilds based on their foraging mode (Uetz *et al.* 1999): (1) Orb web weavers; (2) Stalkers; (3) Ambushers; (4) Foliage hunters; (5) Sheet web builders; and (6) Scattered line weavers (Table 1). Among the spiders, 41 species (52%) belong to the guild of orb web weavers, followed by the stalkers (24 species, 30.4%), ambushers (5 species), foliage hunters (4 species), scattered line weavers (3 species), and sheet web builders (2 species) (Figure 2).

The current study also reports two new records for India: *Clubiona melanosticta* Thorell, 1890, and *Oxyopes mirabilis* Zhang, Yang & Zhu, 2005. The systematics of these two new records is given below.

Family Clubionidae Wagner, 1887

***Clubiona melanosticta* Thorell, 1890**

(Figures 3a–d)

Clubiona melanosticta Thorell, 1890: 374.

Clubiona melanothele Thorell, 1895: 42.

Clubiona melanosticta — Thorell, 1895: 42. — Deeleman-Reinhold, 2001: 123, figs 51–52. — Dankittipakul and Singtripop, 2008: 42, figs 8–10, 52–54. — Zhang, Yu & Li, 2021: 49, figs 44A–E, 45A–H, 59A, 69A, 78F, 86F, 94F.

Material examined. 1♀ (NZC-ZSI-8215/18), INDIA: Kerala, Kollam district, Shendurney Wildlife Sanctuary, 9°17'33.0"N, 77°03'33.9"E, h= 792 m a.s.l., 09.xii.2021, collected by P. Girish Kumar.

Diagnosis. The male of *C. melanosticta* Thorell, 1890 can be distinguished from other *Clubiona* species by the shape of the conductor, which is elongate, transverse, flat, aligned along the distal edge of tegulum, retrolaterally ending in a short beak (see Deeleman-Reinhold, 2001: figs 51-52; Zhang *et al.*, 2021: figs 59A, 69A). The female distinguished by the epigyne with anterior U-shaped window lined with conspicuous black rim, and copulatory openings representing two black spots (Figure 3c).

Description: Female (Figs 3a–d): Measurements: Body length 5.13. Carapace length 2.31, width 1.58. Abdomen Length 2.64, width 1.64. Eye diameters: AME 0.11; ALE 0.12; PME 0.13; PLE 0.12. Eye inter distances: AME-AME 0.11; AME-ALE 0.08; ALE-ALE 0.47; PME-PME 0.26; PLE-PLE 0.86; PME-PLE 0.18; ALE-PME 0.12; ALE-PLE 0.07; AME-PME 0.12; AME-PLE 0.28. Clypeus height 0.05. Length of chelicera 0.87. leg I 4.31 [1.27, 0.61, 1.06, 0.75, 0.62], II 4.54 [1.33, 0.61, 1.19, 0.79, 0.62], III 3.88 [1.11, 0.52, 0.81, 1.02, 0.42], IV 5.63 [1.39, 0.70, 1.37, 1.55, 0.62]. Leg formula: 4213. Carapace pale yellow, slightly darker on ocular region. Chelicerae light yellowish-brown, promargin with 1 and retromargin with 2 teeth. Endites light yellow, outer margin with dark brown lines. Labium light yellow. Sternum pale yellow. Abdomen whitish-yellow, mottled with dark brown spots; venter whitish-yellow, without any markings. Spinnerets light brown. Epigyne as shown in Figs 3c–d. Epigyne with anterior U-shaped window lined with conspicuous black rim; copulatory openings representing 2 black spots; copulatory ducts wide and elbow shaped (Figs 3c–d; see Zhang *et al.*, 2021: fig 45A–D).

Distribution. India (new record), China, Myanmar, Thailand, Laos, Indonesia, and Papua New Guinea (present study; World Spider Catalog, 2023).

Family Oxyopidae Thorell, 1869

***Oxyopes mirabilis* Zhang, Yang & Zhu, 2005**

(Figures 3e–h)

Oxyopes mirabilis Zhang, Yang & Zhu, 2005: 76, figs 2A–C.

Oxyopes mirabilis — Tang & Li, 2012: 32, figs 29A–D, 30A–D.

Material examined. 1♂ (NZC-ZSI-8214/18), INDIA: Kerala, Kollam district, Shendurney Wildlife Sanctuary, 852′20″°N, 77°11′36″E, h= 899 m a.s.l., 20.i.2019, collected by P.M. Sureshan.

Diagnosis. *O. mirabilis* is most similar to *O. gaofengensis* Zhang, Zhang & Kim, 2005, from which it can be distinguished by the male palp with triangular cymbial apophysis, L-shaped palpal tegular apophysis, and female epigynum with three times twisted copulatory ducts (cf. Figs 6g–h, and figs 29A–B, D in Tang & Li [2012] with figs 3–5 in Zhang, Zhang & Kim [2005]).

Description: Male (Figs 3e–h): Measurements: Body length 6.07. Carapace length 2.85, width 2.34. Abdomen length 3.12, width 1.56. Eye diameters: AME 0.11; ALE 0.24; PME 0.23; PLE 0.25. Eye inter distances: AME-AME 0.15; AME-ALE 0.08; ALE-ALE 0.25; PME-PME 0.23; PLE-PLE 1.06; PME-PLE 0.32; ALE-PME 0.45; ALE-PLE 0.23; AME-PME 0.76; AME-PLE 0.52. Clypeus height 0.47. Length of chelicera 0.81. leg I 11.56 [2.94, 0.79, 3.15, 3.22, 1.46], II 9.96 [2.59, 0.64, 2.53, 2.81, 1.39], III 8.29 [2.05, 0.94, 1.77, 2.47, 1.06], IV 10.04 [2.62, 0.94, 2.46, 2.94, 1.08]. Leg formula: 1423. Carapace yellow. Ocular area grayish brown. Clypeus yellow, with inconspicuous stripes extending from anterior median eyes to the distal tip of chelicerae. Chelicerae yellow, pro-and retromargins with single tooth. Labium pale yellow. Endites light yellowish to light brown. Sternum pale yellow. Abdomen grayish-white, dorsally with few grayish-black spots and laterally with several grayish-black markings. Venter grayish-white, medially with a broad light brown longitudinal stripe. Palp as in Figs 3g–h: Patella and tibia with long black spines; cymbium with few spines and several bristles; Ventral tibial apophysis leaf-shaped in retrolateral view; tegular apophysis large and "L"-shaped; embolus slender (figs 3g–h).

Distribution. India (new record) and China (present study; World Spider Catalog, 2023).

Table 1. Number of genera and species, and feeding guilds of spider families reported from the Shendurney Wildlife Sanctuary.

Sl. No.	Families	Genera	Species	Guilds
1	Araneidae	17	35	Orb-web weavers
2	Tetragnathidae	2	4	
3	Uloboridae	2	2	
4	Ctenidae	2	4	Stalkers
5	Oxyopidae	3	5	
6	Salticidae	14	15	
7	Thomisidae	3	3	Ambushers
8	Philodromidae	1	1	
9	Pisauridae	1	1	
10	Cheiracanthiidae	1	2	Foliage hunters
11	Clubionidae	1	1	
12	Sparassidae	1	1	
13	Theridiidae	2	2	Scattered line weavers
14	Pholcidae	1	1	
15	Eresidae	1	1	Sheet web builders
16	Theraphosidae	1	1	
Total		**53**	**79**	

Table 2. Checklist of spiders recorded from the Shendurney Wildlife Sanctuary, with registration numbers for the present collection.

Sl. No.	Species	Registration Numbers	Remarks
	Family: Araneidae Clerck, 1757 (Orb web spiders)		
1	*Acusilas coccineus* Simon, 1895	-	*
2	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	-	*
3	*Arachnura angura* Tikader,1970	-	*$
4	*Araneus viridisomus* Gravely, 1921	-	*$
5	*Argiope aemula* (Walckenaer, 1841)	-	*
6	*Argiope anasuja* Thorell, 1887	ZSI/WGRC/I.R-INV 16747-16748	+
7	*Argiope catenulata* (Doleschall, 1859)	-	*
8	*Argiope pulchella* Thorell, 1881	NZC-ZSI-7701/18; ZSI/WGRC/I.R-INV 16749-16755	+
9	*Bijoaraneus mitificus* (Simon, 1886)	-	*
10	*Cyclosa bifida* (Doleschall, 1859)	--	*
11	*Cyclosa confraga* (Thorell, 1892)	-	*
12	*Cyclosa gossypiata* Keswani, 2013	-	*$
13	*Cyclosa hexatuberculata* Tikader, 1982	-	*
14	*Cyclosa insulana* (Costa, 1834)	-	*
15	*Cyclosa moonduensis* Tikader, 1963	-	*$
16	*Cyclosa neilensis* Tikader, 1977	-	*$
17	*Cyclosa purani* Keswani, 2013	-	*$
18	*Cyclosa simoni* Tikader, 1982	--	*$
19	*Cyclosa spirifera* Simon, 1889	-	*
20	*Cyrtarachne raniceps* Pocock, 1900	ZSI/WGRC/I.R-INV 16136	+
21	*Cyrtophora unicolor* (Doleschall, 1857)	-	*
22	*Eriovixia excelsa* (Simon, 1889)	-	*
23	*Eriovixia laglaizei* (Simon, 1877)	-	*
24	*Eriovixia sakiedaorum* Tanikawa, 1999	-	*
25	*Gasteracantha dalyi* Pocock, 1900	NZC-ZSI-7699/18; 7703/18.	+
26	*Gasteracantha geminata* (Fabricius, 1798)	ZSI/WGRC/I.R-INV 16744-16746	+
27	*Gea subarmata* Thorell, 1890	-	*
28	*Herennia multipuncta* (Doleschall, 1859)	-	*

Sl. No.	Species	Registration Numbers	Remarks
29	*Neoscona bengalensis* Tikader & Bal, 1981	-	*
30	*Neoscona mukerjei* Tikader, 1980	-	*
31	*Neoscona nautica* (L. Koch, 1875)	-	*
32	*Neoscona yptinika* Barrion & Litsinger, 1995	-	*
33	*Nephila pilipes* (Fabricius, 1793)	NZC-ZSI-7698/18; 7700/18; 7705/18	+
34	*Nephilengys malabarensis* (Walckenaer, 1841)	-	*
35	*Parawixia dehaani* (Doleschall, 1859)	ZSI/WGRC/I.R-INV 16756-16757	+
Family: Cheiracanthiidae Wagner, 1887 (Yellow sac spiders)			
36	*Cheiracanthium melanostomum* (Thorell, 1895)	ZSI/WGRC/I.R-INV 16758-16760	+
37	*Cheiracanthium murinum* (Thorell, 1895)	ZSI/WGRC/I.R-INV 16761	+
Family: Clubionidae Wagner, 1887 (Sac spiders)			
38	*Clubiona melanosticta* Thorell, 1890	NZC-ZSI-8215/18	# +
Family: Ctenidae Keyserling, 1877 (Wandering spiders)			
39	*Africactenus unumus* Sankaran & Sebastian, 2018	ZSI/WGRC/I.R-INV 16062	$ +
40	*Bowie cochinensis* (Gravely, 1931)	ZSI/WGRC/I.R-INV 16066-069	$ +
41	*Bowie indicus* (Gravely, 1931)	ZSI/WGRC/I.R-INV 16063	$ +
42	*Bowie sikkimensis* (Gravely, 1931)	ZSI/WGRC/I.R-INV 16064-065	$ +
Family: Eresidae C. L. Koch, 1845 (Social spiders)			
43	*Stegodyphus sarasinorum* Karsch, 1892	ZSI/WGRC/I.R-INV 16070-107	+
Family: Oxyopidae Thorell, 1869 (Lynx spiders)			
44	*Hamataliwa indica* Sen & Sureshan, 2022	-	$ +
45	*Oxyopes hindostanicus* Pocock, 1901	NZC-ZSI-8144/18	+
46	*Oxyopes javanus* Thorell, 1887	ZSI/WGRC/I.R-INV 16762-16784	+
47	*Oxyopes mirabilis* Zhang, Yang & Zhu, 2005	NZC-ZSI-8214/18	# +
48	*Peucetia viridana* (Stoliczka, 1869)	NZC-ZSI-8147/18	+
Family: Philodromidae Thorell,1869 (Elongated crab spiders)			
49	*Psellonus planus* Simon, 1897	NZC-ZSI-8146/18	$ +
Family: Pholcidae C. L. Koch, 1850 (Cellar spiders)			
50	*Artema atlanta* Walckenaer, 1837	ZSI/WGRC/I.R-INV 16785-16789	+
Family: Pisauridae Simon, 1890 (Nursery web spiders)			

Sl. No.	Species	Registration Numbers	Remarks
51	*Nilus albocinctus* (Doleschall, 1859)	ZSI/WGRC/I.R-INV 16108-114	+
Family: Salticidae Blackwall, 1841 (Jumping spiders)			
52	*Cocalus shendurneyensis* Sudhin, Sen, Caleb & Hegde, 2022	-	*$
53	*Habrocestum shendurneyense* Asima, Caleb, Babu & Prasad, 2022	-	*$
54	*Carrhotus viduus* (C. L. Koch, 1846)	NZC-ZSI-8148/18	+
55	*Indopadilla insularis* (Malamel, Sankaran & Sebastian, 2015)	ZSI/WGRC/I.R-INV 16127-134; NZC-ZSI-7745/18	+$
56	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	NZC-ZSI-7748/18	+
57	*Orientattus aurantius* (Kanesharatnam & Benjamin, 2018)	NZC-ZSI-7714/18	+
58	*Phintella vittata* (C. L. Koch, 1846)	ZSI/WGRC/I.R-INV 16793-16799	+
59	*Plexippus petersi* (Karsch, 1878)	NZC-ZSI-8150/18	+
60	*Rhene flavicomans* Simon, 1902	NZC-ZSI-8149/18	+
61	*Stenaelurillus albus* Sebastian, Sankaran, Malamel & Joseph, 2015	NZC-ZSI-7762/18	$ +
62	*Stenaelurillus lesserti* Reimoser, 1934	ZSI/WGRC/I.R-INV 17228-17240	+
63	*Tamigalesus munnaricus Żabka*, 1988	NZC-ZSI-7742/18	+
64	*Telamonia dimidiata* (Simon, 1899)	NZC-ZSI-7735/18; 7746/18	+
65	*Thiania bhamoensis* Thorell, 1887	NZC-ZSI-8153/18	+
66	*Siler semiglaucus* (Simon, 1901)	NZC-ZSI-8151/18	+
Family: Sparassidae Bertkau, 1887 (Giant crab spiders)			
67	*Olios lamarcki* (Latreille, 1806)	ZSI/WGRC/I.R-INV 16800	+
Family: Tetragnathidae Menge, 1866 (Long-jawed spiders)			
68	*Leucauge fastigata* (Simon, 1877)	NZC-ZSI-8152/18	+
69	*Leucauge tessellata* (Thorell, 1887)	NZC-ZSI-7697/18; 7704/18	+
70	*Tylorida flava* Sankaran, Malamel, Joseph & Sebastian, 2017	NZC-ZSI-7743/18	$ +
71	*Tylorida ventralis* (Thorell, 1877)	NZC-ZSI-8145/18	+
Family: Theraphosidae Thorell, 1869 (Tarantulas)			
72	*Poecilotheria striata* Pocock, 1895	-	$ + β
Family: Theridiidae Sundevall, 1833 (Comb-footed spiders)			
73	*Argyrodes flavescens* O. P. Cambridge, 1880	ZSI/WGRC/I.R-INV 16116-126	+
74	*Chrysso angula* (Tikader, 1970)	NZC-ZSI-7702/18	$ +

Sl. No.	Species	Registration Numbers	Remarks
Family: Thomisidae Sundevall, 1833 (Crab spiders)			
75	*Camaricus formosus* Thorell, 1887	NZC-ZSI-7734/18	+
76	*Strigoplus netravati* Tikader, 1963	ZSI/WGRC/I.R-INV 16801-16808	$ +
77	*Thomisus projectus* Tikader, 1960	ZSI/WGRC/I.R-INV 16137	$ +
Family: Uloboridae Thorell,1869 (Hackled web spiders)			
78	*Miagrammopes poonaensis* Tikader, 1971	ZSI/WGRC/ I.R - INV 16135; ZSI/WGRC/I.R-INV 16137	$ +
79	*Uloborus shendurneyensis* Asima, Sudhikumar & Prasad, 2021	-	*$

Abbreviations used: + =Present study, ***β***=observed during the survey, **#** =First report from India, **$** =Endemic to India, * =Reported from literature.

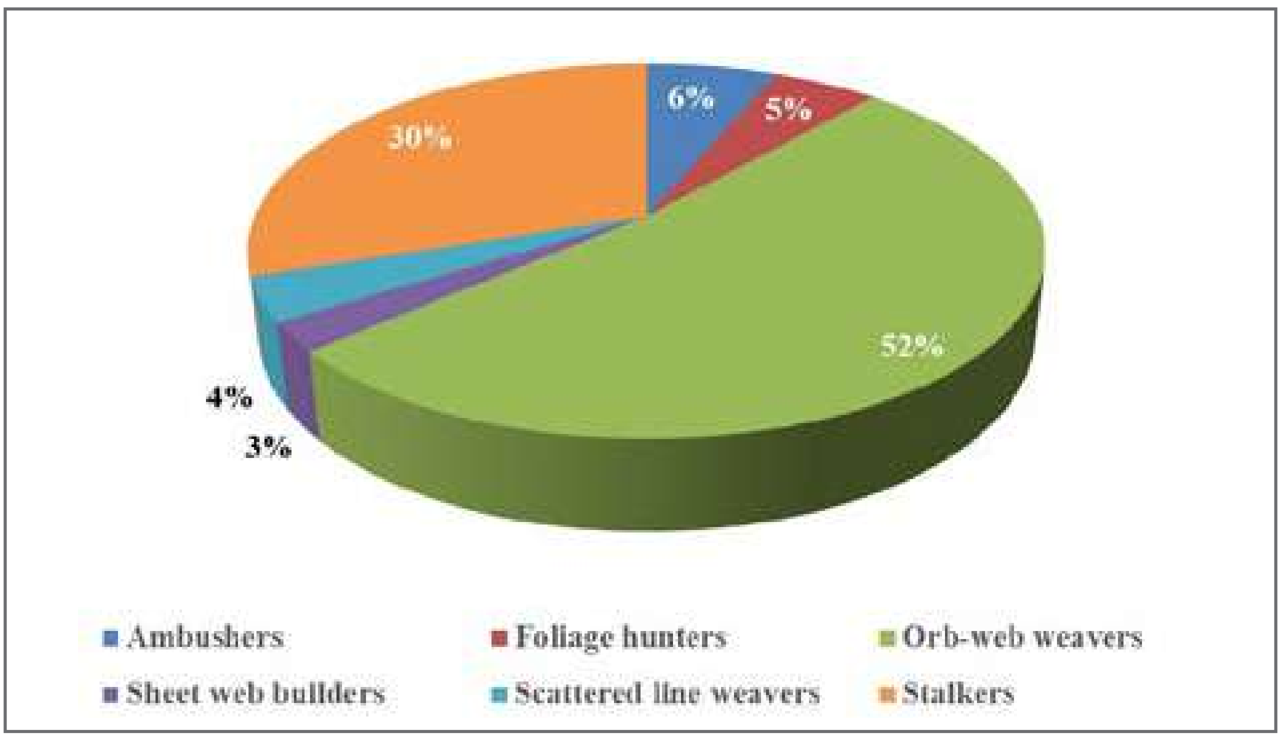

Figure 2. Guild structure analysis based on species richness of spiders reported from the Shendurney Wildlife Sanctuary.

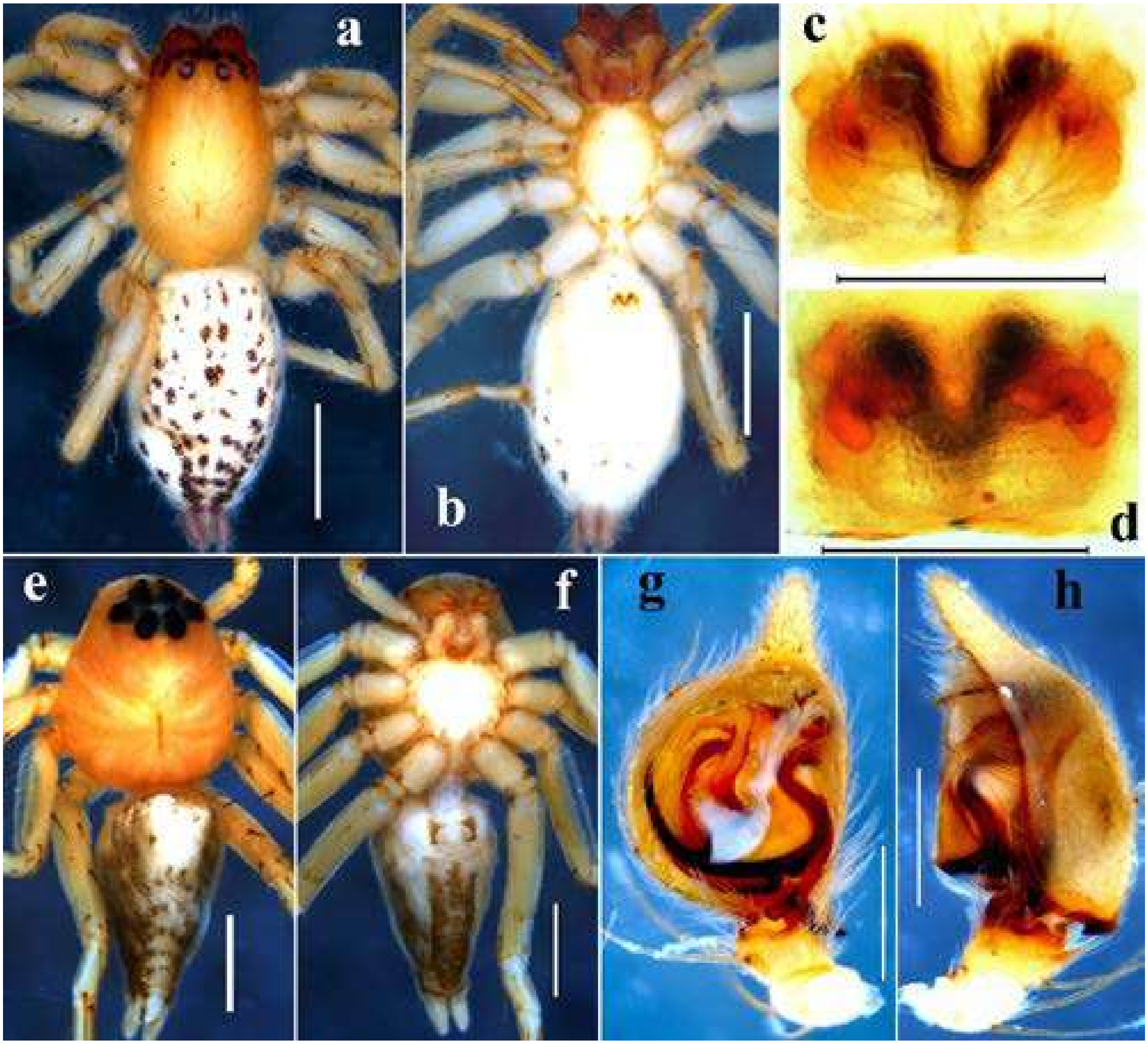

Figure 3. *Clubiona melanosticta*, ♀ (NZC-ZSI-8215/18) (a–d). *Oxyopes mirabilis* ♂ (NZC-ZSI-8214/18) (e–h). a, e –habitus dorsal view; b, f – habitus ventral view; c – epigyne ventral view; d – epigyne dorsal view; g – left male palp ventral view; h – left male palp retrolateral view. Scale bars: a, b, e, f = 1 mm; c, d = 0.2 mm; g, h = 0.5 mm.

Discussion

The present study was carried out with an aim to know the diversity of the spiders of the Shendurney Wildlife Sanctuary and to provide an updated checklist of spiders from the sanctuary. The spider fauna of the Shendurney Wildlife Sanctuary accounts for 4.1% of total species diversity, 9% of generic diversity, and 26.2% of family diversity recorded from India (Caleb and Sankaran, 2023). The most interesting finding of the current study is the first records of two species from India. The sac spider, *C. melanosticta*, is distributed mostly in Southeast Asia; while the lynx spider, *O. mirabilis*, is known only from China (World Spider Catalog, 2023). Both these species, therefore, constitute new records to South Asia as well.

The study shows that the overall diversity of spiders in the Shendurney Wildlife Sanctuary is higher, with Araneidae and Salticidae being the most dominant spider families. The result of this study consistent with earlier works, which confirm that the natural forest ecosystems support many species of Araneidae and Salticidae (Ganesan and Shunmugavelu, 2012; Solanki *et al.*, 2020; Sen *et al.*, 2022). Araneidae and Salticidae are the most species rich families found in India and are distributed across the country (Caleb and Sankaran, 2023). The dominance of these families in the study area is mainly due to the area's vegetation structure, which supports a variety of microhabitats in which araneids and salticids can live. The categorization of spider guilds also denotes the effect of habitat type on the spider composition (Freitas *et al.*, 2013). Orb web weavers and stalkers are the most common guilds observed in the study area. The sanctuary contains mostly bushes, shrubs, and understory plants, providing a convenient environment for spiders to build their webs, hunt for food and construct retreats (Uetz, 1991).

Acknowledgements

The authors are grateful to Dr Dhriti Banerjee, Director, Zoological Survey of India, Kolkata, for providing the necessary facilities to carry out this study. We are thankful to the Officer-in-Charge, Western Ghat Regional Centre, Zoological Survey of India, Kozhikode, Kerala, for his support. We also thank the Chief Conservator of Forest and the Chief Wildlife Warden, Kerala State Forest Department, for providing necessary permission and support during the surveys. Thanks to Mr. Chandan Bera, Zoological Survey of India, Kolkata, for his curatorial assistance.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Flower Visiting Flies (Insecta: Diptera) and Their Interaction with The Flowering Plants in A Tropical Island Ecosystem

Debdeep Pramanik[1*], Koustav Mukherjee[1], Debjani Ghosh[1], Saikat Sarkar[1], Atanu Naskar[1], Dhriti Banerjee[1]**

[1]*Diptera Section, Zoological Survey of India, Prani Vigyan Bhawan, 'M' Block New Alipore, Kolkata – 700053, India*
([*]Presenting author Email ID: mailtodebdeep.005@gmail.com

Abstract

Pollen transportation and pollination is an essential ecological function. Flies of order Diptera perform a significant role in transfer of pollen and pollination to some extent (Raguso, 2020). In tropical island ecosystems the flower visiting dipteran flies may function simultaneously with the bees to maintain a healthy ecosystem service. However, the study of flower visiting Dipteran flies in India has received less attention from the entomologists and even lesser in island ecosystems. In tropical areas the Hymenopterans can be outnumbered by the Dipterans in terms of biodiversity (Inouye, 2001). So, the main objective of this study is to identify and make an inventory of flower visiting Dipteran flies of a tropical island along with their visited plant species. The study was conducted across the Sagar Island, West Bengal. The collection of flies and observation of the plants visited by them was done through line transect method in 10 chosen study sites containing both the crop and non-crop flowering plants. Throughout the study, a total of 41 species of flies belonging to 34 genera under 13 families have been observed to visit flowers of 32 species in our studied landscape. *Paragus (Paragus) serratus* of family Syrphidae has been found to be the most interactive fly visiting 27 different flowering plant species and *Mangifera indica* appears to be the most visited plant with 17 dipteran species visiting its flowers. We have also observed the variation in seasonal occurrence of the flower visiting flies and prepared a simple bipartite network representing the links between the dipteran flower visitors and their visited flowering plants. The outcomes illustrate a clear scenario of flower visiting Dipteran flies occurring in a tropical island which interact with the plants. This can also lead to future studies about pollination by Diptera in an island ecosystem.

Keywords: Insect-plant interaction, bipartite network, island agro-ecosystem, flower-visiting Diptera, Syrphidae

Introduction

Biodiversity in islands especially in the tropical area is always a fascinating field of study. The insect biodiversity has reached its heights in the tropics. Among the insects, order Diptera comprises about 14% of the global insect fauna (Evenhuis and Pape, 2020). The association of flowers and Dipteran flies enables pollination of various plants to some extent such as in chocolate plants (Raguso, 2020). In fact they are considered to be the primitive pollinators as they possess suctorial or lapping mouthparts (Kevan and Baker, 1983). Although bees are capable of carrying pollen with higher load, diversity and viability as compared to the flies, dipterans (specifically species from family Stratiomyidae and Syrphidae) are efficient to carry pollen up to further distances than the bees (Rader *et al.*, 2011). From the tropical region, a total of 42 families of Diptera are reported to visit flowers of which 12 families belong to the suborder Nematocera and 30 families under the suborder Brachycera (Roubik,

**Author for correspondence : atanu.diptera@gmail.com
Article Received on: 02.04.2023

Accepted on: 24.04.2023

1995). Syrphidae, Bombyliidae, Tephritidae, Stratiomyidae, Calliphoridae, Muscidae, Tachinidae are some of the notable families in which flower visiting flies belong to.

Bipartite ecological networks are used to depict the interaction patterns existing between two groups of organisms (such as organisms from two trophic levels) in which the connections between these two groups in different sets are considered (Zhou *et al.*, 2007). Study of ecological networks is considered as a useful tool for species conservation perspectives. In some cases, study of plant–animal mutualistic interactions may reflect the co-evolutionary processes that function dynamically throughout the timescale (Jordano *et al.*, 2003; Leimberger *et al.*, 2022). Here, the direct interactions among the organisms of same trophic level are less important (Dormann *et al.*, 2008). In this communication we try to represent the bipartite network of flowering plants (crop and non-crop) and the flower visiting flies of a tropical island. This will further demonstrate the possible interactions and foraging preferences of the flies of the island.

The study of flower visiting Dipteran flies in India has received less attention from the entomologists and even lesser in island ecosystems. It is primarily because of the Hymenopterans (the bees) who are considered as the major insect pollinators. But, in tropical areas the Hymenopterans can be outnumbered by the Dipterans in terms of biodiversity (Inouye, 2001). Limited research works exist which contributes to our knowledge about the flower visiting Diptera of India. Dhara Jothi and Tandon (1993) studied pollinator activity on Ber (*Ziziphus mauritiana*). Priti (1998), Priti and Sihag (1998) evaluated the pollination efficiency of insect pollinators on Onion (*Allium cepa*), Carrot (*Daucus carota*) and Cauliflower (*Brassica oleracea*), but the dipteran flower visitors were not given ample importance in those studies. Mukherjee *et al.* (2002) described the flower visiting hoverflies (Diptera: Syrphidae) on *Solanum nigrum* flowers. Mitra and Parui (2002a) published an account of dipteran flower visitors in Jessore Sloth Bear Sanctuary and Balaram Ambaji Wildlife Sanctuary of Gujarat. Later, Mitra *et al.* (2002, 2003, 2004, 2005, 2008); Mitra and Roy (2006); Mitra and Banerjee (2007) and Mitra (2010) published several researches about dipteran pollinators from southern West Bengal. But, no work has been conducted earlier in Sagar Island, West Bengal related to the diversity of flower visiting flies. Some isolated studies have been done in Sundarbans (Chakraborti *et al.*, 2019) and Nayachar Island (Mitra and Parui, 2002b) which are close to the Sagar Island. Moreover, none of the above mentioned works portray the scenario of any ecological interaction between the flower visiting dipteran flies and the flowering plants. Being a separate island the importance of documentation of flower visiting dipteran flies in Sagar Island is necessary from the aspect of pollination to maintain ecological balance.

The main objective of this study is to identify and make an inventory of flower visiting Dipteran flies of Sagar Island along with their visited plant species. We have also observed the variation in seasonal occurrence of the flower visiting flies in the island. At last but not the least, our objective was to prepare a simple bipartite network representing the links between the dipteran flower visitors and their visited flowering plants.

Materials and Methods

Study Area: The present study was conducted in Sagar Island, West Bengal located between 21°37’ N to 21°53’ N latitude and 88°02’ E to 88°10’ E longitude with average elevation of 4 meters. For the sampling and observation of flies, 10 different sites were chosen (Figure I) and the whole study was carried out during the year 2021-2022. The study sites were selected in and around agricultural lands on the basis of two criteria: (i) the agricultural field is active i.e. cultivation of any crop is going at that time or it is not unused in current cultivation season and, (ii) there is considerable amount of non-crop flowering plants at the edge of the agricultural field (at least 3 plants per metre irrespective of the species, when walking through line transect). These criteria were considered in choosing the study sites to ensure that we observe all kinds of flowering plants present in the island i.e. both the crop and non-crop plants.

Collection of Specimen: Each site was surveyed 3 days in each of the three major seasons - summer, monsoon and winter. Thus, it accounts to 9 days of specimen sampling in each site per year. The flies were observed and collected from two types of vegetation around the study sites – from the agricultural field (seasonal crops or vegetables); and from field side herbs, and bushes (different non-crop flowering plants intermixed). For collection of the specimens, we observed line transect method in both the vegetation types, where one covered 100 metres distance in each collection episode and collected specimens from both side of the imaginary line. Transects were carried out once in an hour from 8:00 a.m. to 4.00 pm in both the crop and non-crop vegetation on the study day. Thus it accounts to 16 transects per day in a study site, 8 in crop and 8 in non-crop patch. The data of the visited flowering plant was recorded by another person who was following the former. The fly specimens when observed on the flowers were collected using sweep nets. Then the captured specimens were put into killing-jar where they were exposed to benzene or high dose of chloroform. After that, flies are preserved in 70% ethyl alcohol until further analysis.

Identification: The preserved specimens were identified based on the classification system of McAlpine (1989) and using appropriate literatures and taxonomic keys. For this purpose, Leica EZ4 HD optical microscope was used. The plants were identified on the field whichever possible and rest in the laboratory by taking specimens.

Data Analyses: The preliminary analysis and sorting of the data were performed in Microsoft Excel 2019. To easily visualize the data of flower visiting flies and their visited plants, we constructed a bipartite network combining all seasons and study sites of the Sagar Island. The numbers of species in each family were pooled across all the study sites to evaluate family specific species richness. We also prepared a binary visitation matrix across all the study sites where "0" indicates no encounter and "1" indicates encounter of particular species of fly on particular flowering plant species during our observation period in our study sites. Using this matrix, a bipartite interaction network was constructed in "R" software (version 4.1.3) (R Core Team, 2013) using the 'Bipartite' (Dormann *et al.*, 2020) and 'Vegan' (Oksanen *et al.*, 2013) packages. The statistical analyses were done using 'lme4' (Bates *et al.*, 2015) and 'multcomp' (Hothorn *et al.*, 2008) packages in "R" software.

Results

During our study across the agricultural landscape of Sagar Island, we observed 41 species of Dipteran flies belonging to 34 genera under 13 families. The checklist of the flies along with their seasonal occurrence is represented in Table I. Species richness of Dipteran flower visitors significantly varied in the three seasons (Table. III). From the observation across all sites, in pre-monsoon (April-May) a total of 37 species of flies were recorded followed by 36 in post-monsoon (November-December) and 26 in monsoon (July-August) (Table III). The flies visited on flowers of 32 species of plants belonging to 17 families. The plants and their respective flower visiting flies as observed were listed in Table II. Among the 32 plant species recorded, maximum number of flower visiting flies were found to visit in *Mangifera indica* (17 species), followed by *Lagenaria siceraria*, *Cucurbita maxima, Tagetes erecta* (16 species); *Lantana camara (*14 species*); Tagetes patula (*12 species*); Alternanthera sessilis, Brassica nigra* (10 species), *Parthenium hysterophorus* (9 species), *Psidium guajava, Syzygium jambos* (8 species), *Heliotropium indicum, Lippia alba* (6 species), *Cyanthillium cinereum, Oxalis corniculata, Aegle marmelos* (5 species), *Ageratum conyzoides, Eclipta prostrata, Sonchus asper, Rorippa palustris, Mentha arvensis, Ocimum sanctum* (4 species), *Hygrophila spinosa, Catharanthus roseus, Tabernaemontana coronaria, Tridax procumbens, Ipomoea carnea, Leucas aspera, Mazus pumilus, Solanum nigrum* (3 species), *Trigonella foenum-graecum* (2 species) and *Mimosa pudica* (1 species) (Table II).

Figure II depicts the species richness of the 13 observed Dipteran families. However, the species richness varied in different seasons, we pooled the data of all seasons to represent an overall scenario. Among the 13 Dipteran families, the maximum number of fly species were found from family Syrphidae (13 species), followed by Calliphoridae (6 species), Stratiomyidae, Muscidae (5 species), Tephritidae (3 species) and Rhiniidae (2 species) (Figure II). Remaining observed families (Tabanidae, Bombyliidae, Micropezidae, Lauxaniidae, Sciomyzidae, Sarcophagidae and Tachindae) were found to contain one representative species.

A total of 214 interactions were observed throughout the 3 seasons between the 41 species of flies and 32 species of plants. The resulting bipartite network is represented in Figure III. The network depicts the complete scenario of flower visiting flies and their interaction with the flowering plants of the island.

Discussion

Higher number of flower visiting flies especially Syrphid flies in agricultural landscape can increase the chance of better pollen transportation which leads to successful pollination and good crop yield (Toivonen *et al.*, 2022) thereby helps in stabilizing agro-ecosystems. Despite of having moderately high saline content in soil and water, our study revealed that Sagar Island is home to 32 species of flowering plants with 41 species of flower visiting Dipteran flies present for them to forage. According to the work of Mitra *et al.* (2008), there were 33 species of flower visiting Dipteran flies in Kolkata and its adjoining areas. The comparatively better scenario of Sagar Island suggests that this tropical island may be rich in terms of Dipteran biodiversity as compared to the nearby mainland. However, more consolidated works are needed in the Kolkata and its surroundings for proper assessment of the current status of flower visiting flies.

The high species richness of family Syrphidae (13 species) compared to the other families (Calliphoridae is immediate next with 6 species) suggests that the flies of family Syrphidae may serve better in pollen transportation in this island agro-ecosystem. Dunn *et al.* (2020) have showed that hoverflies of genera *Eupeodes*, *Sphareophoria*, *Syrphus*, *Eristalis* and *Episyrphus* visit a wide variety of flowers, visiting atleast 40 species of plants. In our study we observed that each flowering plant species appears to have at least one species of Syrphid flower visitor (Table II). Our study revealed that *Paragus (Paragus) serratus* of family Syrphidae visited the highest number of plant species (27 species) (Figure IV). However, visiting a wide range of plant species does not establish the fly as a pollinator (Ne'eman *et. al*., 2010). Further evaluation of some key factors like the amount of pollen grains the fly can transport; how frequent the fly species deposit pollen on the stigma of the flower and the flower visitation rate of the species are required to determine the pollination ability of the fly (Herrera *et al.*, 1989; Rader *et al.*, 2009).

Among the 41 species of flies, 37 and 36 species were observed in the summer (pre-monsoon) and winter (post-monsoon) seasons respectively (Table I). Whereas in the monsoon, only 26 species of flower-visiting flies were recorded from the island. The significance of seasonal variation of the flies has been supported by the results of post-hoc Tukey test (Table III). The significant drop in the number of fly species in monsoon is primarily due to the inundation and flooding of majority of the agricultural lands, coupled with the unpleasant weather conditions. Out of the 41 species of flies, 25 species were observed in all the 3 seasons. The species richness of Syrphidae family varied in the seasons (Figure V) as in summer and winter 11 species of Syrphid flies were observed however it dropped in the monsoon to a count of 7 species. After the Syrphidae, the next major family according to species richness is Calliphoridae (Figure II) and interestingly the species richness of this family remained same throughout the year (Figure V) as all the 6 species of Calliphorid flies were encountered in 3 seasons. The flies of family Tabanidae, Bombyliidae and Tachinidae showed specific seasonal occurrence as the flies of those families were observed in monsoon, winter and summer seasons respectively.

The bipartite network (Figure III) clearly depicts that *Paragus (Paragus) serratus* (abbreviated as Pser) of family Syrphidae is the fly species with the highest number of possible interactions (visited 27 different flowering plants). On the other hand, *Mangifera indica* (abbreviated as Mind) is the plant species that received the highest number of fly species (17 species visited). The pollinator diversity of *Mangifera indica* is widely studied (Fajardo *et al.*, 2008; Chauhan *et al.*, 2018) but they do not provide any complete record of Dipteran visitors. In contrast to 7 Dipteran species reported by Chauhan *et al.* (2018), our study revealed 17 species of flies visiting the mango flowers.

Most of the flower visiting flies were unspecific in terms of preference of foraging i.e., they visited flowers of more than one species (Table II). Exceptions are there for some species e.g., *Hemipyrellia pulchra* (Hpul) of family Calliphoridae visiting only *Parthenium hysterophorus* (Phys); *Chrysomya rufifacies* (Cruf) of family Calliphoridae visiting only *Lantana camara* (Lcam) flowers; *Petrorossia ceylonica* (Pcey) of family Bombyliidae was found to visit only *Syzygium jambos* (Sjam); *Mesembrius (Mesembrius) quadrivittatus* (Mqua) *and Merodon (Merodon) equestris* (Mequ) of Syrphidae was only found on flowers of *Targetes erecta* (Tere); *Baccha (Allobaccha) amphithoe* (Bamp) of family Syrphidae visited flowers of *Aegle marmelos* (Amar) only; *Thelaira macropus* (Tmac) of Tachinidae family only visited *Heliotropium indicum* (Hind); *Hydrotaea chalcogaster* (Hcha) of family Muscidae visitied only *Alternanthera sessilis* (Ases) flowers and *Chrysops dispar* (Cdis) of Tabanidae family was found only in *Ipomoea carnea* (Icar) flowers.

Among the plants, *Mimosa pudica* (Mpud) is reported to have been visited by only one species of fly- *Episyrphus (Episyrphus) balteatus* (Table II). The rest of all plants interacted with more than one species of fly.

Our study provides pioneering information about the interactions among specific Dipterans and specific plants in an eastern Indian island ecosystem dominated by tropical agricultural landscape. As our results show, there are a number of fly species encountered in our study that are reported to be pollinators. This information may be useful for the sustainable agriculture where diverse floral species may be maintained that supports ecologically important fly species to augment ecosystem service (e.g., pollination) delivery across an island agro-ecosystem.

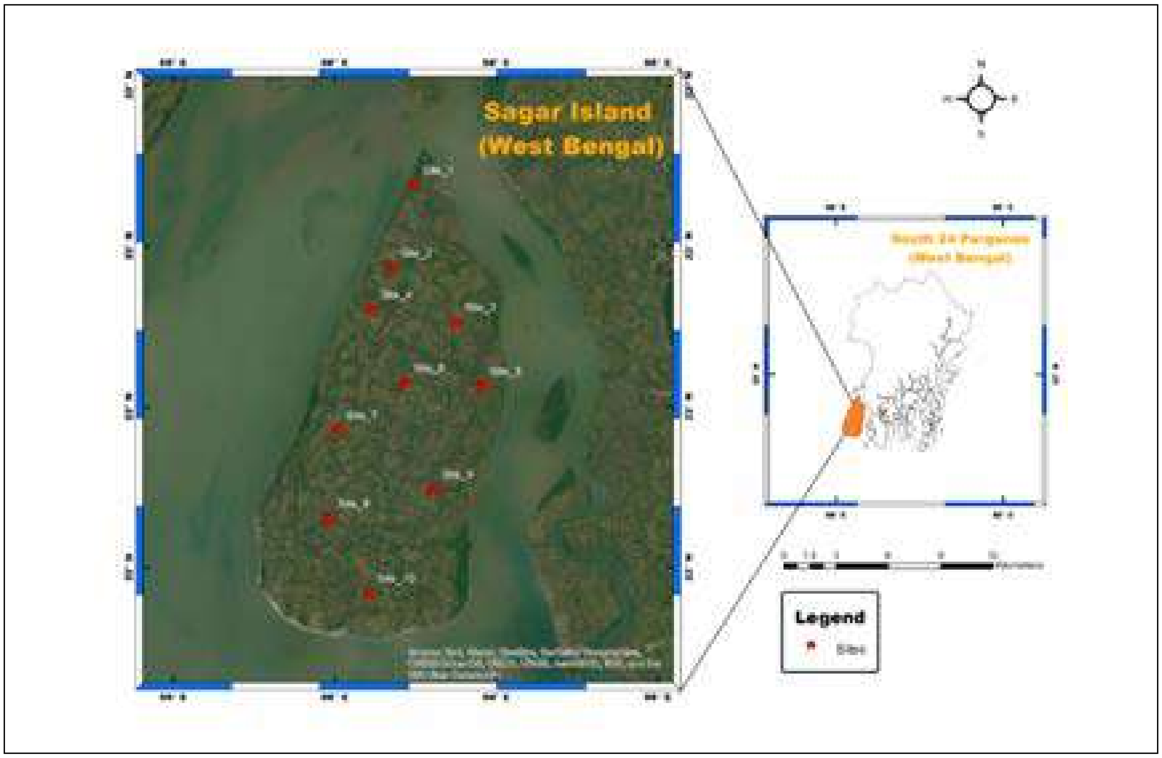

Figure I. Map showing the study sites in Sagar Island.

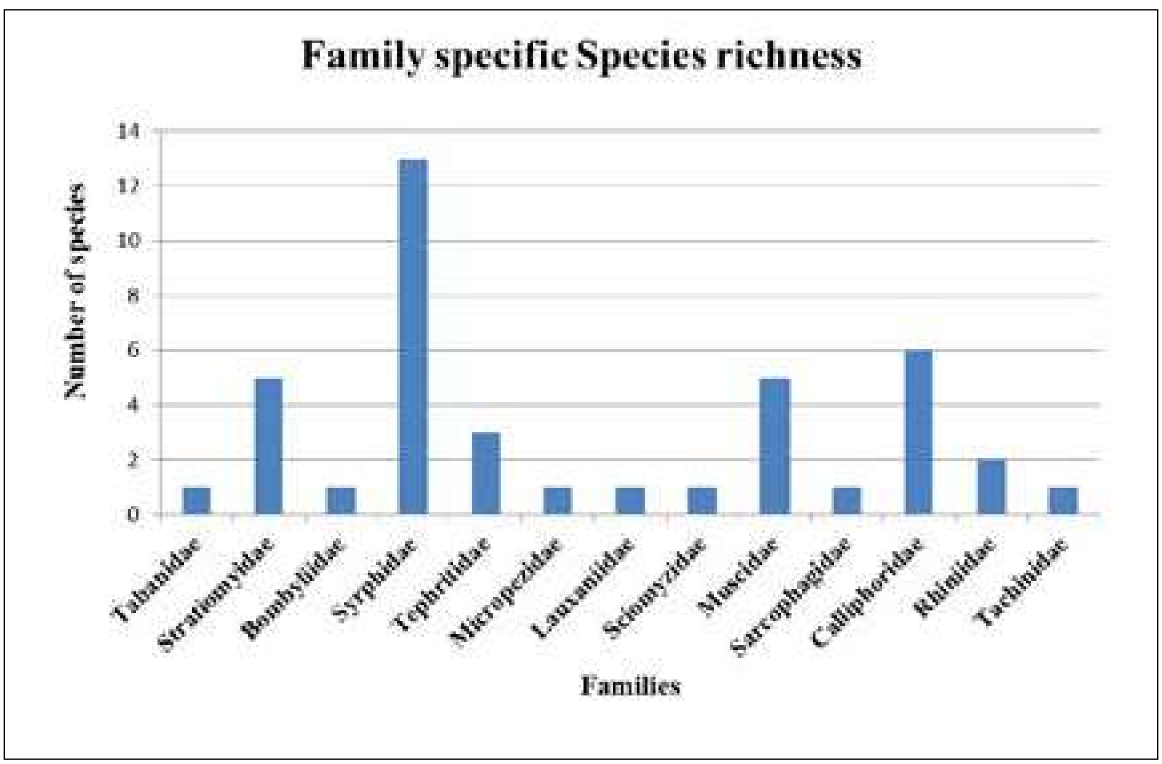

Figure II. Family specific Species Richness of different dipteran families associated with flower visiting in Sagar Island, West Bengal.

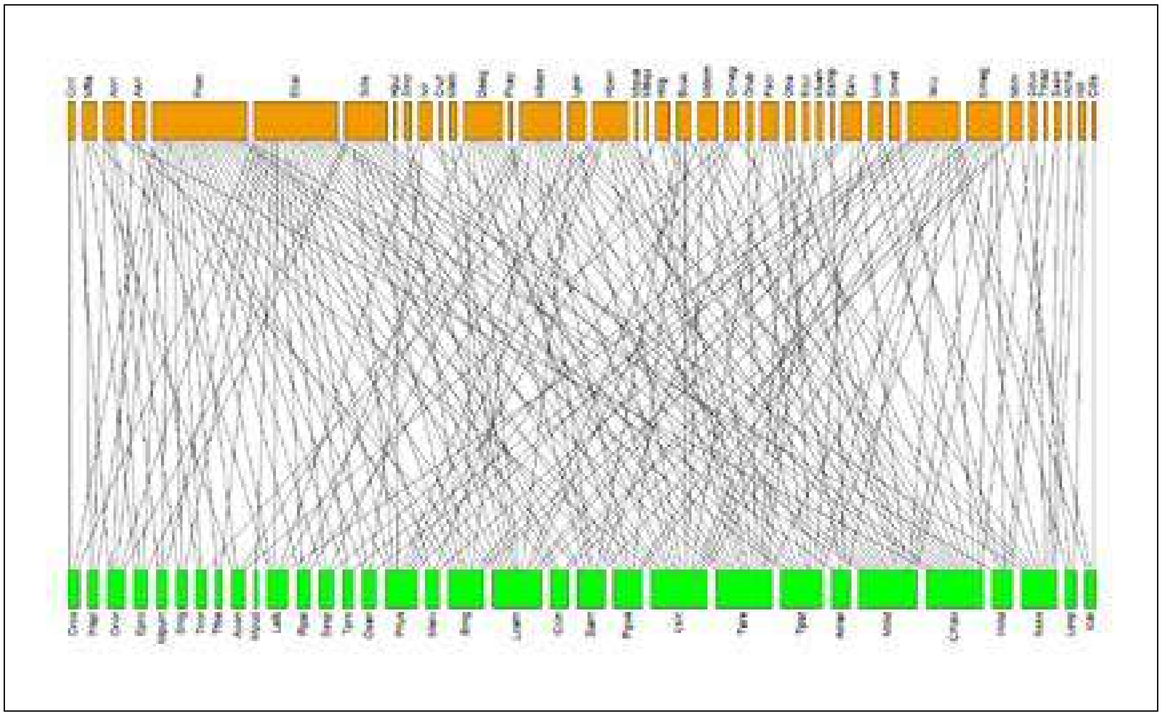

Figure III. Bipartite Network showing the possible interactions between the two trophic levels: the flower visiting dipteran flies (upper orange boxes or nodes) and flowering plants (lower green boxes or nodes) as produced from the observations in Sagar Island, West Bengal. For the abbreviations and respective species names, refer to Table I and Table II.

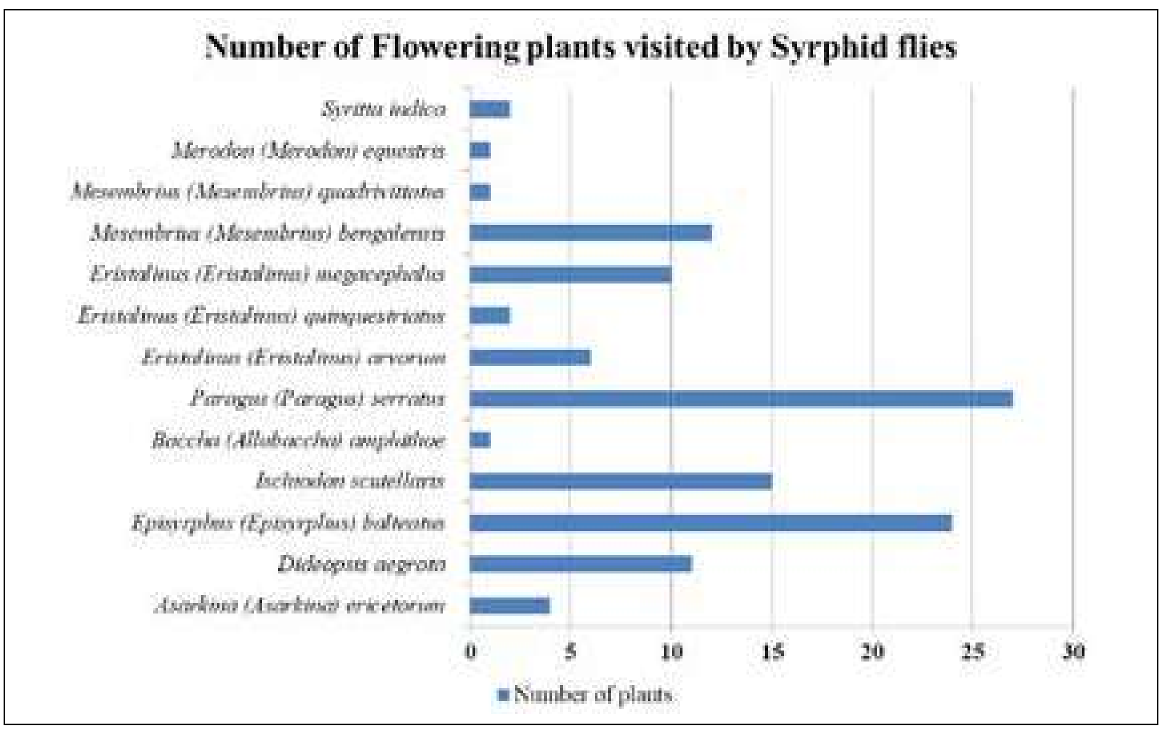

Figure IV. Number of flowering plants visited by different Syrphid species (pooled data of 3 seasons).

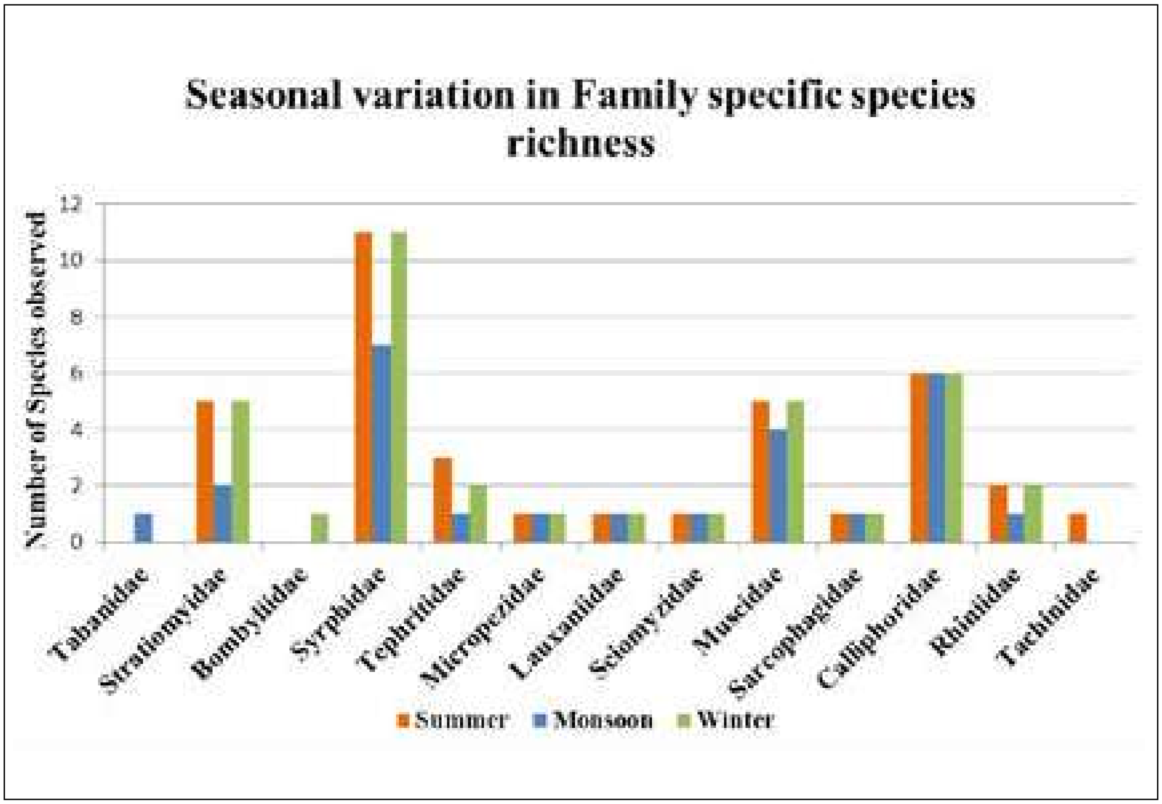

Figure V. Seasonal variation in species richness of different flower visiting fly families as observed in the Sagar Island.

Table I. List of dipteran species recorded during the study with their seasonal occurrence. (S = Summer, M = Monsoon and W = Winter, '+' denotes present, '-' denotes absence).

Sl. No.	Species name	Abbreviation used in the network	Occurrence in season		
			S	M	W
Family Tabanidae					
1	*Chrysops dispar* (Fabricius, 1798)	Cdis	-	+	-
Family Stratiomyidae					
2	*Microchrysa flaviventris* Wiedemann, 1824	Mfla	+	-	+
3	*Sargus metallinus* Fabricius, 1805	Smet	+	+	+
4	*Odontomyia transversa* Brunetti, 1920	Otra	+	-	+
5	*Oplodontha rubrithorax* (Macquart, 1838)	Orub	+	-	+
6	*Hermetia illucens* (Linnaeus, 1758)	Hill	+	+	+
Family Bombyliidae					
7	*Petrorossia ceylonica* (Brunetti, 1908)	Pcey	-	-	+
Family Syrphidae					

Sl. No.	Species name	Abbreviation used in the network	Occurrence in season		
			S	M	W
8	*Asarkina (Asarkina) ericetorum* (Fabricius, 1781)	Aeri	+	+	+
9	*Dideopsis aegrota* (Fabricius, 1805)	Daeg	+	+	+
10	*Episyrphus (Episyrphus) balteatus* (De Geer, 1776)	Ebal	+	+	+
11	*Ischiodon scutellaris* (Fabricius, 1805)	Iscu	+	+	+
12	*Baccha (Allobaccha) amphithoe* Walker, 1849	Bamp	+	-	-
13	*Paragus (Paragus) serratus* (Fabricius, 1805)	Pser	+	+	+
14	*Eristalinus (Eristalinus) arvorum* (Fabricius, 1787)	Earv	+	-	+
15	*Eristalinus (Eristalinus) quinquestriatus* (Fabricius, 1794)	Equi	-	-	+
16	*Eristalinus (Eristalinus) megacephalus* (Rossi, 1794)	Emeg	+	+	+
17	*Mesembrius (Mesembrius) bengalensis* (Wiedemann, 1819)	Mben	+	+	+
18	*Mesembrius (Mesembrius) quadrivittatus* (Wiedemann, 1819)	Mqua	+	-	+
19	*Merodon (Merodon) equestris* (Fabricius, 1794)	Mequ	-	-	+
20	*Syritta indica* (Wiedemann, 1824)	Sind	+	-	-
Family Tephritidae					
21	*Bactrocera (Zeugodacus) cucurbitae* (Coquillett, 1899)	Bcuc	+	+	+
22	*Platensina acrostacta* (Wiedemann, 1824)	Pacr	+	-	+
23	*Campiglossa cribellata* Bezzi, 1913	Ccri	+	-	-
Family Micropezidae					
24	*Mimegralla albimana* (Doleschall, 1856)	Malb	+	+	+
Family Lauxaniidae					
25	*Homoneura (Neohomoneura) bengalensis* (Macquart,1843)	Hben	+	+	+
Family Sciomyzidae					
26	*Sepedon aenescens* Wiedemann, 1830	Saen	+	+	+
Family Muscidae					
27	*Musca (Byomya) ventrosa* Wiedemann, 1830	Mven	+	+	+
28	*Musca (Musca) domestica* Linnaeus, 1758	Mdom	+	+	+
29	*Neomyia timorensis* (Robineau-Desvoidy, 1830)	Ntim	+	-	+
30	*Hydrotaea chalcogaster* (Wiedemann, 1824)	Hcha	+	+	+
31	*Atherigona (Acritochaeta) orientalis* Schiner, 1868	Aori	+	+	+
Family Sarcophagidae					
32	*Sarcophaga (Liosarcophaga) dux* (Thomson, 1869)	Sdux	+	+	+

Sl. No.	Species name	Abbreviation used in the network	Occurrence in season		
			S	M	W
Family Calliphoridae					
33	*Lucilia porphyrina* (Walker, 1856)	Lpor	+	+	+
34	*Lucilia cuprina* (Wiedemann, 1830)	Lcup	+	+	+
35	*Hemipyrellia ligurriens* (Wiedemann, 1830)	Hlig	+	+	+
36	*Hemipyrellia pulchra* (Wiedemann, 1830)	Hpul	+	+	+
37	*Chrysomya megacephala* (Fabricius, 1794)	Cmeg	+	+	+
38	*Chrysomya rufifacies* (Macquart, 1843)	Cruf	+	+	+
39	*Isomyia viridaurea* (Wiedemann, 1819)	Ivir	+	-	+
Family Rhiniidae					
40	*Stomorhina discolor* (Fabricius, 1794)	Sdis	+	+	+
Family Tachinidae					
41	*Thelaira macropus* (Wiedemann, 1830)	Tmac	+	-	-

Table II. List of flowering plant species observed during the study in Sagar Island, along with the visiting fly species.

Sl. No.	Plant Species	Abbreviation used in the network	Observed Dipteran species
Family: Acanthaceae			
1	*Hygrophila spinosa*	Hspi	*Microchrysa flaviventris, Paragus (Paragus) serratus, Atherigona (Acritochaeta) orientalis*
Family: Amaranthaceae			
2	*Alternanthera sessilis*	Ases	*Hermetia illucens, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Mesembrius (Mesembrius) bengalensis, Homoneura (Neohomoneura) bengalensis, Sepedon aenescens, Hydrotaea chalcogaster, Sarcophaga (Liosarcophaga) dux, Lucilia cuprina, Chrysomya megacephala*
Family: Anacardiaceae			
3	*Mangifera indica*	Mind	*Odontomyia transversa, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Eristalinus (Eristalinus) arvorum, Eristalinus (Eristalinus) quinquestriatus, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Platensina acrostacta, Homoneura (Neohomoneura) bengalensis, Musca (Musca) domestica, Neomyia timorensis, Lucilia porphyrina, Hemipyrellia ligurriens, Isomyia viridaurea, Stomorhina discolor*

Sl. No.	Plant Species	Abbreviation used in the network	Observed Dipteran species
Family: Apocynaceae			
4	*Catharanthus roseus*	Cros	*Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Campiglossa cribellata*
5	*Tabernaemontana coronaria*	Tcor	*Asarkina (Asarkina) ericetorum, Paragus (Paragus) serratus, Homoneura (Neohomoneura) bengalensis*
Family: Asteraceae			
6	*Ageratum conyzoides*	Acon	*Microchrysa flaviventris, Paragus (Paragus) serratus, Mesembrius (Mesembrius) bengalensis, Chrysomya megacephala*
7	*Cyanthillium cinereum*	Ccin	*Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Neomyia timorensis, Stomorhina discolor*
8	*Eclipta prostrata*	Epro	*Microchrysa flaviventris, Paragus (Paragus) serratus, Atherigona (Acritochaeta) orientalis, Stomorhina discolor*
9	*Parthenium hysterophorus*	Phys	*Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Eristalinus (Eristalinus) arvorum, Homoneura (Neohomoneura) bengalensis, Lucilia porphyrina, Hemipyrellia ligurriens, Hemipyrellia pulchra, Chrysomya megacephala, Stomorhina discolor*
10	*Sonchus asper*	Sasp	*Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Eristalinus (Eristalinus) arvorum, Mesembrius (Mesembrius) bengalensis*
11	*Tagetes erecta*	Tere	*Odontomyia transversa, Oplodontha rubrithorax, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Eristalinus (Eristalinus) quinquestriatus, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Mesembrius (Mesembrius) quadrivittatus, Merodon (Merodon) equestris, Homoneura (Neohomoneura) bengalensis, Musca (Byomya) ventrosa, Musca (Musca) domestica, Hemipyrellia ligurriens, Isomyia viridaurea, Stomorhina discolor*
12	*Tagetes patula*	Tpat	*Odontomyia transversa, Oplodontha rubrithorax, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Eristalinus (Eristalinus) arvorum, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Homoneura (Neohomoneura) bengalensis, Musca (Musca) domestica, Stomorhina discolor*
13	*Tridax procumbens*	Tpro	*Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus*
Family: Boraginaceae			
14	*Heliotropium indicum*	Hind	*Sargus metallinus, Paragus (Paragus) serratus, Eristalinus (Eristalinus) arvorum, Eristalinus (Eristalinus) megacephalus, Sepedon aenescens, Thelaira macropus*
Family: Brassicaceae			

Sl. No.	Plant Species	Abbreviation used in the network	Observed Dipteran species
15	*Brassica nigra*	Bnig	*Asarkina (Asarkina) ericetorum, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Eristalinus (Eristalinus) arvorum, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Syritta indica, Stomorhina discolor*
16	*Rorippa palustris*	Rpal	*Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Homoneura (Neohomoneura) bengalensis*
Family: Convolvulaceae			
17	*Ipomoea carnea*	Icar	*Chrysops dispar, Ischiodon scutellaris, Eristalinus (Eristalinus) megacephalus*
Family: Cucurbitaceae			
18	*Cucurbita maxima*	Cmax	*Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Bactrocera (Zeugodacus) cucurbitae, Platensina acrostacta, Homoneura (Neohomoneura) bengalensis, Musca (Byomya) ventrosa, Musca (Musca) domestica, Atherigona (Acritochaeta) orientalis, Sarcophaga (Liosarcophaga) dux, Lucilia porphyrina, Lucilia cuprina, Hemipyrellia ligurriens, Stomorhina discolor*
19	*Lagenaria siceraria*	Lsic	*Sargus metallinus, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Bactrocera (Zeugodacus) cucurbitae, Platensina acrostacta, Mimegralla albimana, Homoneura (Neohomoneura) bengalensis, Musca (Musca) domestica, Atherigona (Acritochaeta) orientalis, Lucilia porphyrina, Lucilia cuprina, Stomorhina discolor*
Family: Fabaceae			
20	*Mimosa pudica*	Mpud	*Episyrphus (Episyrphus) balteatus*
21	*Trigonella foenum-graecum*	Tfoe	*Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus*
Family: Lamiaceae			
22	*Leucas aspera*	Lasp	*Hermetia illucens, Ischiodon scutellaris, Neomyia timorensis*
23	*Mentha arvensis*	Marv	*Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Homoneura (Neohomoneura) bengalensis*
24	*Ocimum sanctum*	Osan	*Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Isomyia viridaurea*
Family: Mazaceae			

Sl. No.	Plant Species	Abbreviation used in the network	Observed Dipteran species
25	*Mazus pumilus*	Mpum	*Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Atherigona (Acritochaeta) orientalis*
Family: Myrtaceae			
26	*Psidium guajava*	Pgua	*Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Bactrocera (Zeugodacus) cucurbitae, Stomorhina discolor*
27	*Syzygium jambos*	Sjam	*Petrorossia ceylonica, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Eristalinus (Eristalinus) megacephalus, Mesembrius (Mesembrius) bengalensis, Bactrocera (Zeugodacus) cucurbitae, Platensina acrostacta*
Family: Oxalidaceae			
28	*Oxalis corniculata*	Ocor	*Asarkina (Asarkina) ericetorum, Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Campiglossa cribellata, Stomorhina discolor*
Family: Rutaceae			
29	*Aegle marmelos*	Amar	*Dideopsis aegrota, Ischiodon scutellaris, Baccha (Allobaccha) amphithoe, Paragus (Paragus) serratus, Platensina acrostacta*
Family: Solanaceae			
30	*Solanum nigrum*	Snig	*Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Atherigona (Acritochaeta) orientalis*
Family: Verbenaceae			
31	*Lippia alba*	Lalb	*Asarkina (Asarkina) ericetorum, Episyrphus (Episyrphus) balteatus, Ischiodon scutellaris, Paragus (Paragus) serratus, Mesembrius (Mesembrius) bengalensis, Isomyia viridaurea*
32	*Lantana camara*	Lcam	*Microchrysa flaviventris, Sargus metallinus, Dideopsis aegrota, Episyrphus (Episyrphus) balteatus, Paragus (Paragus) serratus, Syritta indica, Mimegralla albimana, Musca (Musca) domestica, Neomyia timorensis, Lucilia porphyrina, Lucilia cuprina, Chrysomya megacephala, Chrysomya rufifacies, Stomorhina discolor*

Table III. Tukey's post-hoc test to determine the differences in species richness of flower-visiting flies among three seasons across all study sites.

Seasons	Z - value	P - value
Pre-monsoon – Monsoon	- 6.336	< 0.001
Monsoon – Post-monsoon	- 9.630	< 0.001
Post-monsoon – Pre-monsoon	3.315	0.00256

Acknowledgements

This work was supported by The Zoological Society, Kolkata (Award No.: ZSK/NIA-12/B1-2021) to the first author. We would also like to thank Mr. Supratim Laha (Ph.D. student, Department of Zoology, University of Calcutta) for his assistance in data analysis and manuscript correction.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Integrative Taxonomy of Tetraodontiform Fishes (Tetraodontiformes: Percomorpha) From Southwest Coast of India

Suvarna S. Devi[1]*, Mosab Ali Alzahaby[1,2], Vishnuraj R[1]., NisanthH.P[1]., Shabina A[1]., Biju Kumar, A.[1]

[1]*Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram-695 581, Kerala*

[2]*Department of Zoology, Section of Marine Biology, Faculty of Science, Al-Azhar University, Assiut Branch, Assiut- 71524, Egypt.*

E-mail: suvarnaraja.abf@keralauniversity.ac.in

Abstract

The taxonomy of the order Tetraodontiformes is not well studied from the Indian coast, hence an integrated approach was attempted in this paper. Forty-two species of tetraodontiform fishes classified under 8 families in 25 genera were identified using morpho-molecular approach from southern west coast of India. Tetraodontidae is the most speciose family with fourteen species, followed by Balistidae and Monacanthidae with seven species each; Ostraciidae, Diodontidae, Triacanthodidae and Tricanthidae harbour three species each and Molidae is represented by two species. Eight species collected during the present study are new records to the Kerala coast. DNA barcoding using mitochondrial CO1 gene confirmed 12 species of tetraodontiform fishes. The molecular data of the present study were compared with sequences from GenBank, and the selected published sequences by expert taxonomists were matched for their maximum identity. The heat map shows low pairwise distances between the nearest species, and the phenetic tree shows that the studied species are nested in clades with closely related species.

Keywords: Taxonomy, morphology, molecular studies, Southwest coast, heat map

Introduction

The systematics of taxonomically and structurally diversified and extensively distributed clade of acanthomorphs, the Tetraodontiformes, have been elucidated recently (Matsuura, 2015), with the persisting nomenclatural challenges. These fishes are widely distributed globally and inhabit the pelagic, deep sea, coastal, reef and freshwater habitats (Tyler, 1980; Matsuura, 2014). Many of the bony structures of the body and head are reduced or fused; reduction in the vertebrae and reduction or losses in fin supporting elements, thick skin covered with spines, prickles, ossicles, scales or bony plates are the key features of this order (Bray, 2020). Four hundred and thirty four extant species represent the order under ten families and five suborders (Nelson *et al*., 2016). The diversity and taxonomic works carried out in India for the order Tetraodontiformes include those of Veeruraj *et al.* (2011), Sahayak *et al.* (2015), Sujatha and Padmavathi (2015), Raj and Seshserebiah (2015), Kaleshkumar *et al.* (2015, 2021, 2018), Mohapatra *et al.* (2018), Naranji *et al.* (2016), Kumar *et al.* (2019), Ray and Mohapatra (2020), Mary *et al.* (2021) and Ramachandran (2022).

Mitochondrial DNA is helpful in tracking ancestry as it is maternally inherited, easily isolated and, with its rapid base substitution rate, a powerful molecular marker for evolutionary studies (Avise *et al*., 1987). An integrated taxonomic approach is always useful in the identification

*Author for correspondence : suvarnaraja.abf@keralauniversity.ac.in
Article Received on: 02.04.2023 Accepted on: 24.04.2023

of complex species which are difficult to identify morphologically alone (Padial *et al.*, 2010; Tornabene *et al.*, 2010). The taxonomy of Tetraodontiformes is not well studied from the Indian coast, and hence in the present study, an integrated approach using the traditional morphometrics and DNA barcoding using the mitochondrial cytochrome oxidase subunit 1 (COI) gene was attempted for selected species. The molecular taxonomic studies conducted on Tetraodontiformes from India include those of Kaleshkumar *et al.* (2015, 2018), Devi (2016), Bemis *et al.* (2020) and Ramachandran (2022).

Here we present a detailed taxonomic account of fishes under the order Tetraodontiformes landed in the major fishing harbours of south India and also DNA barcoding of selected tetraodontiform fishes using COI gene to confirm identification and to understand the phylogeny of identified species.

Materials and methods

The specimens were randomly collected from trawl bycatch, seine nets and gill nets from the major fishing harbours of south India: Neendakara and Sakthtikulangara (Kerala) and Jeppiar harbour, Muttom (Tamil Nadu). The collection was performed in 2019 and 2020. The tissue samples from fin clips were taken for molecular analysis and stored in 90 per cent ethanol. For the identification and measurements of members of each family, specific literature was used and compared with the descriptions of species following (Matsuura and Tyler 1997), Matsuura (2001, 2015), Bemis *et al.* (2020) and Froese and Pauly (2023). The specimens were finally preserved in 10 % buffered formalin. Voucher specimens are deposited in the Department of Aquatic Biology and Fisheries museum collections, University of Kerala.

Genomic DNA was extracted from the tissue of fin clips of twenty fishes using NucleoSpin® Tissue Kit (Macherey-Nagel) following specific instructions. The mitochondrial cytochrome oxidase I (COI) gene was amplified using the Universal primer set Fish-F1(TCAACCAACCACAAAGACATTGGCAC) and Fish-R1 (TAGACTTCTGGGTGGCCAAAGAATCA) (Ward *et al.*, 2005) for the mitochondrial cytochrome oxidase I (COI) marker.The PCR amplification was carried out in a PCR thermal cycler (GeneAmp PCR System 9700, Applied Biosystems) using the standard procedures, and Gene sequencing was done at Rajiv Gandhi Centre for Biotechnology (RGCB), Trivandrum, India and the sequence quality was checked using Sequence Scanner Software v1 (Applied Biosystems) and the final sequences and the obtained sequences from GenBank database were edited and aligned using Bio Edit sequence alignment editor V.7.0.9.0. and genetic distance was calculated with the Kimura 2-parameter distance model (K2P) (Kumar *et al.*, 2016). Using MEGA (Version 11). Microsoft Office Excel software (Excel, version 2019 16.0.6742.2048) was used for editingthe heatmap of average K2P divergences between COI barcodes. For the phylogenetic analysis, COI sequence data were analyzed using the neighbor-joining (NJ) tree to infer the evolutionary relationships of the studied species with other closely related species. The phylogenetic tree was planned using FigTree v1.4.4 (Rambaut *et al.*, 2018).

Results and discussion

Forty two species of Tetraodontiformes under 8 families and 25 genera were recorded from the fishing harbours of southwest India (Table 1). Tetraodontidae is the most speciose family (14 species), followed by Balistidae and Monacanthidae (7 species each), Ostraciidae, Diodontidae, Triacanthodidae and Tricanthidae (3 species each) and Molidae (2 species) *Mola alexandrini* and *Mola mola* (Table 1.). *Halimochirurgus centriscoides* (Family: Tricanthodidae); *Balistapus undulatus, Sufflamen chrysopterum* (Family: Balistidae); *Anacanthus barbatus*, *Pervagor melanocephalus* (Family: Monacanthidae), *Canthigaster petersii*, *Sphoeroides pachygaster*, and *Torquigener brevipinnis* (Family: Tetraodontidae) encountered during the present study are new records to Kerala. Species used for molecular studies except *Mola mola* were deposited in the museum of Department of Aquatic Biology and Fisheries, University of Kerala and provided with voucher numbers for future reference.

Voucher numbers were provided as follows: *Sufflamen franetum* (DABFUK/FI/316), *Cyclicthys orbicularis* (DABFUK/FI/317), *Diodon holocanthus* (DABFUK/FI/318), *Arothron stellatus* (DABFUK/FI/319), *Arothron stellatus* (DABFUK/FI/320), *Arothron immaculatus* (DABFUK/FI/321), *Lagocephalus guentheri* (DABFUK/FI/322), *Odonus niger* (DABFUK/FI/323), *Sphoeroides pachygaster* (DABFUK/FI/324), *Lagocephalus scleratus* (DABFUK/FI/325), *Abalistes stellatus* (DABFUK/FI/326), *Canthidermis maculata* (DABFUK/FI/327), *Lactoria cornuta* (DABFUK/FI/328), *Mola mola* (DABFUK/FI/329).

Systematics

1. ***Halimochirurgus centriscoides*** **Alcock, 1899** **(**Longsnout spikefish)

Materials collected: 2 specimens (SL 120mm, 128 mm), Sakthikulangara harbour, Kerala, Suvarna S. Devi; 21/02/2020.

Description: Medium sized stout body, upper jaw prolonged into long snout with a palp/spoon like structure at its end; inferior mouth with a short snout; large eyes; dorsal fin with three spines increasing in size posteriorly with dorsal fin membrane extending between, second dorsal only with rays; pectorals modified into a long sharp spine as lengthy as the first dorsal fin spine; anal fin placed far back on the body long gill opening; scales with spinules; medium sized caudal peduncle with caudal fins with several soft rays.

Colour: Red dorsally and laterally with two white lines, upper thin white line and lower more thick white line; whitish ventrally, long snout and its spoon shaped structure are also red in colour; second dorsal fins last six rays colourless, rest of the dorsal spines and rays red coloured; pectoral spine colourless, caudal fins also red in colour.

Remarks: Only two species, *Halimochirurgus alcocki* M.C.W. Weber, 1913 and *Halimochirurgus centriscoides* Alcock, 1899, are known in this genus. This species is a new record to the Kerala coast.

2. *Balistapus undulatus* (Park, 1797) (Orange-lined triggerfish)

Materials collected: 2 specimens (SL 270 mm, 29 mm); Vizhinjam, Trivandrum, A. Biju Kumar, 09/08/2019.

Description: 3 Dorsal spines; 25 soft rays, 25 Anal soft rays; front of eye without groove; scales above the pectoral-fin base and behind the gill opening to forming flexible tympanum; caudal peduncle scales having 2 longitudinal rows of large spines; rounded caudal fin with narrow peduncle.

Colour: head and body colour greenish brown with diagonal orange lines, large round black blotch covering base of the caudalfin; caudal fin, dorsal, anal and pectoral fins soft rays orange.

Remarks: Mohapatra *et al.* (2020) reported the species from India in their checklist of faunal diversity of the Indian coast. The species is a new record from Kerala.

3. *Sufflamen chrysopterum* (Bloch & Schneider 1801) (Halfmoon triggerfish**)**

Materials collected: 2 specimens (SL 212 mm,224 mm, 225 mm); Sakthikulangara harbour, Kerala, Suvarna S. Devi and A. Biju Kumar,22/04/2019

Description: Head concave with terminal mouth, cheek fully covered with scales; groove before the eye and beneath nostrils, small row of scales behind tympanum; caudals truncate; black bar running through the pectoral base; large scales all over the body forming small conical spines at the posterior region Dorsal spines 3; Dorsal soft rays 26-27; Anal soft rays: 25.

Colour: A pale brown triggerfish with an orangish yellow bar below the rear of the eye, yellowish caudals with triangle edge of white in tail, slight tinge of blue on lower part especially on chin and belly.

Remarks: Recorded from Lakshadweep (Jones and Kumaran, 1980) and Andaman Nicobar islands (Rajan and Mishra, 2018) and Visakhapatnam (Padmavathi *et al.*, 2017); Mohapatra *et al.* (2020). The species is new record to Kerala.

4. *Anacanthus barbatus* Gray, 1830 (Bearded leatherjacket)

Materials collected: 2 specimens (SL 191 mm, 253 mm, 256 mm; from Vizhinjam harbour, Trivandrum; Suvarna S. Devi and A. Biju Kumar; 25/11/2019.

Description: Body and head elongate and compressed, lower jaw with beard; long based dorsal and anal fins; dorsal spines 1, dorsal soft rays 48-50; anal soft rays: 58 - 60.

Colour: light yellowish in colour, an orange stripe extends from tip of the snout to eye.

Remarks: Reported by Day (1871) and listed by Rajan and Mishra (2018) from Andaman Nicobar Islands. The species is a new record to Kerala.

5. *Pervagor melanocephalus* (Bleeker, 1853) **(**Redtail filefish)

Materials collected: 2 specimens (SL 153 mm, 151 mm), collected from Vizhinjam, Kerala, A. Biju Kumar; 21/09/2019.

Description: Long and compressed body; first dorsal spine long and strong, second short and hidden; pelvic rudiment large not attached to posterior margin of ventral flap; scale ridge of male folded.

Colour: Bluish black or light violet on head and anterior portion of body, posterior part of the body orange; black blotch around the gill opening; caudal fin orange with 1/2 blue lines at its tip; first dorsal spine blackish brown; soft dorsal and anal fins yellow.

Remarks: Joshi *et al.* (2016) recorded the species from the Gulf of Mannar, Rao (2003) and Rajan *et al.* (2013) reported it from Andaman Nicobar Islands. The species is a new record for Kerala.

6. ***Canthigaster petersii* (Bianconi, 1854) (**Peter's toby)

Materials collected: 2 specimens (SL 290 mm, 292.20 mm); Vizhinjam harbour, Kollam, A. Biju Kumar and Suvarna S. Devi, 22/04/2019

Description: Laterally compressed body with spinules on belly; gill opening and nostrils minute; rounded tail; dorsal and anal fin rays 9, pectoral fin rays 15.

Colour: white spots on lateral side of the body reaching upto the caudal fin, abdomen white in colour; around the eye and on the dorsal profile white striations; black spot below the base of dorsal fin.

Remarks: Recorded from Andamans (Allen and Erdmann, 2012) and Tuticorin (Mishra *et al.*, 2019)

7. ***Sphoeroides pachygaster* (Muller &Troschel) 1848 (**Blunt-head puffer)

Materials collected:1 specimen (SL 150 mm); Suvarna S. Devi from Sakthikulangara harbour, Kerala;13/12/2019

Description: Body oblong and devoid of prickles or scales; blunt head, jaws heavy forming a beak of two teeth in both jaws, mouth terminal and small, eye small and ovoid; dorsal and anal fins set far back near caudal fin which is truncated, lacks pelvic fin, dorsal fin usually with 9 soft rays, anal fin with 8 or 9 soft rays, no spines on fins.

Colour: Brown to grey above, ventral side white dorsal and lateral surfaces with arbitrary dark blotches and spots. Pectorals and anal translucent white and without markings, dorsal light dusky grey and caudal dark dusky grey but with tips of rays and lower margin lighter.

Remarks: The species was recorded from eastern Arabian Sea (Ramachandran *et al.*, 2022).The species is a new record to Kerala.

8. ***Torquigener brevipinnis* (Regan, 1903)** (Yellow-stripe Toadfish)

Materials collected: 7 Specimens (SL ranging from 39 – 54mm) from Neendakara and Beypore, Kerala; Kerala; A. Biju Kumar; 14/08/2019, 12/03/2019.

Description: Elongated body, round dorsally and flattened ventrally, tapering towards the caudal peduncle; small terminal mouth with thin lips with several tiny papillae; spines over the body is small, less dorsally and moderate ventrally; skin with several longitudinal pleats; three slightly oblique, narrow, creamy-white bands on the cheek; inverted U-shaped band below posterior part of eye; moderate eye; caudal fin truncated with dark brown blotches on rays which looks like six lines.

Colour: Brown dorsally, creamy whitish ventrally, with small round pale yellow spots, outlined by brownish dots. A yellowish-brown band is seen extending from the pectoral fin to the base of caudal fin.

Remarks: The species is similar in many aspects to its congener *T. flavimaculosus,* which lacks the caudal fin bands; whitish bands on the body, below the eyes and yellow spots are lacking in the latter. Biswas *et al.* (2010) and Kaleshkumar *et al.* (2021) recorded the species from the Tamil Nadu coast. The species is a new record for Kerala.

Molecular Taxonomy

The present study included 38 nucleotide sequences of different Tetraodontiformes belonging to 8 different families, out of which 13 sequences (accession numbers are provided in brackets) from the present study were included for the current analysis, and 1 nucleotide sequence of *Pterois volitans* (Perciformes; Scorpaenidae) was used as an outgroup. The neighbor-joining phenetic tree showed deep divergences between all families of Tetraodontiformes and relatively small differences within members of each family (Fig.1). Furthermore, *Odonus niger* (OQ916876) and *Abalistes stellatus* (OQ918289), the two species belonging to Balistidae nested in two clades with 79.9% bootstrap value. Moreover, there are two separate clades comprising

Lactoria cornuta (OQ918269) (Ostraciidae), *Mola mola* (OQ918272) (Molidae), with 100% bootstrap value. On the other hand, *Cyclichthys orbicularis* (OQ916400) and *Diodon holocanthus* (OQ916419) (Diodontidae) nested in one clade with 99.6% bootstrap value. Also, *Arothron immaculatus* (OQ916460) and *Arothron stellatus* (OQ916427, OQ916435) (Tetraodontidae) nested in clade with 99.5% bootstrap value. Furthermore, the remaining species belonging to Tetraodontidae, *Sphoeroides pachygaster* (OQ918225), *Lagocephalus sceleratus* (OQ918252) and *Lagocephalus guentheri* (OQ916833), are nested in three separate clades with 100% bootstrap value (Fig.1).

The heatmap describing average K2P divergences between COI barcodes of different Tetraodontiformes species in the present study is given in Fig. 2. The overall genetic distance average recorded was 0.20. The highest interspecific genetic distance observed was 0.29 from different localities. The lowest genetic distance was recorded between the sequences of the same species in the present study and the matched sequences from NCBI.

Molecular genetics and DNA analyses helped in the estimation of similarities and differences in genes among organisms (Antoniou and Magoulas, 2014). Genetic data are widely used in fisheries management, including identification, discrimination, and species conservation (Basheer *et al.*, 2016; Victor, 2016; Alzahaby and Biju Kumar, 2023). The heat map exhibits genetic distances between species where the smaller genetic distances between species indicate a close genetic relationship (deep blue), while the large genetic distances indicate a more distant genetic relationship (deep violet) (Fig. 2). Genetic diversity within species were calculated as zero between members of each family from the 8 families.

Even though the taxonomy and systematics of Tetraodontiformes are thoroughly studied by Matsuura (2014), several taxonomic problems persist in various families, especially in the phylogenetic positions of Triodontidae and Molidae, which is obscure. In India, under the order Tetraodontiformes, 70 species under 8 families are reported in Fish Base (Ferose and Pauly, 2023), which needs revision, as Gopi and Mishra (2015) have listed 101 species under the order.

The records of the order Tetraodontiformes reported from Kerala till now comprised 8 families with 41 species (Biju Kumar *et al.*, 2019). In addition to this, *Lagocephalus spadiceus* (Devi, 2016), *Mephisto fraserbrunneri* (Bemis *et al.*, 2020) and *Mola alexandrini* (Mohan *et al.*, 2006; Kishore *et al.*, 2013) were also recorded. The present study identified 42 species of fishes in the order Tetraodontiformes from the southwest coast of India, and eight new records to Kerala *Halimochirurgus centriscoides* Alcock, 1899 (Tricanthodidae); *Balistapus undulatus* (Park, 1797), *Sufflamen chrysopterum* (Bloch & Schneider 1801) (Balistidae); *Anacanthus barbatus* Gray, 1830, *Pervagor melanocephalus* (Bleeker, 1853) (Monacanthidae); *Canthigaster petersii* Richardson 1845, *Torquigener brevipinnis* (Regan, 1903) and *Sphoeroides pachygaster* Muller &Troschel, 1848 (Tetraodontidae), making the total number of tetraodontiforms recorded so far from Kerala as 52 species. This short-term survey reflects the higher diversity of these fish taxa on the southwest coast of India.

Out of the twenty samples given for DNA barcoding, only 13 yielded results, revealing 12 different species from five families: Balistidae (*Odonus niger, Canthidermis maculata*); Ostaciidae (*Lactoria cornuta*); Tetraodontidae (*Arothron hispidus, Arothron immaculatus, Arothron stellatus, Lagocephalus guentheri, Lagocephalus scleratus, Sphoeroides pachygaster*); and Diodontidae (*Cyclichthys orbicularis, Diodon holocanthus*); Molidae (*Mola mola*). Species in the same family formed distinct clades in the phylogenetic tree (Fig.2.). Kaleshkumar *et al.* (2015) analysed mitochondrial CO1 gene of *Chilomycterus reticulatus, Arothron hispidus* and *Lagocephalus guentheri* and confirmed that the three species had a dichotomous relationship with their ancestor species.

In conclusion, the present study has strongly authenticated the efficacy of COI in identifying different tetraodontiform species with designated barcodes. The present results also suggest that COI barcoding can be used as a practical method for resolving unequivocal identification of the collected species from south Indian waters of India with applications in its management and conservation.

Further in-depth studies of coral reefs and long-term integrative taxonomic research are recommended to consolidate India's marine fish fauna database.

Table 1. List of Tetraodontiformes obtained from the southwest coast of India in the current study

Sp No	Family	Species	Samples collected
1	Triacanthodidae	*Halimochirur gusalcocki* Weber, 1913	1
2		*Halimochirur guscentriscoides* Alcock, 1899	4
3		*Mephistofraser brunneri* Tyler 1966	5
4	Triacanthidae	*Triacanthus biaculeatus* (Bloch, 1786)	11
5		*Triacanthus nieuhofii* Bleeker, 1852	2
6		*Pseudotriacanthus strigillifer* (Cantor, 1849)	2
7	Balistidae	*Abalistes stellatus*(Anonymous 1798)	7
8		*Balistapus undulatus* (Park, 1797)	2
9		*Canthidermis maculata* (Bloch, 1786)	2
10		*Pseudobalistes flavimarginatus*(Rüppell 1829)	2
11		*Sufflamen chrysopterum* (Bloch & Schneider 1801)	2
12		*Sufflamen fraenatum* Latrielle 1804	10
13		*Odonus niger* Rüppell 1836	6
14	Monacanthidae	*Aluterus monoceros* (Linnaeus, 1758)	7
15		*Aluterus scriptus* (Osbeck, 1765)	2
16		*Anacanthus barbatus* Gray, 1830	3
17		*Cantherhines pardalis* (Rüppell, 1837)	2
18		*Paramonacanthus frenatus* (Peters, 1855)	3
19		*Paramonacanthus pusillus* (Rüppell, 1829)	2
20		*Pervagor melanocephalus*(Bleeker, 1853)	2
21	Ostraciidae	*Lactoria cornuta* (Linnaeus, 1758)	4
22		*Ostracion cubicus* (Linnaeus, 1758)	4
23		*Tetrasomus gibbosus* (Linnaeus, 1758)	2
24	Tetraodontidae	*Arothron hispidus* (Linnaeus, 1758)	8
25		*Arothron immaculatus* Bloch and Schneider 1801	9
26		*Arothron nigropunctatus* Bloch and Schneider 1801	3
27		*Arothron reticularis* (Bloch & Schneider, 1801)	9
28		*Arothron stellatus* (Bloch & Schneider, 1801)	7
29		*Canthigaster bennetti* Bleeker, 1854	2
30		*Canthigaste r petersii* Richardson 1845	2
31		*Chelonodon patoca* (Hamilton, 1822)	2

Sp No	Family	Species	Samples collected
		Chelonodontops leopardus(Day, 1878)	2
33		*Lagocephalus inermis* (Temminck& Schlegel, 1850)	12
34		*Lagocephalus scleratus* Gmelin, 1789	9
35		*Lagocephalus guentheri* Miranda Ribeiro, 1915	12
36		*Sphoeroides pachygaster* (Muller&Troschel) 1848	1
37		*Torquigener brevipinnis* (Regan, 1903)	7
38	Diodontidae	*Cyclicthys orbicularis* Bloch 1785	9
39		*Diodon holocanthus* Linnaeus 1758	8
40		*Diodon hystrix* Linnaeus, 1758	8
41	Molidae	*Mola alexandrini* (Ranzani 1839)	1
42		*Mola mola* (Linnaeus, 1758)	1

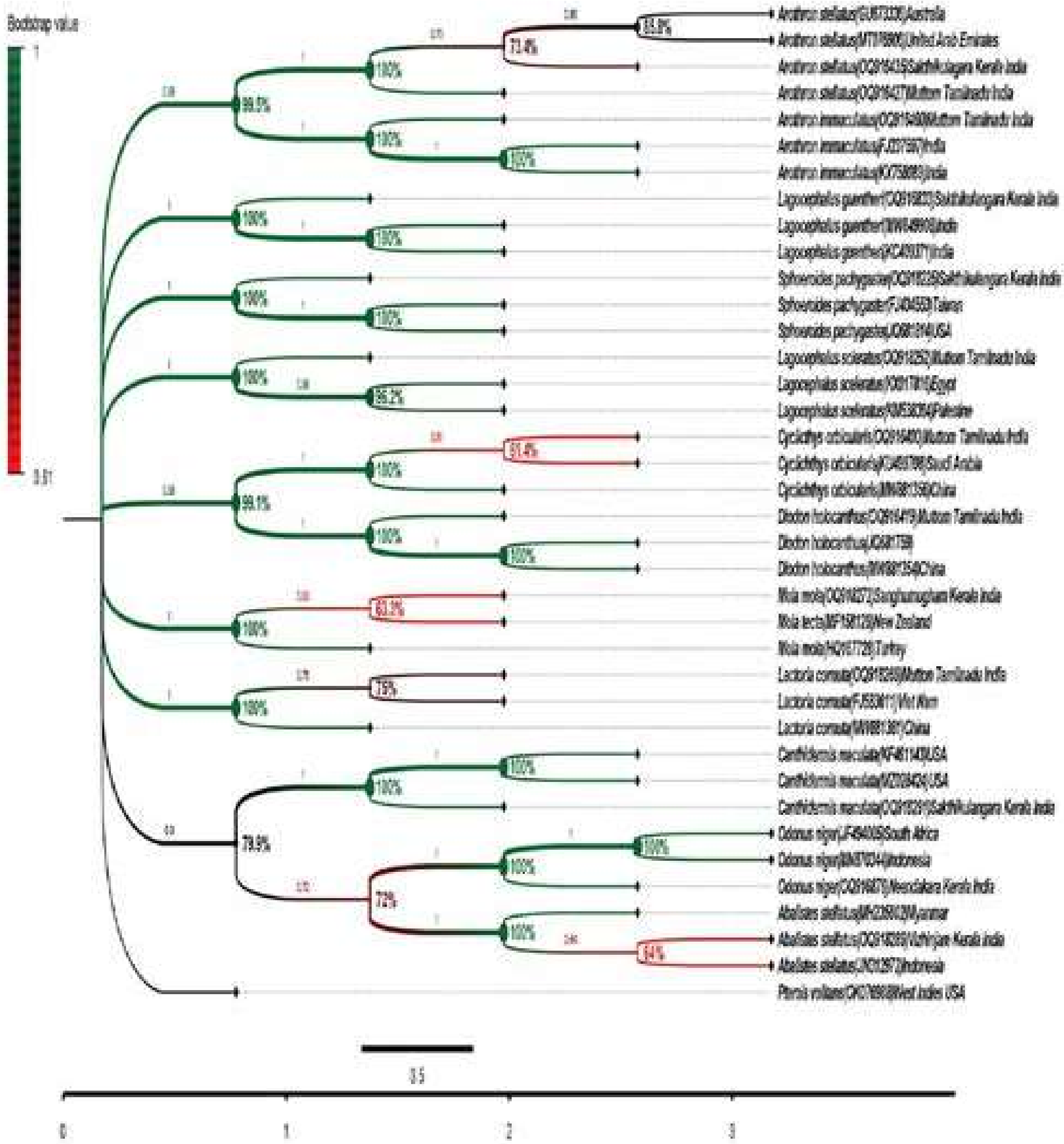

Fig.1. The neighbor-joining (NJ) phenetic tree of various Tetraodontiformes species from South India developed using Kimura two-parameter model (K2P) distance among 38 COI sequences. The scale bar represents a 0.2 sequence difference. The numbers along the nodes are bootstrap values based on 1000 iterations. Species' names, collection locations, and Gene Bank accession numbers are shown for each taxon. *Pterois volitans* (OK076988) is the outgroup sequence.

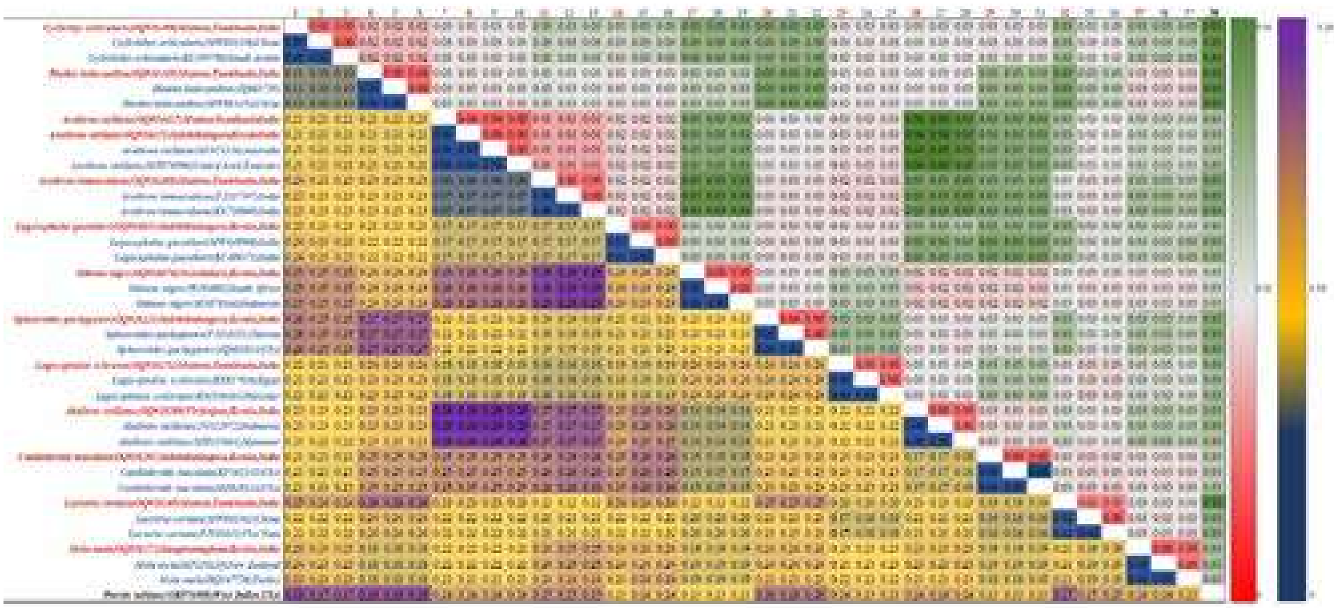

Fig.2. Heatmap describing average K2P divergences between COI barcodes of different Tetraodontiformes species in the present study.

Acknowledgements

Thanks are due to Dr Keiichi Matsuura, Curator Emeritus, Division of Fishes, National Museum of Nature and Science, Tsukuba, Japan, for the help in the identification of a few species.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Preliminary Assessment of Arthropod Diversity of the Rock-Cut Caves of Satara district, Maharashtra, India

Pooja Kumar Misal[1] and Aparna Sureshchandra Kalawate[2]

[1]Shivaji University, Vidyanagar, Kolhapur- 416 004. Maharashtra, India.

[2]Zoological Survey of India, Western Regional Centre, Vidya Nagar, Sector-29, P.C.N.T. (PO), Rawet Road, Akurdi, Pune, Maharashtra 411044, India.

Abstract

Palpeshwar caves are located near Lohare village,Wai in Satara district. These caves are situated in the Northern Western Ghat's, Maharashtra. These are rock-cut caves and never been explored for their assessment of biodiversity, particularly arthropod fauna. Today, the need of the hour is to document the cave fauna before its extinction due to anthropogenic pressure. Consequently, an attempt has been made to document the preliminary arthropod diversity of the Lohare, Palpeshwar cave. The two exploratory surveys were conducted for two months to investigate arthropod diversity in the study area. The results of the two surveys revealed that a total of six different orders representing 21 species of the phylum Arthropoda were recorded in different microhabitats of rock-cut cave. Among these orders, Lepidoptera shows its dominance over other species of arthropodan fauna. For a proper assessment of the arthropod diversity of the cave, more extensive surveys will be undertaken seasonally.

Keywords: Palpeshwar, Rock-cut caves, Arthropods, Diversity, Satara.

Introduction

Palpeshwar caves are the oldest caves, located near Lohare village and situated five Kilometers from Wai, Satara. Wai was an important village in ancient India, also known as Dakshin Kashi, as it is situated next to the banks of the Krishna River. These caves are important for local people due to the presence of the Shiva Lingam there. Thousands of devotees from the surrounding villages visit this cave, especially during *Shravan* month, an auspicious month for the Shiva devotees, and it thus faces anthropogenic pressure. These caves are the true example of marvelous rock engineering in ancient India. Caves are natural or man-made subterranean cavities that can also be formed in front of cliffs or slopes. (Derek and Williams, 2007; Sail, *et al.*, 2021). Rock-cut Caves form a varied number of habitats with cracks, crevices, a ground floor, and a roof. Few studies have been carried out on Arthropodan diversity in India (Kemp and Chopra 1924; Harries *et al.* 2008; Biswas, 2009; Syiemiong and Paul, 2016; Dhamorikar *et al.* 2020; Harries *et al.* 2021; Sail *et al.*, 2021 and Kawalkar *et al.*, 2022). Some caves have been transformed into ecotourism sites, facing immense anthropological pressure. On perusal of literature, it was found that the systematic document on the arthropod diversity of the caves is generally lacking in Maharashtra and is particularly lacking in the Satara district of Maharashtra. Hence, the present study was undertaken to document the diversity of the Arthropod fauna of the Palpeshwar rock-cut caves of Satara district, Maharashtra.

Material and Methods:

Palpeshwar caves are located at 17.99 N and 73.91 E coordinates. Elevation ranges from 700m to 1000m (Fig. 1 and Fig. 3). The rapid survey of Arthropodan faunal diversity was carried out twice for two months, from January 2023 to February 2023 in short period of time to document preliminary data. These are ancient caves which have Chaitya hall and stupa and due to this it has compartments and provides different microhabitats like a ground floor, cracks

*Author for correspondence : pkmspider@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

and crevices, a cave roof, a platform, small passages and walls (Fig.3). We have divided these rock-cut caves according to compartments to assess the arthropod fauna. During survey we observed remains of moth wings left after eating the abdomen by predators. We collected those remains of wings and used them for the identification of moths (Fig. 5).

Results and Discussion:

The data on the diversity of arthropod in the cave is presented here based on two preliminary surveys. A total of six different orders of Phylum Arthropoda, like Araneae, Lepidoptera, Coleoptera, Hemiptera, Phasmatodea and Orthoptera have been recorded during the study. Among them, Lepidoptera shows its dominance over other orders (Fig.2). We have documented 21 species of Phylum Arthropoda, such as 10 species from Order Lepidoptera, 7 species from Order Araneae, 1 species from Order Hemiptera, 1 species from Order Coleoptera, 1 species from Order Orthoptera, and 1 from Order Phasmatodea (Table 1, Fig. 4 and Fig. 5).

Kulkarni and Ghate (2016) recorded the first thread-legged assassin bug, *Myiophanes greeni* Distant, 1903 (Heteroptera: Reduviidae: Emesinae) from a cave located at Chalkewadi Road near Sajjangad Fort, Satara. Kharkongor and Saikia (2018) studied the cave arthropod fauna from Krem Lawkhlieng and observed the predominance of terrestrial arthropod species, mainly insects: orthoptera (cave crickets), coleoptera (cave beetles), lepidoptera, diptera, fungus gnats, springtails, cockroaches, and other Arthropods such as woodlice, millipedes, harvestmen, and spiders. All these studies are in accordance with our study. Hence, according to the available literature, there is no detailed study on the arthropodan cave fauna in Satara, Maharashtra. This preliminary study is the first of its kind, from this region, and provides information on the diversity of arthropod fauna in Palpeshwar caves.

Table No.1 Preliminary checklist of Arthropod diversity of Rock-cut caves, Palpeshwar, Satara.

Sr.No	Order	Family	Scientific Name
1	Lepidoptera	Erebidae	*Eudocima materna* (Linnaeus, 1767)
2		Erebidae	*Eudocima* sp.
3		Erebidae	*Erebus hieroglyphica* (Drury, 1773)
4		Erebidae	*Digama* sp.
5		Eupterotidae	*Eupterote* sp.
6		Noctuidae	*Condica* sp.
7		Spingidae	*Nephele hespera* (Fabricius, 1775)
8		Geometridae	*Scardamia* sp.
9		Crambidae	*Agrotera scissalis* (Walker, 1866)
10		Hesperiidae	*Celaenorrhinus ambareesa*(Moore, 1865)
11	Coleoptera	Hybosoridae	*Hybosorus* sp.
12	Hemiptera	Gerridae	*Gerris* sp.
13	Phasmatodea	Diapheromeridae	*Pseudosermyle* sp.
14	Orthoptera	Gryllidae	*Gryllus* sp.
15	Araneae	Sicariidae	*Loxosceles* sp. 1
16		Sicariidae	*Loxosceles* sp. 2
17		Uloboridae	*Zosis* sp. 1
18		Uloboridae	*Zosis* sp. 2
19		Sparassidae	*Heteropoda* sp.
20		Lycosidae	*Hippasa* sp.
21		Salticidae	*Hasarius* sp.

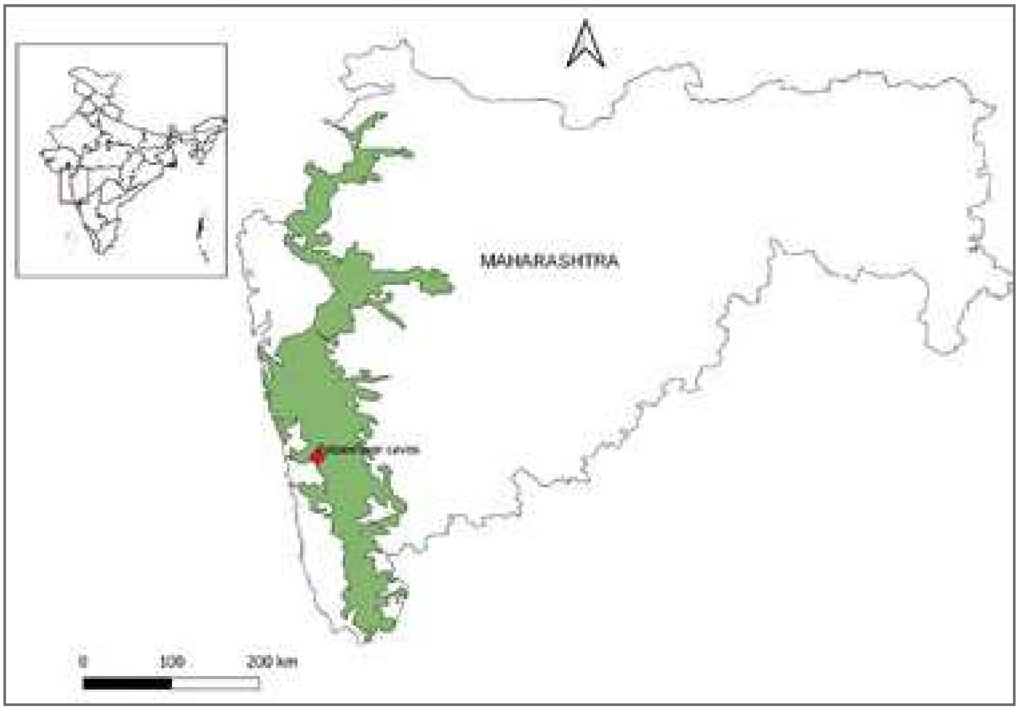

Fig. 1 Study area location Palpeshwar rock-cut caves, Wai, Satara.

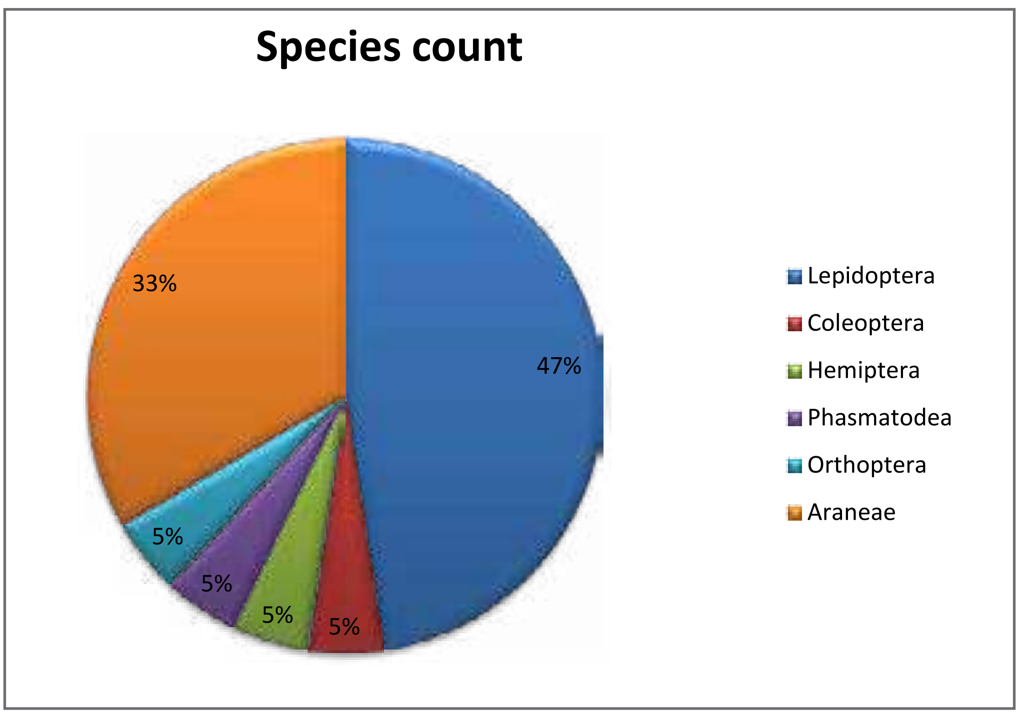

Fig. 2 Pie chart showing diversity of Arthropods in Rock- cut caves Palpeshwar, Satara

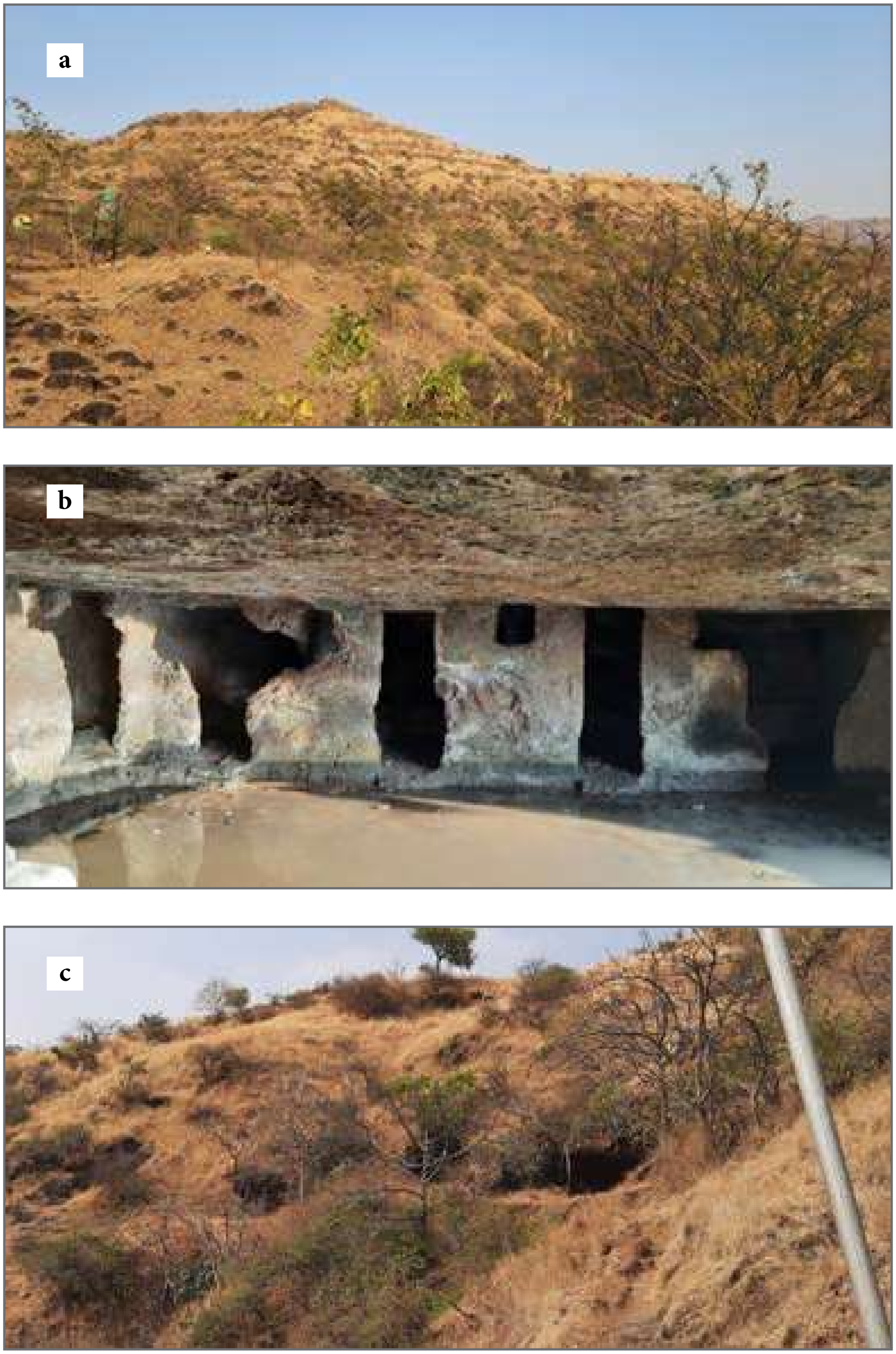

Fig. 3 Palpeshwar caves: a. General view, b. Inside view and c. Outside view.

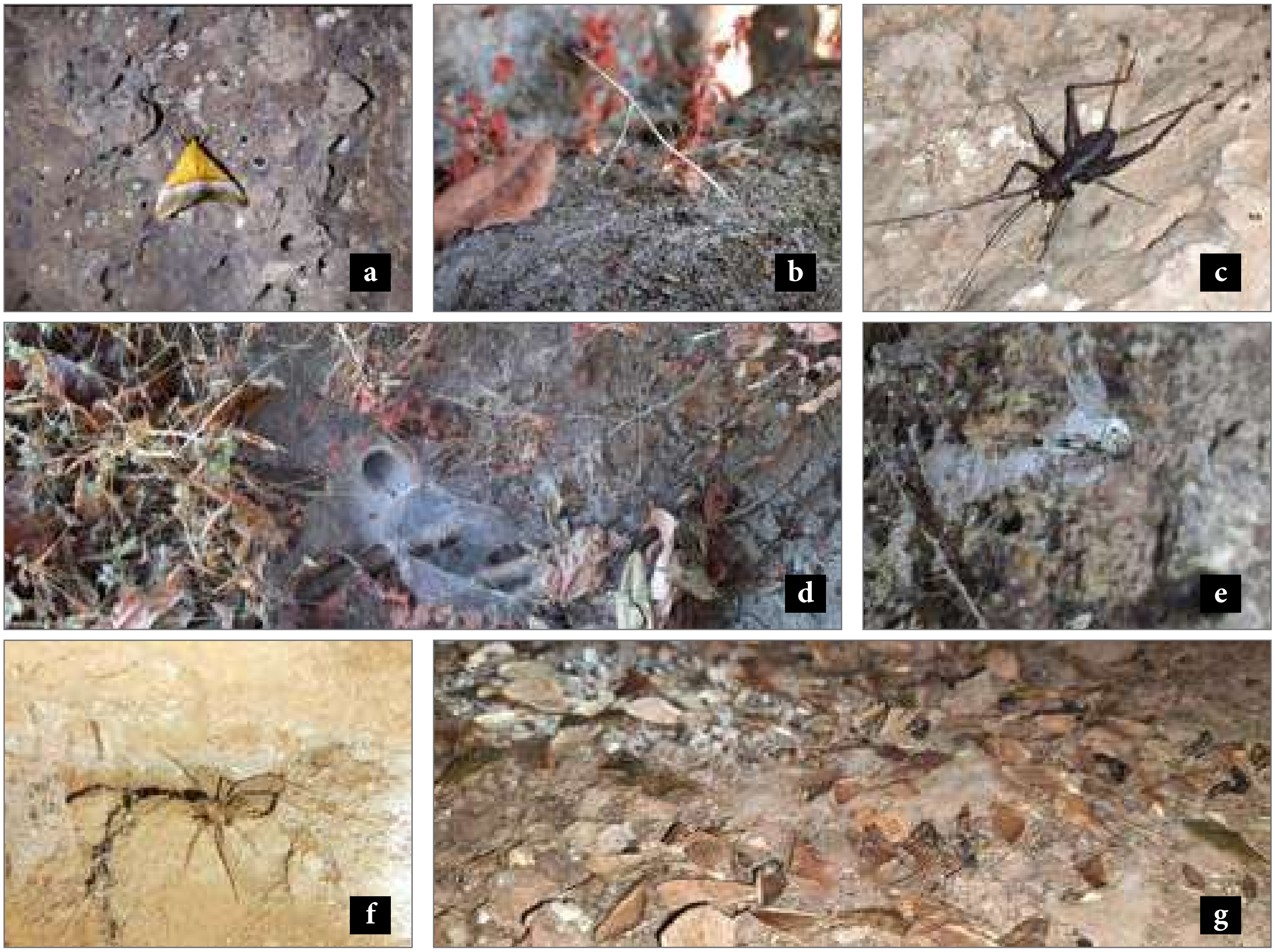

Fig. 4 Arthropod diversity in Palpeshwar cave: a) *Agrotera scissalis,* b) *Pseudosermyle* sp. c) Cricket d) *Hippasa* sp. e) *Zosis* sp. f) *Loxosceles* sp g) Moth wings

Fig. 5 Moth wings remains after abdomen eaten by predators

Acknowledgements:

The authors are thankful to the Director, Zoological Survey of India, Kolkata and the Officer-in-Charge, WRC, ZSI, Pune for facilities and encouragement. Thanks are extended to the Head of the Department of Zoology of Shivaji University, Kolhapur. The first author acknowledges DST-INSPIRE Fellowship Program.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Shining leaf chafers (Coleoptera, Scarabaeidae, Rutelinae) of Jammu and Kashmir, India

Irtiza Wani[1], Joyjit Ghosh[2] and Devanshu Gupta[3]

[1,2,3]Zoological Survey of India, Prani Vigyan Bhawan Block M, New Alipore, Kolkata, West Bengal 700053

[1]University of Calcutta, India, Kolkata, 35, Ballygunge Circular Rd., Ballygunge,Kolkata-700019, West Bengal, India

Emails: [1]irtiza.wani.9@gmail.com, [2]arkazoology@gmail.com, [3]devanshuguptagb4102@gmail.com

Abstract

In the present communication, a total of 17 species belonging to 7 genera of the subfamily Rutelinae (Insecta: Coleoptera: Scarabaeidae) are documented from the union territory of Jammu & Kashmir (India). We examined the specimens from the recent surveys of Jammu & Kashmir, and the specimens present in the collections of the Zoological Survey of India, Kolkata. The genus *Adoretus* Dejean, and *Popillia* Serville are known by maximum number of species (4 species each), followed by *Anomala* Samouelle (3 species), *Callistethus* Blanchard (2 species), and *Mimela* Kirby (2 species), *Rhinyptia* Burmeister and *Tropiorhynchus* Blanchard (1 species each).

Keywords: Distribution, Himalayas, Pest, Scarabs, Species.

Introduction

Shining leaf chafers (Coleoptera, Scarabaeidae, Rutelinea) includes over 4,617 species worldwide belonging to 254 genera (Schoolmeesters, 2023). These beetles are phytophagous and comprise commercially significant chafers that act as serious pests feeding on foliage, fruit, and flowers (Sawada, 1991; Jackson, 2006; Valois *et al.*, 2019). Some adults can also act as pollinators for certain plant species (Kirmse and Ratcliffe, 2019) Larvae are saprophagous, help in breakdown of dead organic matter in forests and contribute to the nutrient cycling (Hardy 1991; Morón *et al.*, 1997). Jammu and Kashmir lies in the Himalayan Biogeographic Zone and lacks the baseline data on the diversity of subfamily Rutelinae. There has been a lack of study on diversity of this group from India. Studies on the diversity of shining leaf chafers the Jammu and Kashmir have not resulted into more data. Hence, there is a considerable lack of taxonomic literature on these beetles except for some monumental work by Arrow (1917), who documented eight species followed by Bashir et al (2017) who reported only one species of Rutelinae from Jammu and Kashmir, union territory of India. Therefore, this article aims to study and report the materials collected in the recent surveys and the specimens present in the Coleoptera Section of the Zoological Survey of India, Kolkata in order to provide an account of the Rutelinae from this union territory.

Material and Methods

Study Area

Jammu and Kashmir is located in the western part of the Indian Himalayan region (Rodger, 1988). It lies between latitude 32.26' to 34.78'N and longitude 73.16' to 76.76'E (Fig.1) and covers an area of 42,241 km^2. It is centered on the plains around Jammu to the south and the Vale of Kashmir to the north, from west to east, consists of the plains, the foothills, the Pir Panjal Range, the Kashmir Valley and the Great Himalayan Zone with a total forest area of 8,128 km^2 (Singh and Bedi, 2017) and is known for its rich biodiversity. Samples were collected from various areas of Ramban, Anantnag, Kulgam and Pulwama.

*Author for correspondence :
Article Received on: 02.04.2023

Accepted on: 24.04.2023

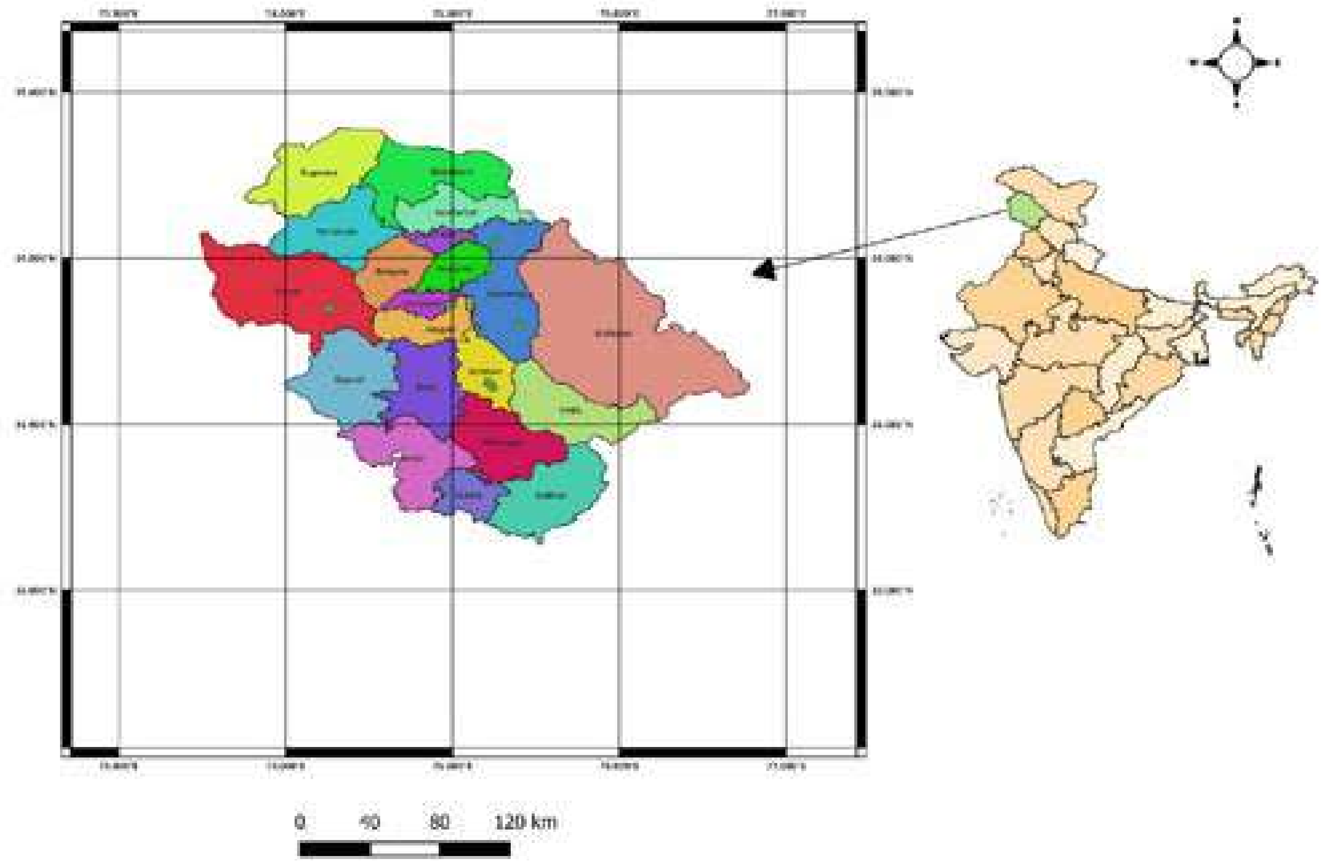

Figure 1. Map of Jammu & Kashmir showing collection localities.

Collection and Preservation

Samples for the study were collected from July to August 2022 from various locations in Jammu and Kashmir using light trapping methods. After collection, the samples were killed in a jar with benzene vapours. The samples were then pinned and dry preserved. The collected samples were analysed and examined under the Leica EZ4 HD microscope. In addition, the specimens from the Coleoptera section of the Zoological Survey of India were also studied. Species level identification was performed using keys and descriptions in Arrow (1917) and compared to reference collections held at the Zoological Survey of India, Kolkata. The structure of aedeagus was also taken into consideration for species-level identification.

Results and Discussions

A total of 17 species belonging to 7 genera and 2 tribes (Adoretini and Anomalini) of subfamily Rutelinae are reported in this study from Jammu & Kashmir (Table 1). The genera *Adoretus* Dejean, 1833 and *Popillia* Serville, are represented by maximum most number of species (4 species each), followed by *Anomala* Samouelle (3 species), *Callistethus* Blanchard (2 species), and *Mimela* Kirby (2 species), *Rhinyptia* Burmeister and *Tropiorhynchus* Blanchard (1 species each). The species are documented based on the pre-existing information, recent collection, and the collection present at Zoological Survey of India, Kolkata.

Table 1. Checklist of Shining leaf chafers (Rutelinae: Scarabaeidae: Coleoptera) from Jammu and Kashmir, India

S. N.	Name of the species	Material examined	Distribution in India.	References
Subfamily **Rutelinae** Macleay, 1819				
Tribe **Adoretini** Burmeister, 1844				
Subtribe: **Adoretina** Burmeister, 1844				
Genus ***Adoretu***s Dejean, 1833				
1	*Adoretus simplex* Sharp, 1878	India: Jammu and Kashmir Ramban, Rampur, 33.2486501N, 75.2107535E, 13.vii.2022, (3♂), leg. Irtiza Wani, India: J&K Kulgam, Qaimoh, Yamrach, 33.728864N, 74.989902E, 17.vii.2022, (5 ♂), leg. Irtiza Wani, India: Jammu and Kashmir Anantnag, Kokernag, 33.600302N, 75.390609E, 19.vii. 2022, (3♀), leg. Irtiza Wani.	IN: HP, JK E: NP	Arrow (1917) Schoolmeesters (2023).
2	*Adoretus (Adoretus) duvauceli* Blanchard, 1851	India: Jammu and Kashmir, Udhampur, 15.ix.1964, leg. Raj Tilak.	IN: CH, HR, MP, UP, WB, HP, JK, SK, UK	Arrow (1917) and Schoolmeesters (2023).
3	*Adoretus (Adoretus) versutus* Harold, 1869	India: Jammu and Kashmir, Anantnag, Pahalgam, Aru Valley, 7919.9ft, 34.0859336N, 75.2638140E, 20.vii.2022, (2♀), leg. Irtiza Wani, India: Jammu and Kashmir Pulwama, Tral, 33.9392190N, 75.1324990E, 17.vii.2022, (1♂), leg. Irtiza Wani.	IN: JK, AN, AP, BH, HR, KL, MP, UP, WB, UK E: ID, MY, MD, FJ	Arrow (1917) Bashir *et al.* (2017)
4	*Adoretus (Adoretus) limbatus* Blanchard, 1850		IN: BH, CH, HR, JK, MP, MH, OD, UP, WB E: BD, MM, TH	Löbl and Smetana (2006)
Tribe: **Anomalini**				
Subtribe: **Anomalina** Streubel, 1839				
5	Genus ***Anomala*** Samouelle, 1819 *Anomala rufiventris* Kollar & Redtenbacher, 1848	India: Jammu and Kashmir, Ramban, Rampur, 4494.8ft., 33.2206050N, 75.2107535E, 13.viii.2022, (2♀), leg. Irtiza Wani. India: Jammu and Kashmir Poonch, Surankote, 33.6928910N, 74.237860E, 01.viii.2022, (5♂), leg. Irtiza Wani	IN: HP, JK, SK, AS, HR, MN, ML, UP, WB E: NP, CN, VN, BT	Löbl and Smetana (2006)
6	*Anomala dorsalis* (Fabricius, 1775)		IN: HP, JK, Sk, UK, AN, AP, AS, BH, CH, GJ, HR,KR, KL, MP, MN, , PB, RJ, TN, UP, WB E: NP, PK, BD	Schoolmeesters (2023).
7	*Anomala dimidiate barbata* Burmeister, 1855		IN: HP, JK, UK E: AF, PK	Löbl and Smetana (2006)
Genus: ***Callistethus*** Blanchard, 1851				

S. N.	Name of the species	Material examined	Distribution in India.	References
8	*Callistethus auronitens* (Hope,1835)		IN: HP, JK, SK,UK; E: BT, CN, LA, MM, VN, NP	Löbl and Smetana (2016)
9	*Callistethus stoliczkae* (Sharp, 1878)		IN: HP, JK, SK, PB, UP, WB E: BT, CN, NP, PK.	Löbl and Smetana (2016)
Genus ***Mimela*** Kirby, 1825				
10	*Mimela passerinii passerinii* Hope, 1842	India: Jammu and Kashmir, Anantnag, Pahalgam, Aru Valley, 7919.9ft, 34.0859336N, 75.2638140E, 20.vii.2022, (1♂), leg. Irtiza Wani.	IN: HP, JK, ML, SK, UK, AR E: CN, NP, PK. BT	Löbl and Smetana (2016)
11	*Mimela horsfieldi* Hope, 1836		IN: AR, AS, HR, HP, JK, ML, PB, SK, UK, WB. E: NP, PK, TB,CN	Löbl and Smetana (2016)
Subtribe: **Popilliina** Ohaus, 1902				
Genus ***Popillia*** Serville, 1825				
12	Genus ***Popillia*** Serville, 1825 *Popillia cyanea* Hope, 1831	India: Jammu and Kashmir Udhampur city, 15.ix.1964, leg. Raj Tilak	IN: AR, AS, JK, ML, SK, UK, WB E: CN, NP	Arrow (1917)
13	*Popillia cupricollis* Hope, 1831		IN: AR, AS, HP, JK, PB, SK, ML, HR, PB, UP, SK, UK E: NP.	Arrow (1917) Löbl and Smetana (2016)
14	*Popillia clypealis* Ohaus, 1897		IN: JK, UK, AS, PB	Arrow (1917) Löbl and Smetana, (2016)
15	*Popillia sulcata* Kollar & Redtenbacher, 1848		IN: JK, UK. E: CN, NP.	Arrow (1917)
Subtribe: **Anisopliina** Burmeister, 1844				
Genus: ***Tropiorhynchus*** Blanchard, 1851				
16	*Tropiorhynchus podagricus* (Burmeister, 1844)		IN: MH, JK	Arrow (1917) Gupta (2017)
Genus: ***Rhinyptia*** Burmeister, 1844				
17	*Rhinyptia (Rhinyptia) suturalis* Kraatz, 1895		IN: JK, PB; E: AF, PK, IR	Löbl and Smetana (2016)

Abbreviations: IN: India, E: Elsewhere AP: Andhra Pradesh, AR: Arunachal Pradesh, AS: Assam, BR: Bihar, CH: Chhattisgarh,HR: Haryana, HP: Himachal Pradesh, JK: Jammu and Kashmir, KL: Kerala, MP: Madhya Pradesh, MH: Maharashtra, MN: Manipur, ML: Meghalaya, PB: Punjab, UK: Uttarakhand, UP: Uttar Pradesh, WB: West Bengal, AN: Andaman and Nicobar Islands, GJ: Gujarat, SK: Sikkim, AF: Afghanistan,CN: China, BT: Bhutan, FJ: Fiji, IR: Iran, VN: Vietnasm, TB: Tibet, MM: Myanmar, LA: Laos, BD: Bangladesh, TH: Thailand, KZ: Kazakhstan, ID: Indonesia, MY: Malaysia, MD: Madagascar.

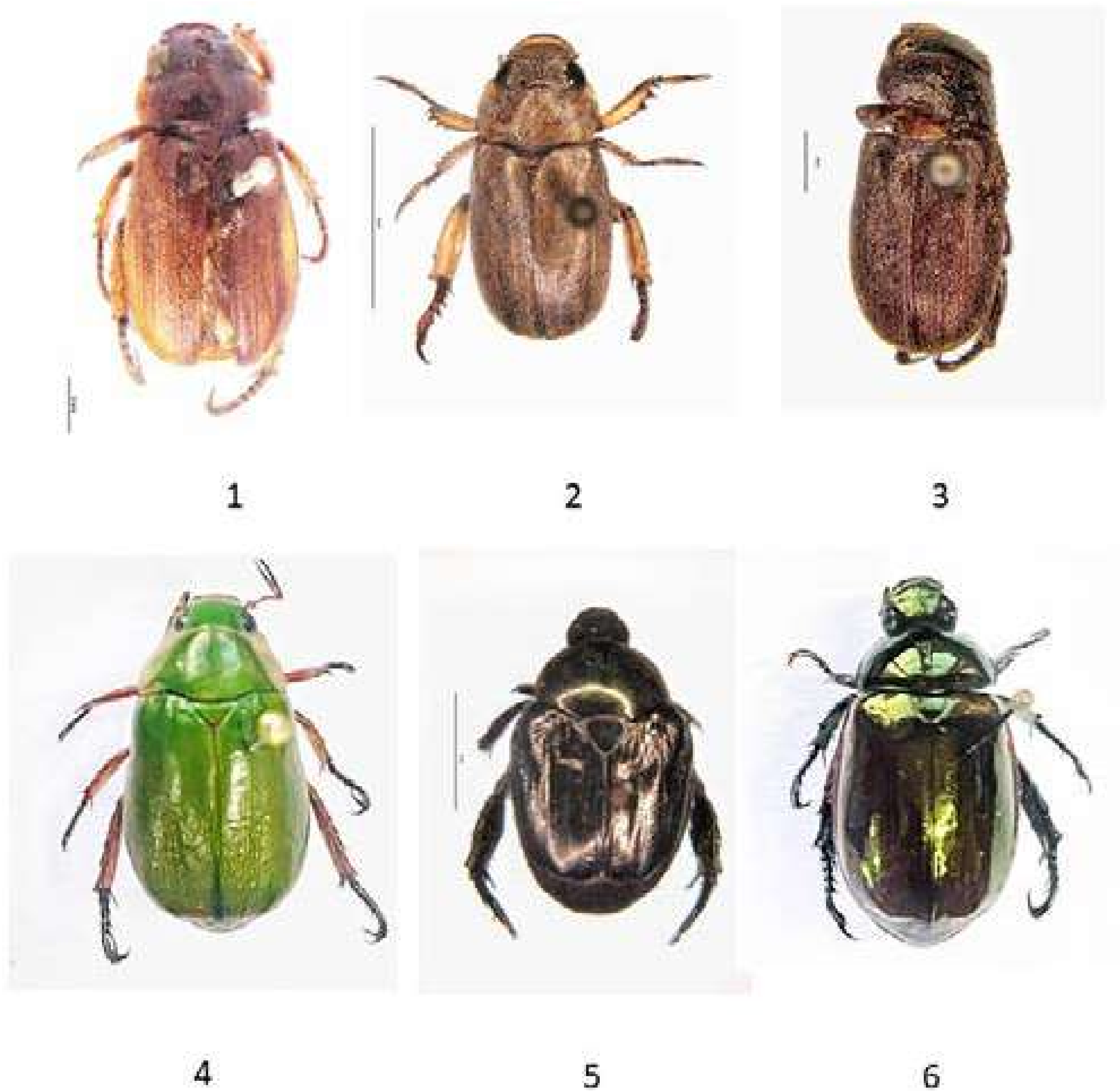

Fig (1-4) 1. *Adoretus (Adoretus) versutus* Harold, 1869 **2.** *Adoretus simplex* Sharp, 1878

3. *Adoretus (Adoretus) duvauceli* Blanchard, 1851 **4.** *Mimela passerinii passerinii* Hope, 1842 **5.** *Popillia cyanea* Hope, 1831 **6.** *Anomala rufiventris* Kollar & Redtenbacher, 1848

Acknowledgement

The authors are thankful to Dr. Dhriti Banerjee, Director Zoological Survey of India for providing all the necessary facilities and encouragement.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Studies on the prevalence of endoparasitic Protozoans of Oligochaetes in the Bankura district of West Bengal

Moumita Sinha and Biplob Kumar Modak*
Department of Zoology, Sidho - Kanho - Birsha University, Purulia
Pin: 723104, West Bengal, India

Abstract

Endoparasitic aseptate gregarines are commonly found in Annelida, particularly in seminal vesicles of earthworms. An extensive survey has been carried out for aseptate gregarine in earthworms in the Bankura district during the period of January 2022- December 2022. Different genera of host earthworms were studied for occurrence of aseptate gregarines throughout the year. To study the morphology, prevalence and life cycle of these parasites, earthworms were dissected and a small amount of seminal fluid was drawn out on the slide. Then they are fixed in Schaudin's fixative, stained in Heidenhain's hematoxylin and studied under the light microscope. During the survey four genera viz. *Monocystis* Stein, 1848, *Nematocystis* Hesse, 1909, *Stomatophora* Drzhevetskii, 1907, *Apolocystis* Cognetti de Martiis, 1923 are recorded but the prevalence of *Monocystis* Stein, 1848 and *Stomatophora* Drzhevetskii 1907, are much higher than the others. These endoparasites reproduce sexually and exhibit mainly three distinct stages viz. trophozoite, gametocyst and oocyst in their lifecycle.

Keywords: Endoparasite, *Monocystis*, Earthworm, Oligochaetes, Bankura

Introduction

Gregarines are mainly a diverse group of protozoan parasites belonging to Phylum Apicomplexa, Order Eugregarinorida (Leger, 1900). All the members of this phylum are parasitic and they are restricted to wide range of invertebrates. Gregarines often not studied because they do not cause any harm to the vertebrates and do not even causes any serious harm to invertebrate hosts also. They exist as two form aseptate and septate. Aseptate gregarines infect the oligochaete host and are characterized by undivided septum while septate forms tend to harbour mainly arthropods and molluscs and bear septum. Grasse (1935) recognized gregarines as a taxon. Under this taxon, currently 250 genera and approximately 1650 species of aseptate forms are known (Levine, 1976, 1977 and 1988; Clopton, 2000; Hausmann *et al.*, 2003). Though aseptate gregarines have been reported from various regions of world, even in India, but very limited work has been reported in India including West Bengal on these endoparasitic gregarines (Bandyopadhyay *et al.*, 2004). Therefore it is very much useful to study further regarding this matter.

A preliminary biodiversity survey of aseptate gregarines from earthworm was carried out in different regions of Bankura district of West Bengal during the period of January 2022- December 2022.

Materials and Methods

Study Area

The study area is located at different fields of Bankura district of the state West Bengal. Earthworms were collected from different locations namely Christian college campus (23.2381°N, 87.0593°E), Junbedia gram (23.2566°N, 87.0546°E), Chhatna (23.3121°N, 86.9664°E), Susunia (23.4085°N, 86.97413°E), Fulkushma (22.7112°N, 86.86348°E), Bheduasole (23.11476°N, 86.9065°E) regions.

*Author for correspondence : bkmodak09@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Study Period

The study was carried out for a period of one year (January 2022 to December 2022). For better prevalence study, total study period was divided into four seasons namely summer, monsoon, post-monsoon and winter. Host earthworms were collected during early morning.

Collection Methods

Collection of earthworms was done mainly by digging up the soil with a soil digger and then hand sorting method. They were collected from various ecological niches. After collecting, earthworms were kept in a soil filled plastic bucket and taken to the parasitology laboratory alive. Some of the collected earthworms were dissected while in alive condition. Removal of seminal vesicle was done carefully. On a clean glass, these were then put in with a drop of 0.6% NaCl solution. After that, a little amount of seminal fluid was taken from it and then placed on a slide. Then it was covered with a cover slip for examination of living protozoan under phase contrast microscope. The semi-dried contents of seminal vesicles were fixed in Schaudin's fluid (20 mins). The smears were then kept in 70% ethyl alcohol following fixation, in order to remove mercuric chloride. The slides were kept in distilled water after passing through a descending series of graded alcohols (for 5 minutes each). These were transferred to a 3% iron alum solution (for overnight) and staining was done with Heidenhain's haematoxylin (for 20 mins). Then transferred to 1% iron alum solution for differentiation. After a thorough washing, slides were dehydrated in ascending series of graded alcohol, then it is cleared in xylene and finally mounted in DPX. Photomicrographs were taken using ZEISS DIC microscope (Axiocam 506 mono). The preservation of earthworm was done within a glass vial with 5% formalin solution. They were identified according to earthworm identification keys of Gates (1972) and Julka (1988). Measurements were taken with the help of a calibrated ocular micrometer. The prevalence is expressed in percentage and is calculated by total number of infected earthworms divided by total number of host earthworms examined (Srivastava, 1980).

Prevalence of infection = (Total number of infected earthworms / total number of host earthworms examined) x 100.

Systematic Account

Phylum APICOMPLEXA Levine, 1988

Class SPOROZOA Leuckart, 1879

Order EUGREGARINIDA Leger, 1900

Family MONOCYSTIDAE Butschli, 1882

Subfamily MONOCYSTINAE Bhatia, 1930

Genus *Monocystis* Stein, 1848

Nematocystis Hesse, 1909

Stomatophora Drzhevetskii, 1907

Apolocystis Cognetti de Martiis, 1923

Results and Discussion

During the survey period four aseptate gregarines such as *Monocystis* Stein,1848; *Nematocystis* Hesse, 1909; *Stomatophora* Drzhevetskii, 1907; *Apolocystis* Cognetti de Martiis, 1923 are recorded from different genera of host earthworm. For better prevalency study, the survey period was divided according to seasonal variation like: Summer period (March-May); Monsoon period (June-Sept.); Post-monsoon period (Oct-Nov); Winter period (Dec-Feb). Altogether 169 earthworms out of 264 were found to be infected with aseptate gregarines, i.e., 64.02% earthworms were infected during survey time. The percentage of infection of earthworms during different seasons were also calculated (Table 2). The rate of infection of all host genera was recorded as very high during Monsoon and Post-monsoon period than in comparison with summer and winter period (Fig 1). Out of four aseptate gregarine genera, *Monocystis* Stein, 1848 and *Stomatophora* Drzhevetskii, 1907 were more prevalent than the others. The detailed percentages of infection were given in Table 1.

Description

Description of these endoparasites and photomicrographs that were taken during survey period are given below.

GENUS *Monocystis* Stein, 1848

This is the most prevalent endoparasite of Oligochaetes. The members of the genus *Monocystis* Stein, 1848 are characterized by trophozoites variable in form, from spherical to cylindrical, slightly swollen at median portion, solitary and motile, late syzygy in lifecycle; spores biconical, being symmetrical. Some of them are characterized with a mucron at the anterior pole. Trophozoites measures in average 75.0-110.2 µm x 46.0-75.72µm. Spores measure 22.5-25 x 8-10 µ.

GENUS *Stomatophora* Drzhevetskii, 1907

The characters of genus *Stomatophora* Drzhevetskii, 1907, as given by Levine (1988); Trophozoites spherical or ovoid; anterior end sucker-like with a central mucron (for adhesion) and radiating ribs; spores biconical, sometimes assembled into a chain. The main characteristic feature is the possession of sucker, which is an epimerite structure situated at anterior end. Gamont measures 39.32-97.2 µm in diameter. Gametocyst measures 67.88-90.1 µm x 38.74-54.37 µm. Oocyst measuring 10.0-12.1 µm x 6.0-7.0 µm.

GENUS *Nematocystis* Hesse, 1909

The characters of genus *Nematocystis* Hesse, 1909, as given by Levine (1977); Gamonts elongated, cylindrical and shaped like a nematode, solitary. In this genus likewise the trophozoite, nucleus also elongated and nuclear length is proportional to trophozoite length. Oocyst biconical.

GENUS *Apolocystis* Cognetti de Martiis, 1923

Trophozoites spherical, without principal axis marked by presence of any special peripheral organ, solitary, spore biconical. Mucron indistinct. Large zymogen granules for food storage often observed within cytoplasm which are evenly distributed.

Conclusion

In the present survey, it was observed that the prevalence of aseptate gregarines in the monsoon and post-monsoon season, were very high in comparison with summer and winter. It may be due to the maximum availability of mature earthworms in this time. The sampling sites were chosen based on the high appearance of surface vermicast present on soil. Gregarine genera *Stomatophora* Drzhevetskii, 1907 was generally found in earthworm belonging to genus *Metaphire*; and *Monocystis* Stein, 1848 was found from both the earthworm genera *Eutyphoeus* and *Metaphire*. Genus *Nematocystis* Hesse, 1909 found in earthworm *Eutyphoeus*. Comparatively rare gregarine *Apolocystis* Cognetti de Martiis, 1923 was recorded from *Perionyx* sp. Same host of different geographic area may harbour different gregarine genera or species. Intensity of infections also varies seasonally. In West Bengal, research on aseptate gregarines mostly restricted on discovery of new species (Sarkar and Bandyopadhyay, 2013; Bandyopadhyay *et al.*, 2018; Kundu and Bandyopadhyay, 2019). Till now it is hard to find work on prevalence of aseptate gregarine in any geographical region of West Bengal. Practically gregarines are interesting for their significant diversity among invertebrate hosts. Since India belongs to tropical region and covers a vast geographical area, so, it is expected that the species diversity will be proportionally high in comparison to other parts of the world. So, it may be suggested that further study regarding this endoparasites must be required for gaining comprehensive knowledge about the diversity and seasonal prevalence of these aseptate gregarines in West Bengal as well as in India.

Tables and Figures

Table 1. Percentage of infection (%) of aseptate gregarines in different genera of earthworms from Bankura district during the survey period Jan 2022-Dec 2022

Host Earthworms (Family)	Aseptate gregarines Found	No of earthworm dissected and infected with gregarine genera in different seasons during Jan 22-Dec 22								Percentage of infection (%) in different seasons during Jan 22-Dec 22			
		S		M		PM		W		S %	M %	PM %	W %
		E	I	E	I	E	I	E	I				
Metaphire Sims & Easton, 1972 (Megascolecidae)	*Monocystis* Stein, 1848	14	05	66	26	32	14	07	00	35.71	39.39	43.75	-
	Stomatophora Drzhevetskii, 1907	14	04	66	30	32	12	07	02	28.57	45.45	37.50	28.57

Host Earthworms (Family)	Aseptate gregarines Found	No of earthworm dissected and infected with gregarine genera in different seasons during Jan 22-Dec 22								Percentage of infection (%) in different seasons during Jan 22-Dec 22			
		S		M		PM		W		S %	M %	PM %	W %
		E	I	E	I	E	I	E	I				
Eutyphoeus Michaelsen, 1900 (Octochaetidae)	*Monocystis* Stein, 1848	22	07	48	23	26	12	09	01	31.82	47.92	46.15	11.11
	Nematocystis Hesse, 1909	22	04	48	17	26	07	09	00	18.18	35.42	26.92	-
Perionyx Perrier, 1872 (Megascolecidae)	*Apolocystis* Cognetti de Martiis, 1923	06	00	19	04	09	01	06	00	-	21.05	11.11	-

E=Examined, I=Infected, S= Summer, M=Monsoon, PM= Post-monsoon, W= Winter

Table 2. Prevalence of aseptate gregarines in earthworms in Bankura district in different seasons

Total no of examined earthworm of all genera	Season wise no of examined earthworm				Aseptate gregarines found	Season wise no of infected earthworms with gregarines (Prevalence in %)			
	S	M	PM	W		S	M	PM	W
264	42	133	67	22	*Monocystis* Stein, 1848	12 (28.57)	49 (36.84)	26 (38.81)	01 (4.54)
					Stomatophora Drzhevetskii, 1907	04 (9.52)	30 (22.56)	12 (17.91)	02 (9.09)
					Nematocystis Hesse, 1909	04 (9.52)	17 (12.78)	07 (10.45)	00
					Apolocystis Cognetti de Martiis, 1923	00	04 (3.00)	01 (1.49)	00

S= Summer, M=Monsoon, PM= Post-monsoon, W= Winter

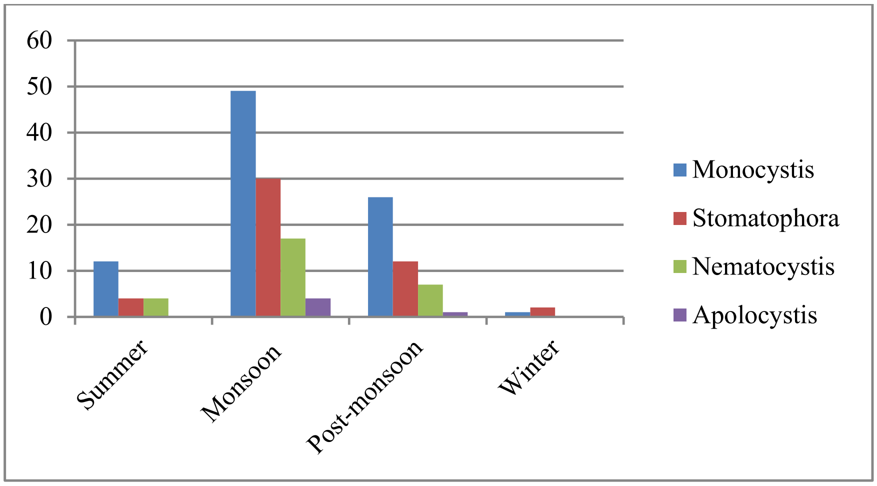

Figure 1. Seasonal fluctuation of aseptate gregarines infection in oligochaete earthworms during survey period Jan 22-Dec 22

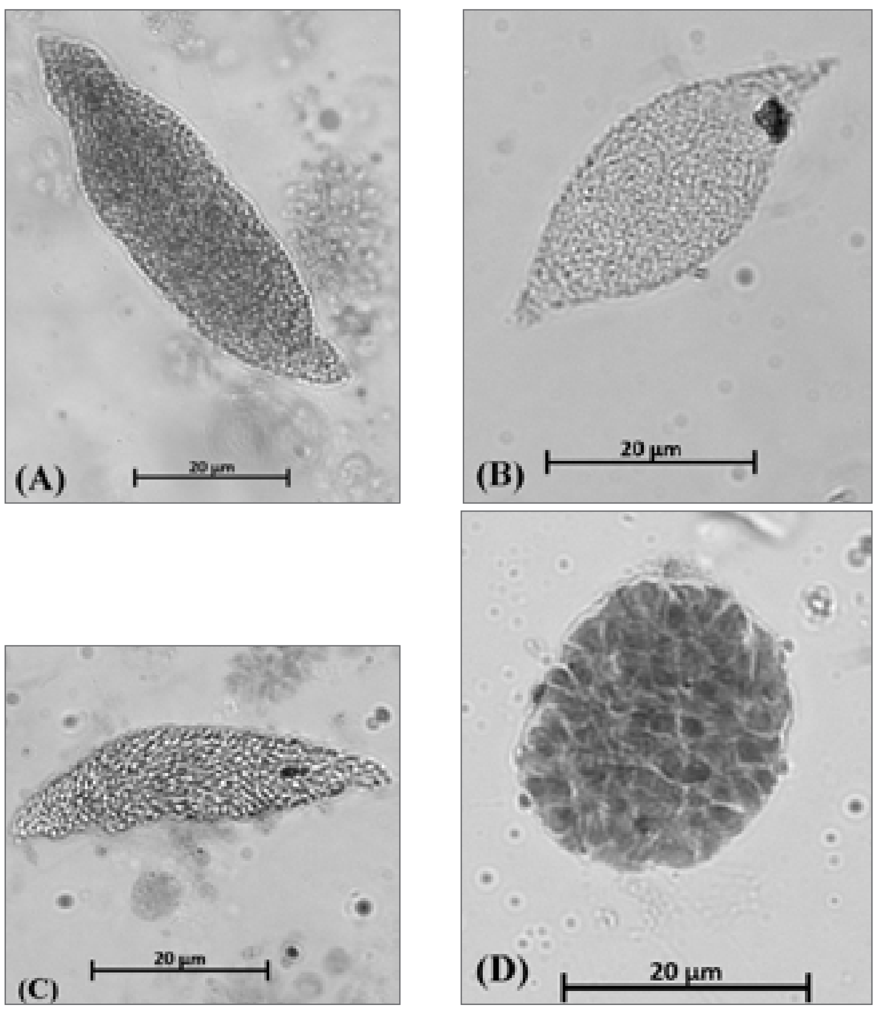

Figure 2. Photomicrographs of different stages of life history of *Monocystis* Stein, 1848 A-C. Trophozoites. D. Mature gametocyst filled with sporocyst. Scale bars 20µm (A-D)

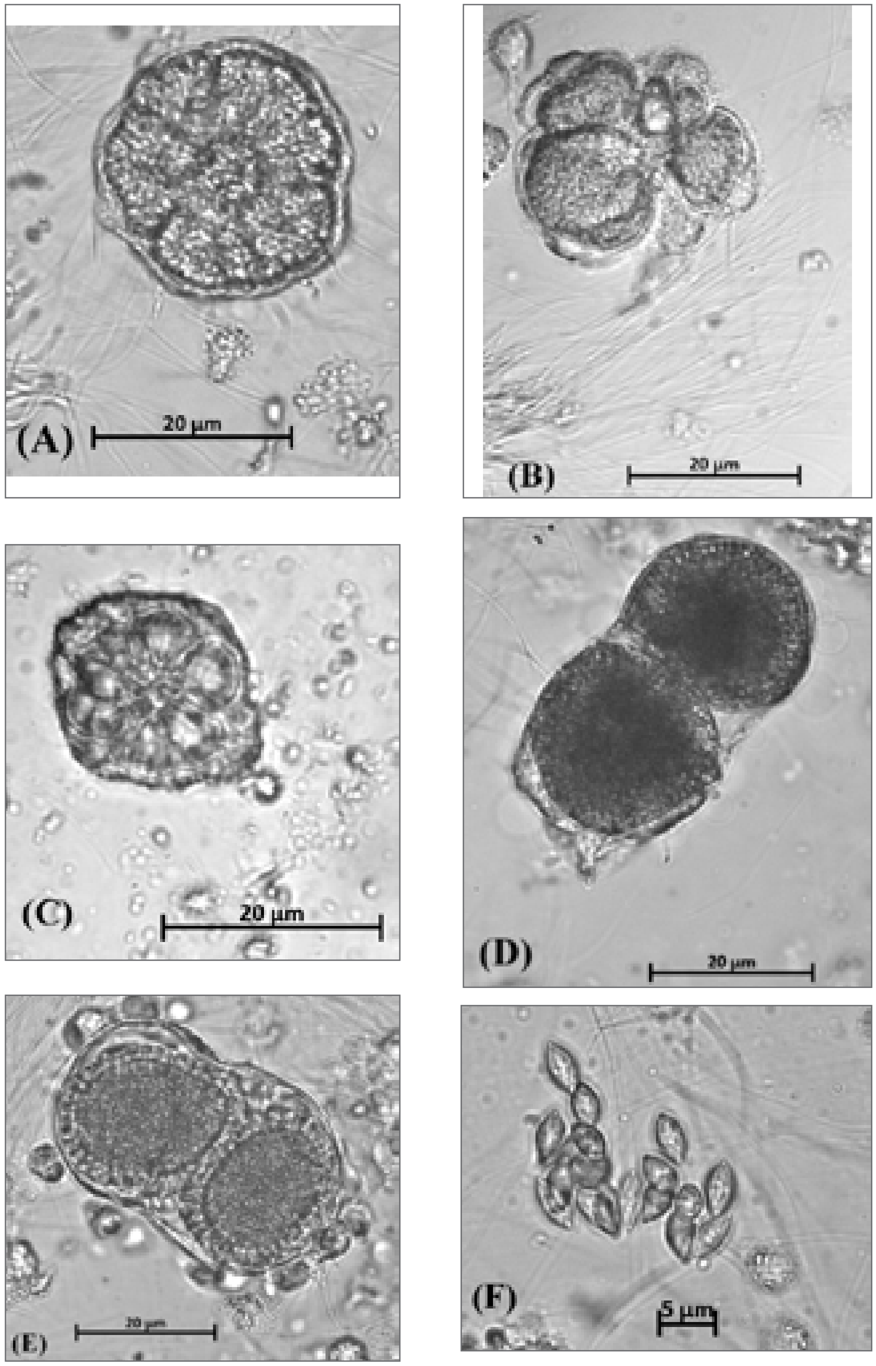

Figure 3. Photomicrographs of different stages of life history of *Stomatophora* Drzhevetskii, 1907**,** A-C. Trophozoites. D-E.Gametocysts, F.Oocyst. Scale bars 20µm (A-E), 5 µm (F)

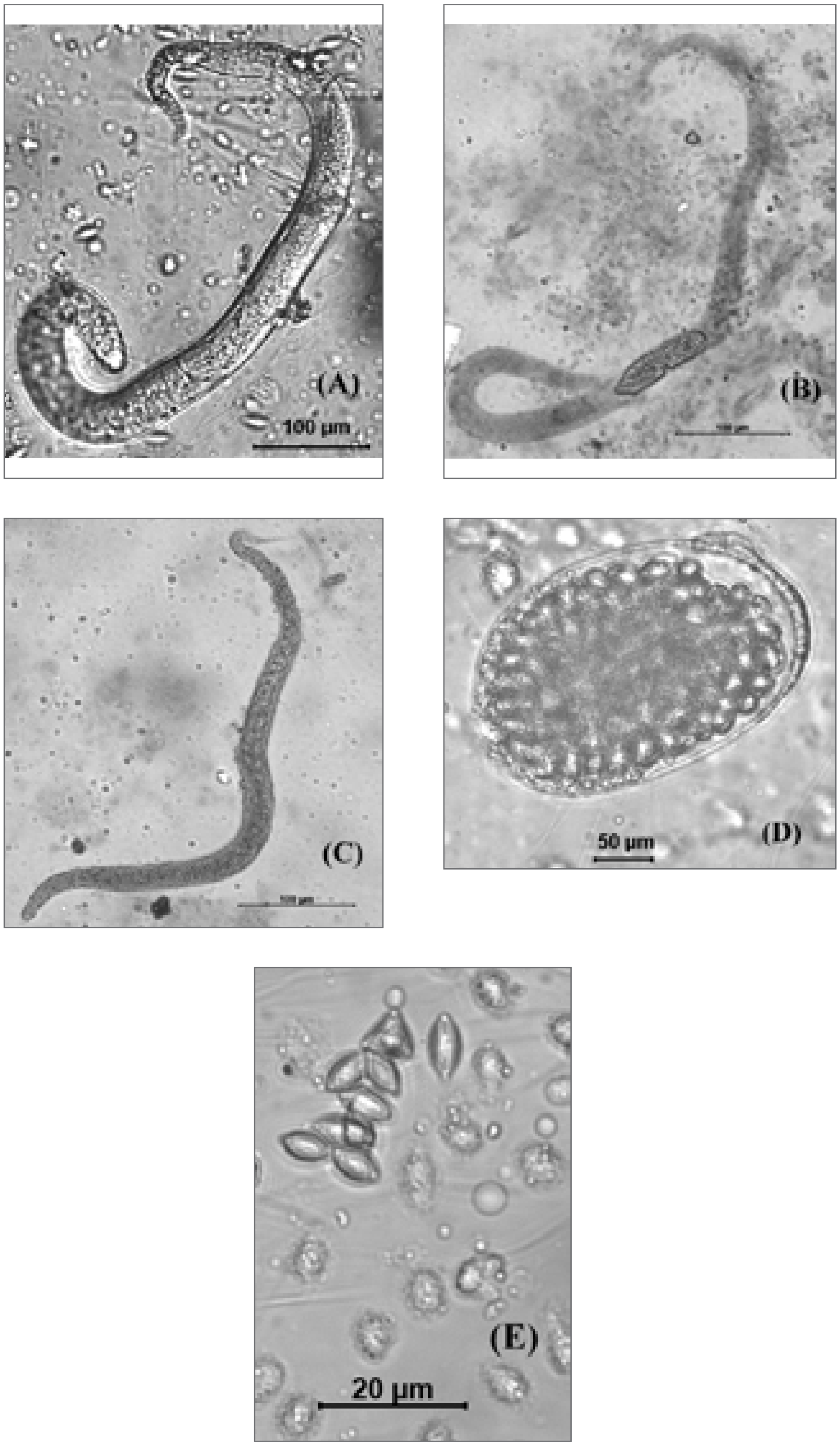

Figure 4. Photomicrographs of different stages of life history of *Nematocystis* Hesse, 1909, A-C. Trophozoites. D.Gametocyst, E.Oocyst. Scale bars 100µm (A-C), 50 µm (D), 20 µm (E)

Acknowledgements

First author would like to thank the Department of Zoology of Sidho-Kanho-Birsha University, Purulia for extending their permission to do the work. Corresponding author is thankful to authorities of DST- FIST [No. SR/FST-LSI/2018/173(c) for the infrastructural support.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

An insight into the taxonomy and diversity of pollinating Hoverflies (Insecta: Diptera: Syrphidae) from dry deciduous landscape of West Bengal

Jayita Sengupta, Arka Mukherjee*, Atanu Naskar and Dhriti Banerjee**

Diptera Section, Zoological Survey of India
M-Block, New Alipore, Kolkata-700053
**Presenting author mail id: mukherjee.arka03@gmail.com*

Abstract

Alternative uses of land use pattern have caused declination in pollinator globally. The current pollinator catastrophe anomaly affects food scarcity, magnifies problems with hidden hunger, erodes ecological resilience and threatens ecosystems. Despite visiting at least 72% of global food crops, dipteran pollinators always have received much less research attention than hymenopterans. Hoverflies (Insecta:Diptera: Syrphidae) being one of the largest pollinator group from the Dipteran lineage is worthy of more research priorities. The study on this group of flies represents a huge research gap, particularly from the plain land ecosystems of West Bengal. According to the report, the ISHI score (India State Hunger Index) is 20.97 which is atan alarming level. The current study includes a detailed systematics & diversity analysis of this pollinator from the dry deciduous landscape (Sonamukhi Forest) from the state. For the current study purpose, pollinators have been collected by net sweeping & by using different traps over 3 years. The detailed study includes 20 species under 16 genera over two subfamilies where Syrphinae (53%) are more prevalent than Eristalinae (47%). The most prevalent species is found to be *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) whereas *Sphaerophoria indiana* Bigot, 1884 is rarely present in all the seasons. On the other hand, the results of the diversity analysis study show species diversity to be at its highest during the Pre-Monsoon season (H = 4.261) and its lowest during the Monsoon season (H=1.12). Further detailed studies at periodic interval are necessary for more accurate database development and for ecosystem monitoring.

Keywords: Pollinator, Hoverfly, Food security, Diversity, Ecosystem

Introduction

The current valuation of insect pollination globally is approximately $577 billion (Decourtye *et al.*2019), unfortunately it is still underrated (Chain *et al.*2019). Over the past few years, a dramatic decline in the ratio of insects to insect pollinators has occurred across the globe (Rhodes, 2019). Syrphids are one of the most widespread groups of flies with considerable potentiality as the first liner pollinator of the ecosystem (Gilbert, 1985). Particularly in specific landscape, where the hymenopteran pollination proficiency is facing a high risk of exhaustion due to their dependency on endothermically generated energy (Milicic *et al*, 2017). Such ecosystem thus have an immediate urgency of the introduction of a strong alternate line of pollinators. Who can act strongly to conserve the network. Here lies the utmost importance of conservation of the second line pollinators like hoverflies. Although hover flies have been recognized for their role in increasing and stabilizing crop pollination services in very recent times (Garibaldi *et al* 2011). But are still struggling for their identity as principal pollinators (Jauker *et al.*2019), pollination services rendered by all of them thus should be properly assessed and addressed (Winder, 1978).

**Author for correspondence : atanu.diptera@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

The syrphid adults feed on nectar and pollens whereas the larvae are aphidophagous (Rothery, 1981).Thus making these groups a twofold beneficial fly group (Woodcock *et al.* 2014). Accurate species identification is the first and fundamental step required to generate other biological information on this emerging pollinators.

In the current work, an attempt is made encompassing taxonomy and ecological diversity study across Sonamukhi protected forest area of Bankura district. It represents unique geographical features for its location as an Ecotone which houses a unique pattern in its annual climatic scenario, as well as in vegetation & topographical fashion. the data on Syrphidae from this region was not updated and sufficient (Fabricius 1787, Brunetti: 1907), because although stray survey had been done over this long time by different dipterists altogether consolidated information regarding Syrphid fauna was not available from this region. Despite of vast distribution of hoverflies still past the British era much major contribution was lacking in the field of syrphid fauna from dry deciduous forest ecosystems like the Sonamukhi forest. This study is therefore the first exhaustive study of syrphid fauna from the Sonamukhi protected forest area and thereby it carries immense importance as it leads to the discovery of biodiversity and also depicts the extensive species richness of syrphid fauna from this area. Our current study includes **20** species of syrphid under **16** genera from this protected area. This study depicts the updated taxonomic account of hoverflies from this protected forest area. Furthermore, Seasonal changes in dipteran abundance in the dry deciduous forest of Sonamukhi Protected Area, Bankura, West Bengal has been studied over three years w.e.f from November 2017 to March 2020. Population abundance, species composition and community structure were investigated over these 3 yearlong study periods. Out of the total reported species from our collected data, 47% of the species belong to Eristalinae subfamily and 53% to the Syrphinae subfamily. The current study was intended to determine: the year-long variations in abundance and composition of hoverfly species; the similarity of resources use among different hoverfly species; the relationship between abundance and species composition and abiotic (temperature and rainfall) and biotic factors. For such a comprehensive assessment, the diversity of this pollinating Diptera has been studied here extensively for three years. Such an attempt and their outcome thus further validate their emergence as an alternative leading pollinator of present and future time, an insurance against the rising hunger index from this dry deciduous landscape of West Bengal.

As for the study we have chosen Sonamukhi protected forest area of Bankura district. It represents unique geographical features for its location as an Ecotone which houses a unique pattern in its annual climatic scenario, as well as in vegetation & topographical fashion. the data on Syrphidae from this region was not updated and sufficient (Fabricius 1787, Brunetti: 1907), because although stray survey had been done over this long time by different dipterists altogether consolidated information regarding Syrphid fauna was not available from this region. Despite of vast distribution of hoverflies still past the British era much major contribution was lacking in the field of syrphid fauna from dry deciduous forest ecosystems like the Sonamukhi forest. This study is therefore the first exhaustive study of syrphid fauna from the Sonamukhi protected forest area and thereby it carries immense importance as it leads to the discovery of biodiversity and also depicts the extensive species richness of syrphid fauna from this area. Our current study includes **20** species of syrphid under **16** genera from this protected area.

This study thus includes a thorough out study of Syrphidae fauna from the Sonamukhi Protected Forest area, as updated knowledge on this important group of pollinators from this region is essential for further and future studies. This study depicts the updated taxonomic account of hoverflies from this protected forest area. Furthermore, Seasonal changes in dipteran abundance in the dry deciduous forest of Sonamukhi Protected Area, Bankura, West Bengal has been studied over three years w.e.f from November 2017 to March 2020. Population abundance, species composition and community structure were investigated over these 3 yearlong study periods. Out of the total reported species from our collected data, 47% of the species belong to Eristalinae subfamily and 53% to the Syrphinae subfamily. The current study was intended to determine: the year-long variations in abundance and composition of hoverfly species; the similarity of resources use among different hoverfly species; the relationship between abundance and species composition and abiotic (temperature and rainfall) and biotic factors.

Materials and Methods

i. **Study area:** Our study area for survey was the Sonamukhi Protected Forest area, which is located in the Sonamukhi Block of Bankura district, West Bengal. This proposed area was surveyed extensively in the period of three years (2017-2020) covering all three seasons of pre-monsoon, Monsoon and post-monsoon. Sonamukhi protected forest, Bankura holds one of the best quality Sal forests in West Bengal. The soil profile of this forest area is typically characterised by red-lateritic soil. The forest is mainly dominated by medium-density Sal trees. The survey was done thoroughly in Sonamukhi protected forest and its adjacent villages to get a complete scenario of pollinating hoverflies' diversity in this protected forest area. The places that have been surveyed mostly are namely: Sonamukhi forest area, Churamanipur, Muslo, Balarampur, Patharmura, Krishtobati, Kalyanpur, Pachal, Lokesol, Naphardanga, Palsora, Bandarhati, Hamirhati, Kasdihi beat area, Naphardanga, Lokesol, Inkata, Bhulara, Manik Bazar. The landscape and vegetation pattern of some of these areas where collection has been done extensively has been discussed shortly. Altogether we have selected 10 study sites for collection. The collection has been done through net sweepning and using different traps including Pan traps , Malaise trap etc. The collected samples are narcotized by using ethyl acetate and stored for further study in insect envelopes in the field. This envelope is specialised dehydration envelope which helps to dehydrate the collected samples. The specimens were later carried back to the laboratory, where they are kept in desiccator for rehydration purposes and then mounted on insect pins and stored in insect cabinets.

Identification of the adults followed the keys of Thomson (2013), Vockeroth (1992) and Brunetti (1923) keeping in mind the recent nomenclatural changes (Pape and Thompson, 2016; Pape and Evenhuis, N.L.2010). All the identified specimens were deposited in the designated repository of National Zoological Collection, Diptera section, Zoological Survey of India, Kolkata. The graphical representations here were made by using Microsoft Excel 2013. The GPS data has been taken by using Garmin GPS 72H reader. The photograph of habitus and insect body and parts were taken by using Leica Microscope M205A, where 0.32x Acro lens was used for habitus photography and PLANAPO 1.0X lens was used for the photography of body parts.

ii. **Ecological diversity calculation:** We have used Microsoft Excel 2016 for statistical analysis and graph preparation.

- **Species diversity:** It is defined as the number of species and abundance of each species that live in a particular location.
- **Species richness**: The number of species in a certain location is called the species richness of that particular area.
- **Abundance:** It is defined as the number of individuals of each species.
- **Evenness:** Evenness is a measure of the relative abundance of the different species making up the richness of an area.
- **Simpson's Index of Diversity:** Simpson's Diversity Index is a measure of diversity which takes into account both richness and evenness. Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species. The value of D ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. **D=1- [Σn (n-1)/N(N-1)]**

  Where n = the total number of organisms of a particular species, N = the total number of organisms of all species.
- **Shannon Diversity Index (H):** High values of H would be representative of more diverse communities. If the species are evenly distributed then the H value would be high. So the H value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community. H = Σ - (Pi * ln Pi), Where, H = the Shannon diversity index, Pi = fraction of the entire population made up of species i, S = numbers of species encountered, Σ = sum from species 1 to species S
- **Menhinick's richness index** (I_{Mn})**:** Another index of measuring species richness. The ratio of the number of taxa to the square root of the sample size. I_{Mn} =S/

  where S= Number of species, N= total number of individuals.
- **Margalef's richness index:** An index measuring species richness *(S-1)*/ln*(n)*, where *S* is the number of taxa, and *n* is the total number of individuals.
- **Berger-Parker index of dominance (d):** It is an index of dominance, simply the number of individuals in the dominant taxon relative to n. d=N_{max}/N, where N_{max}= no of individual from the most abundant spe-

cies, N= total number of individuals.

- **Relative abundance (p_i):** It is the per cent composition of an organism of a particular kind relative to the total number of organisms in the area.

  Pi is denoted as the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: n_i/N where n_i is the number of individuals of particular species; N= total number of individuals.

Result

A. Taxonomic Account

Systematic list of taxa (New record from the state is marked with double asterisk marks)

Order DIPTERA

Suborder BRACHYCERA Macquart, 1834

Clade ASCHIZA Becher, 1882

Superfamily SYRPHOIDEA Latreille, 1802

Family SYRPHIDAE Latreille, 1802

Subfamily SYRPHINAE Latreille, 1802

Tribe Bacchini Bigot, 1883

I. Genus ***Baccha*** Fabricius, 1805

1. ***Baccha maculate*** Walker, 1852

II. Genus ***Melanostoma*** Schiner, 1860

2. ***Melanostoma orientale*** (Wiedemann, 1824)

Tribe Paragini Glumac, 1961

III. Genus ***Paragus*** Latreille, 1804

SubGenus *Paragus* Latreille, 1804

3. ***Paragus (Paragus) serratus*** (Fabricius, 1805)

Tribe Syrphini Latreille, 1802

IV. Genus ***Asarkina*** Macquart, 1842

SubGenus ***Asarkina*** Macquart, 1842

4. ***Asarkina*** (***Asarkina***) ***ericetorum*** (Fabricius, 1781)

V. Genus ***Dasysyrphus***Enderlein, 1938

5. ***Dasysyrphus orsua***(Walker, 1852)

VI. Genus ***Dideopsis*** Matsumura 1917

6. ***Dideopsis aegrota*** (Fabricius, 1805)

VII. Genus ***Episyrphus*** Matsumura & Adachi, 1917

SubGenus ***Episyrphus*** Matsumura & Adachi, 1917

7. ***Episyrphus*** (***Episyrphus***) ***balteatus*** (De Geer, 1776)

VIII. Genus ***Eupeodes*** Osten Sacken, 1877

SubGenus ***Macrosyrphus*** Matsumura, 1917

8. ***Eupeodes*** (***Macrosyrphus***) ***confrater*** (Wiedemann, 1830)

IX. Genus ***Ischiodon*** Sack, 1913

9. ***Ischiodon scutellaris***(Fabricius, 1805)

X. Genus ***Sphaerophoria*** Lepeletier & Serville, 1828

SubGenus ***Sphaerophoria*** Wiedemann, 1830

10. ***Sphaerophoria (Sphaerophoria scripta) Indiana*** Bigot, 1884

Subfamily ERISTALINAE (Newman, 1834)

Tribe EristaliniNewman, 1834

XI. Genus ***Eristalinus*** Rondani, 1845

Subgenus ***Eristalinus*** Rondani, 1845

11. ***Eristalinus*** (***Eristalinus***) ***arvorum*** (Fabricius, 1787)

12. ***Eristalinus (Eristalinus) tabanoides*** (Jaennicke, 1867)**

Subgenus ***Eristalode s***Mik, 1897

XII. Genus ***Eristalis*** Latreille, 1804

Subgenus ***Eoseristalis***Kanervo, 1938

13. ***Eristalis*** (***Eoseristalis***) ***cerealis***Fabricius, 1805

XIII. Genus ***Phytomia*** Guerin-Meneville, 1833

Subgenus ***Phytomia*** Guerin-Meneville, 1833

14. ***Phytomia (Phytomia) errans*** (Fabricius, 1787)

Subgenus ***Dolichmerus*** Macquart, 1850

15. ***Phytomia*** (***Dolichomerus***) ***crassa*** (Fabricius, 1787)

XIV. Genus ***Mesembrius*** Rondani, 1857

Subgenus ***Mesembrius*** Rondani, 1857

16. ***Mesembrius (Mesembrius) bengalensis***

(Wiedemann, 1819)

17. ***Mesembrius*** **(*Mesembrius*)** ***quadrivittatus*** (Wiedemann, 1819)

Tribe Merodontini Edwards, 1915

XV. Genus ***Eumerus*** Meigen, 1822

18. ***Eumerus aeneithorax*** Brunetti, 1915

19. ***Eumerus aurifrons*** (Wiedemann, 1824)

Tribe Milesiini (Rondani, 1845)

XVI. Genus ***Syritta*** Lepeletier & Serville, 1828

20. ***Syritta indica*** (Wiedemann, 1824)

Subfamily SYRPHINI

Tribe: Bachini

1. ***Baccha maculata*** Walker, 1852

1852.*Baccha maculata* Walker, *Insecta Saundersiana..***1**: 223.

Type-locality: East Indies.

Material examined: 3♀♀ 5♂♂Chachanpur agricultural field,Bankura district, 23° 17 '54.9"N, 86°53'55.3"E, 110 Mt.21.xi.2017, coll. D.Banerjee& party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Himachal Pradesh, Uttar Pradesh.

Elsewhere: Borneo, Formosa, Java, Japan; Korea, Malaya, Philippines, Sumatra.

I. **Genus *Melanostoma*** Schiner, 1860

1860, *Melanostoma* Schiner, *Wien.Ent.Monats*, **4**:213

Type species: *Musca mellina* Linnaeus

2. ***Melanostoma orientale*** Wiedemann, 1824

1824. *Syrphus orientale* Wiedemann. *Analecta. Ent*: 36.

Type-locality: "Ind. Or."

Material examined:5♀♀ Churamanipur forest village, Bankura district, 23°19'59.3"N, 86°55'55.1"E, 144 Mt, 26.ii.2017, 4♀♀ Churamanipur forest village, Bankura district, 23°19'59.3"N, 86°55'55.1"E, 144 Mt, 26.vi.2018, coll. D.Banerjee& party.12♂♂ Chachanpur river belt, 23°17'48.4"N, 86°54'10.9"E, 109 Mt, 21.xi.2017, coll. D.Banerjee& party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Arunachal Pradesh, Himachal Pradesh, J & K, Karnataka, Meghalaya, Sikkim, T.N, Tripura, Uttar Pradesh.

Elsewhere: Bhutan, Nepal, Pakistan, Sri Lanka, and other parts of oriental region and Palaearctic region.

Tribe Syrphini

II. Genus ***Asarkina*** Macquart 1834

1842. *Asarkina* Macquart, *Dipt. Exot.***2** (2): 77(137)

Type species: *Syrphus rostrata* Wiedemann.

Subgenus ***Asarkina*** Macquart, 1842

3. ***Asarkina (Asarkina) ericetorum*** (Fabricius, 1781)

1781. *Syrphus ericetorum* Fabricius, *Spec. Insect. ,***2**: 425.

=*Asarkina formosae* Bezzi, 1908

=*Asarkina typical* Bezzi, 1908

=*Asarkina usambarensis* Bezzi, 1908

=*Didea diaphana* Doleschall, 1857

=*Didea macquarti* Doleschall, 1857

=*Syrphus incisuralis* Macquart, 1855

Type-locality: Africa..

Material examined: 3♂♂ 2♀♀ Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 116 Mt., 26.ii.2020, coll. D. Banerjee & party. 18♀♀Sonamukhi protected forest area, Bankura district,23°17'04.7"N, 87°22'20.2"E, 78 Mt., 22.xi.2017, coll. D.Banerjee & party.

***Distribution*:** India:West Bengal (Bankura: Sonamukhi Protected Forest Area), Arunachal Pradesh, Assam, Chandigarh, Gujarat, Himachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh.

Elsewhere: Widely distributed through Oriental region.; Afrotropical region.; Australian region.

III. Genus ***Dasysyrphus*** Enderlein 1938

1938. *Dasysyrphus* Enderlein*Sber. Ges. Naturf. Freunde Berl.***1937**:208

Type species: *Scaeva albostriata* Fallen

4. ***Dasysyrphus orsua*** (Walker, 1852)

1852. *Syrphus orsua* Walker, *Insecta. Saund.***1**:231

=*Syrphus brunettii* Herve-Bazin, 1924

Type-locality: East Indies.

Material examined: 2♂♂Kalayanpur, Bankura district, 23°14'12.1"N, 86°51'19.1"E, 123 Mt., 28.ii.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Himachal Pradesh, Jammu & Kashmir, Uttarakhand.

Elsewhere: Nepal, Sri Lanka, Sumatra..

IV. Genus ***Dideopsis*** **Matsumura 1917**

1917. *Dideopsis* Matsumura, *Ent.Mag., Kyoto***2**(4):142

Type species: *Eristalis aegrotus* Fabricius

5. ***Dideopsis aegrota*** (Fabricius, 1805)

1805. *Eristalis aegrota,* Fabricius, *Syst.antl.***14**:243

Type locality: India: Tamil Nadu: Tharangambadi

Material examined:4♀♀5 ♂♂Bandarhati, Bankura district, 23°13'16.9"N, 86°51'59.2"E, 167 Mt., 26.ii.2018, coll. D.Banerjee & party.8♂♂ 6♀♀Sonamukhi Village side, Bankura district, 23°13'48.8"N, 87°04'44.7"E, 101 Mt., coll. D.Banerjee & party.

***Distribution*:** India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Karnataka, Kerala, Meghalaya, Sikkim, Tamil Nadu, Tripura..

Elsewhere: Nepal, SE Asia, New Guinea, Australia.

V. Genus ***Episyrphus*** Matsumara & Adichi, 1917

1917 *Episyrphus*, Matsumura & Adachi. *Ent. Mag. Kyoto*, **3**:16

Type species: *Musca balteata* De Geer

Sub Genus ***Episyrphus*** Matsumura & Adachi, 1917

6. ***Episyrphus*(*Episyrphus*) *balteatus*** (DeGeer, 1776)

1776. *Musca balteata* De Geer, *Mem. Pour. serv. Hist. Ins.* **6**:116

= *Episyrphus fallaciosus* Matsumura, 1917

=*Episyrphus hirayamae* Matsumura, 1918

=*Musca alternate* Schrank, 1781

=*Musca cannabina* Scopoli, 1763

=*Musca elegans* Villers, 1789

=*Musca nectarine* Gmelin, 1790

=*Musca palustris* Scopoli, 1763

=*Musca scitule* Harris, 1780

=*Musca scitulus* Harris, 1780

=*Syrphus andalusiacus* Strobl, 1899

=*Syrphus cretensis* Becker, 1921

=*Syrphus nectareus* Fabricius, 1787

=*Syrphus pleuralis* Thomson, 1869

=*Syrphus proximus* Abreu, 1924

=*Syrphus signatus* Abreu, 1924

Type locality: Sweden.

Material examined:8 ♂♂ 2 ♀♀Dihipara, Bankura district, 23°19'32.5"N, 86°56'15.7"E, 167 Mt., 28.ii.2019 coll. D.Banerjee & party.6♂♂Dihipara, Bankura district, 23°19'32.5"N, 86°56'15.7"E, 167 Mt., 18.vii.2017, coll. D. Banerjee & party.18♀♀ 10♂♂Anchuri, Bankura district,23°13'48.6"N, 87°04'44.5"E, 100 Mt.,22.xi.2018, coll. D.Banerjee& party.

***Distribution*:** India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam. Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Kerala. Meghalaya, Orissa, Punjab. Sikkim, Tripura.

Elsewhere: Oriental region, Australia, Bonin Island, Palaearctic region.

VI. Genus ***Eupeodes*** OstenSacken, 1877

1877. *Eupeodes* OstenSacken; *Bull. U.S. Geol. Surv. Terr.***3**:328

Type species: *Eupeodes volucris* OstenSacken.

Sub Genus ***Macrosyrphus*** Matsumura,1917

1917. *Macrosyrphus* Matsumura *Ent. Mag., Kyoto.***3**:23

Type- species: *Syrphus* okinawae Matsumura

7. ***Eupeodes*** (***Macrosyrphus***) ***confrater*** (Wiedemann, 1830)

1830, *Syrphus confrater* Wiedemann, Auss. *Zweifl. Theil. Schulz, Hamm.* **12**: 684

Type-locality: China.

Material examined:3♂♂ Lokesol, Bankura district,23°21'27.3"N, 86°56'47.1"E, 143 Mt., 28.ii.2017, coll. D.Banerjee & party.1♂ Dihipara, Bankura district, 23°19’32.5”N, 86°56’15.7”E, 167 Mt., 19.vii.2018, coll. D.Banerjee& party 13♀♀ Namoachari, Bankura district,23°16’02.4”N, 87°00’19.3”E,104 Mt., 22.xi.2017coll. D.Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Manipur, Meghalaya, Punjab, Sikkim, Tamil Nadu, Uttarakhand.

Elsewhere: Afghanistan, Australia, China, Nepal, New Guinea, Pakistan, Sri Lanka, Sumatra.

VII. Genus ***Ischiodon*** Sack, 1913

1913. ***Ischiodon*** Sack, *Ent. Mitt.***2**:5

Type species: *Ischiodon trochanterica* Sack

8. ***Ischiodon scutellaris*** (Fabricius, 1805)

1805. *Scaeva scutellaris* Fabricius, *Syst. Antliat.*:**252**.

=*Epistrophe magnicornis* Shiraki, 1963

=*Epistrophe platychiroides* Frey, 1946

=*Ischiodon boninensis* Matsumura, 1919

=*Ischiodon penicillatus* Hardy, 1952

=*Ischiodon trochanterica* Sack, 1913

=*Melithreptus novaeguineae* Kertesz, 1899

=*Melithreptus ogasawarensis* Matsumura, 1916

=*Sphaerophoria annulipes* Macquart, 1855

=*Sphaerophoria macquarti* Goot, 1964

=*Syrphus coromandelensis* Macquart, 1842

=*Syrphus erythropygus* Bigot, 1884

=*Syrphus nodalis* Thomson, 1869

=*Syrphus ruficauda* Bigot, 1884

=*Syrphus splendens* Doleschall, 1856

Type-locality: Tranquebar, India.

Material examined: 5♂♂ Naphardanga, Bankura district, 23°26’16.2”N, 86°61’32.1”E, 187 Mt., 26.ii.2020, coll. D. Banerjee & party.11 ♀♀ Namoachari, Bankura district, 23°16’02.4”N, 87°00’19.3”E,104 Mt., 22.xi.2017coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Andhra Pradesh, Assam, Chandigarh, Delhi, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Manipur, Meghalaya, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand.

Elsewhere: Java, Philippines, Taiwan and other parts of the S.E. Asia; Australia, Hawaii, Japan and Micronesia.

VIII. Genus ***Sphaerophoria*** Lepeletier & Serville, 1828

1828. *Sphaerophoria* Lepeletier & Serville, *Encycl.method*,: 513.

Type species: *Musca cripta* Linnaeus.

9. ***Sphaerophoria*** **(*Sphaerophoriascripta*)** ***Indiana*** Bigot, 1884

1884. *Sphaerophoria indiana* Bigot, *Annls. Soc. ent. Fr.* (6) **4**: 99

=*Melithreptus diminutus* Matsumura, 1916

=*Melithreptus kumamotensis* Matsumura, 1916

=*Sphaerophoria nigritarsis* Brunetti, 1915

Type-locality: “Indes”

Material examined: 3♂♂ Hamirhati, Bankura district,23°27’49.6”N, 86°62’35.3”E, 103 Mt., 24.ii.2017, coll. D. Banerjee & party.2♂♂ Dihipara, Bankura district, 23°19’32.5”N, 86°56’15.7”E, 167 Mt., 19.vii.2018, coll. D. Banerjee & party.6♀♀Agua, Bankura district, 23°23’42.2”N, 86°58’36.3”E, 195Mt., 22.xi.2019.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Arunachal Pradesh, Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Meghalaya, Sikkim, Uttar Pradesh.

Elsewhere: China, Sri Lanka, Korea.

Tribe Paragini

IX. Genus ***Paragus*** Latereille, 1804

1804. *Paragus* Latereille, *Hist.Nat.Crust.Ins*, **14**:259.

Type species: *Mulio bicolor* Fabricius.

10. ***Paragus (Paragus) serratus*** (Fabricius, 1805)

1805. *Mulio serratus* Fabricius, *Syst. Antliat*.:186

Type-locality: (Tranquebar) Tamilnadu, India

Material examined: 2 ♂♂ Muslo, Bankura district,23°36.1‹18»N, 349.1‹54°86»E, 124 Mt., 26.ii.2017, coll. D.Banerjee & party. 16♀♀ 6♂♂ Cochdihi, Bankura district, 23°17'48.4"N, 86°54'10.9"E, 109 Mt., 22.xi.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area, Assam, Bihar, Delhi, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Punjab, Tamil Nadu, Tripura, Uttar Pradesh.

Elsewhere: Jakarta, Java, E. Malaysia, Nepal, Pakistan, Sri Lanka, Africa and Papuya.

Sub family ERISTALINAE

Tribe Eristalini

X. Genus ***Eristalinus*** Rondani 1845

1845. *Eristalinus* Rondani, *Nuovi Ann. Sci. Nat. Bologna.***2** (2): 453

Type species: *Musca sepulchralis* Linnaeus

SubGenus ***Eristalinus*** Rondani, 1845

11. ***Eristalinus(Eristalinus)arvorum*** (Fabricius, 1787)

1787. *Syrphus arvorum* Fabricius, *Mantissa insectorum*. **2**: 335

=*Eristalis anicetus* Walker, 1849

=*Eristalis antidotus* Walker, 1849

=*Eristali sfulvipes* Macquart, 1846

=*Eristalis okinawensis* Matsumura, 1916

=*Eristalomyia eunotata* Bigot, 1890

=*Eristalomyia fo* Bigot, 1880

=*Musca tranquebarica* Gmelin, 1790

=*Syrphus aruorum* Fabricius, 1787

=*Syrphus quadrilineatus* Fabricius, 1787

Type-locality: (Tranquebar) Tamilnadu, India

Material examined:12♂♂14♀♀Palsora, Bankura district,23°27'49.6"N, 86°62'35.3"E, 103 Mt., 01.iii.2019, coll. D.Banerjee & party.11♂♂Namoachari, Bankura district, 23°16'02.4"N, 87°00'19.3"E,104 Mt., 25.xi.2018, coll. D.Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area, Arunachal Pradesh, Jammu & Kashmir, Meghalaya, Odisha, Sikkim, Tripura.

Elsewhere: Australia, China, Hawaii, Japan, Micronessi, South East Asia.

12. ***Eristalinus (Eristalinus) tabanoides*** (Jaennicke, 1867)

(Plate 1a-f)

1867. *Eristalis tabanoides* Jaennicke, *Neu. exot. Dipt. Asen. Nat. Ges.***6**: 402

=*Eristalis punctifer* Walker, 1871

Type-locality: (Tranquebar) Tamilnadu, India

Material examined:16 ♂♂ Krishtobati, Bankura district, 23°22'47.9"N, 86°'59.8"E, 97 Mt., 01.iii.2018, coll. D. Banerjee & party.12♀♀ Pechuasimue, Bankura district, 23°23'41.2"N,

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Delhi.

Elsewhere: Eritrea, Djibouti, Tunisia, Egypt.

XI. **Genus *Eristalis*** Latreille 1804

1804, *Eristalis*, Latreille, *Hist. Nat. Crust. Ins*. **14**: 363.

Type species: *Musca tenax* Linnaeus

Sub Genus ***Eoseristalis*** Kanervo, 1938

Type species: *Musca tenax* Linnaeus

13. ***Eristalis (Eoseristalis) cerealis*** Fabricius, 1805

1805. *Eoseristalis cerealis* Fabricius, *Syst. Antliat*. **14**: 232.

Type-locality: China.

Material examined: 13♀♀ Muslo, Bankura district, 23°22'42.2"N, 86°57'52.1"E,114Mt., 2.xii.2017, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Himachal Pradesh, Jammu &Kashmir, Meghalaya, Sikkim, Tamil Nadu, West Bengal. ***Elsewhere:*** Widespread in Oriental region.

XII. Genus ***Phytomia*** Guerin-Meneville, 1833

1833. ***Phytomia*** Guerin-Meneville, *Insectes.*: 509

Type species: *Eristalis chrysopygus* Wiedemann

Sub Genus ***Phytomia*** Guerin-Meneville, 1833

14. ***Phytomia (Phytomia) errans*** (Fabricius, 1787)

1787. *Syrphus errans* Fabricius,*Mantissa insectorum*. **2**: 337

=*Eristalis agyrus* Walker, 1849

=*Eristalis amphicrates* Walker, 1849

=*Eristalis babytace* Walker, 1849

=*Eristalis macquartii* Doleschall, 1856

=*Eristalis plistoanax* Walker, 1849

=*Eristalis varipes* Macquart, 1842

=*Phytomia aryrus* Knutson, Thompson & Vockeroth, 1975

Type-locality: India. Tamil Nadu: Tharangambadi.

Material examined: 1♀Sonamukhi forest area, Bankura district,23°15'41.3"N, 86°51'29.3"E,144mt., 04.iii.2019, coll. D. Banerjee & party.2♀♀ Bandarhati, Bankura district,23°18'36.01"N, 86°54'34.1"E, 124 Mt., 2.xii.2017, coll. D. Banerjee & party.

Elsewhere: China, Throughout SE Asia, Japan.

Sub Genus **Dolichomerus** Macquart, 1850

15. ***Phytomia*(*Dolichomerus*) *crassa*** (Fabricius, 1787)

1787.*Syrphus crassa* Fabricius, *Mantissa Insect.***2:** 334.

=*Phytomyia sculptata* Wulp, 1868

=*Syrphus megacephalus* Fabricius, 1798

Type-locality: Tranquebar, Chennai (Tamil Nadu), India

Material examined:1♀ Churamanipur forest village, Bankura District, 23°17'59.9"N, 86°53'55.3"E, 110 Mt., 04.iii.2017, coll. D. Banerjee & party.1♀Sonamukhi forest area, Bankura district,23°15'41.3"N, 86°51'29.3"E, 144mt., 17.vii.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Andhra Pradesh, Assam, Himachal Pradesh, Tamil Nadu.

Elsewhere: Sri Lanka, Laos, Malaya, Nepal, Thailand.

XIII. Genus **Mesembrius** Rondani 1857

1857. *Mesembrius* Rondani, *Dipterol Italic prodromus.***2**: 50

Type species: *Helophilus peregrinus* Loew

16. ***Mesembrius (Mesembrius) bengalensis*** (Wiedemann, 1819)

=*Eumerosyrphus indianus* Bigot, 1882

1819. *Eristalis bengalensis* Wiedemann, *Zool. Mag. (Wied)* **1**: 16.

Type-locality: Bengal, India.

Material examined: 3♀♀ 3♂♂ Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 116 Mt., 5.iii.2018, coll. D. Banerjee & party.14♀♀Hamirhati, Bankura district,23°22'47.9"N, 86° 59'08.0"E, 97 Mt., 4.xii.2020,coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area, Himachal Pradesh.

Elsewhere: SE Asia to New Guinea & northern Australia.

17. ***Mesembrius (Mesembrius) quadrivittatus*** (Wiedemann, 1819)

1819. *Eristalis quadrivittatus* Wiedemann, *Zool. Mag,* **1:**17

Type-locality: Tranquebar, India.

Material examined:3♀♀, Naphardanga, Bankura Distict, 23°26'16.2"N, 86°61'32.1"E, 187 Mt., 05.iii.2019, coll. D. Banerjee & party.11♂♂ Palsora, Bankura District, 23°27'49.6"N, 86° 52' 35.3"E, 103 Mt., 4.xii.2017, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Bihar, Chhattisgarh, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Tripura.

Elsewhere: Java, Moluccas, Nepal, Sri Lanka.

Tribe Merodontini

XIV. Genus **Eumerus** Meigen, 1822

1822. *Eumerus* Meigen, *zweifl. Insekten. Dritter Theil.***10**: 202

Type species: *Syrphus tricolor* Fabricius

18. ***Eumerus aenithorax*** Brunetti, 1915

1915.*Eumerus aenithorax* Brunetti; *Rec.Ind.Mus*; **11**:244.

Type-locality: Shimla, Himachal Pradesh, India

Material examined:1♀ Krishtobati, Bankura District, 23°22'47.9"N, 86°'59.8"E, 97 Mt., 05.iii.2017, coll. D. Banerjee & party.3♂♂ Palsora, Bankura District, 23°27'49.6"N, 86° 52' 35.3"E, 103 Mt., 5.xii.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi

Protected Forest Area), Himachal Pradesh.

Elsewhere: Nil.

19. ***Eumerus aurifrons*** (Wiedemann, 1824)

(Plate 2 a-e)

1824. *Eumerus aurifrons* Wiedemann, *Analecta. ent.* **1**:32

Type locality: Ind Orient region.

Material examined:10♀♀3♂♂Sonamukhi Forest Area, Bankura District, 23°15'41.3"N, 86°51'29.3"E, 144 Mt., 05.iii.2019, coll. D. Banerjee & party.4♂♂ Palsora, Bankura District, 23°27'49.6"N, 86° 52' 35.3"E, 103 Mt., 5.xii.2017, coll. D. Banerjee & party.

Distribution: India West Bengal (Bankura: Sonamukhi Protected Forest Area).

Elsewhere: Philippines, Indonesia, Hawaii.

XV. **Genus Syritta** Lepeletier & Serville, 1828

1825. *Syritta* St.Fargeau&Serville, *Encyl.Meth.* 10:888,

Type species: *Musca pipiens* Linnaeus.

20. ***Syritta indica*** (Wiedemann, 1824)

1884. *Syritta rufifacies* Bigot, *Ann. Soc. Ent. Fr. Ser.* **6**, 3: 535-560.

=*Syritta femorata* Sack, 1913

=*Syritta rufifacies* Bigot, 1884

Type locality: East Indies.

Material examined: 6♂♂ Kalyanpur, BankuraDistict, 23°14'12.1"N, 86°51'19.1"E, 123 Mt., 05.iii.2018, coll. D. Banerjee & party.9♀♀ Dihipara, Bankura District, 23°13'16.9"N, 86° 51' 59.2"E, 167 Mt., 2.xii.2019, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Bihar, Himachal Pradesh, Karnataka, Pondicherry.

Elsewhere: No

1A. Dorsal view of head of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1B. Dorsal view of thorax of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1C. Dorsal view of abdomen of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1D. Dorso lateral view of leg of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1E. Dorso lateral view of wing of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1F. Habitus of *Episyrphus* (*Episyrphus*)*balteatus* (De Geer, 1776)

2A. Dorsal view of head of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2B. Dorsal view of thorax of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2C. Dorsal view of abdomen of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2D. Dorso lateral view of leg of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2E. Dorsal view of wing of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2F. Habitus of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

Figure 3: Status of subfamilies of family Syrphidae from Sonamukhi Protected Forest area.

Figure 4: Status of tribes of family Syrphidae from Sonamukhi Protected Forest area.

Figure 5: Status of genera of family Syrphidae from Sonamukhi Protected Forest area.

B. **Ecological Studies**

The overall species diversity from Sonamukhi protected forest area was qualitatively and quantitatively satisfactory. Altogether 20 species under 16 genera have been found here. Species diversity found to be maximum at pre-monsoon season that is in the month of march to June while least during the monsoon season that is in the month of July to October (figure 6-7). Overall collection scenario depicts a positive correlation between seasonal factors (temperature and rainfall) with diversity of pollinating hoverflies. Among this 20 species ***Eristalinus (Eristalinus) arvorum*** (Fabricius, 1787)found to be the most abundant species throughout the survey period, while among other hoverflies,***Paragus (Paragus) serratus*** (Fabricius, 1805), ***Asarkina (Asarkina) ericetorum*** (Fabricius, 1781)found to be quite abundant. ***Phytomia (Dolichomerus) crassa*** (Fabricius, 1787) found to be least abundant among this group of pollinating hoverflies (figure 6). Considering the species richness status, thePre-monsoon andpost-monsoon season depicts nearly similar level of species richness while the monsoon season exhibits the least in term of richness percentile. Simple linear regression reveals that species abundance has a direct negative correlation with temperature, thereby species abundance is found to be maximum at comparatively lower temperatures. That is why collection scenario found to be most enriched during pre-monsoon season, we have also considered other environmental parameters like rainfall, humidity, latitude, availability of host plants, habitat type. It has been found that species availability is positively correlated with availability of host plants and habitat type. While negatively correlated with rainfall and humidity and latitude does not reveal any correlation at all. During the preceding 3 years, we have surveyed casing pre monsoon, monsoon and post monsoon season to observe seasonal correlation with dipteran diversity if any. Summarising the results of the study revealed that dipteran alpha diversity in this protected forest area is reliably getting affected by the seasonal arrangement there.The assortment is maximum in the pre monsoon season, while slightly in a lesser amount during post monsoon atmosphere and nearly minuscule in amount duringmonsoonal time. If we consider theyear-wise assortment scenario, then dipteran diversity was supreme during the year of 2019-20, while least in the year of 2018, and if we consider the non-dipteran diversity, then profusion was maximum in the year of 2018-19.

Along the Protected Forest Area, the species are distributed at low densities with high turnover of insect species across the latitudinal and longitudinal axis. Considering the species abundance, the data suggests that ***Eristalinus (Eristalinus) arvorum*** (Fabricius, 1787) is the most abundant species while ***Phytomia (Dolichomerus) crassa*** Fabricius, 1787 is the least abundant. Among the two subfamilies, Syrphinae has a higher percentile of species abundance (53%) than Eristalinae (47%) (figure 3). Whereas species richness is nearly similar (49%-49.5%) for both subfamilies. While among the tribes Syrphini shows the highest species abundance (69%) and Eristalini the highest species richness percentile (55%) (figure 4). Among the genera *Eristalinus* has shown the maximum abundance while the least (figure 5). The least percentile of species richness and abundance is represented by theMilesiini tribe (3% and 5% respectively). Unexpectedly species richness relative abundance and overall diversity found to be highest in pre monsoon season in comparison with post monsoon and monsoon season. Relative abundance has shown that during pre-monsoon season *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787) is most abundant and *Eumerus aeneithorax* Brunetti, 1915 is the least abundant species, while both in monsoon and post monsoon *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) is most abundant syrphid while *Eupeodes (Macrosyrphus) confrater* (Wiedemann, 1830) is least abundant during monsoon and *Syritta indica* (Wiedemann, 1824) is least abundant duringpost-monsoon season. Even considering the very low floristic diversity and the harsh conditions of the environment. Another reason of such high level of diversity is that this ecosystem act as an Ecotone, a connecting fringe between agro and forest ecosystem, thereby expected to exhibit a higher range of species diversity (Sajjad *et al.* 2010)

Figure 6: Overall species collection scenario from Sonamukhi Protected Forest area

Figure 7: Species collection scenario from Sonamukhi Protected Forest area on seasonal account.

Different Alpha (α) diversity indices:

Alpha Biodiversity [α] of the surveyed area refers to a group of organisms interacting and competing for the same resources or sharing the same environment. The calculation is based upon the indexes that have been calculated based upon our overall collected data covering all 3 seasons, it is given in a chart as follows (table 1-3). We have calculated here Shannon index, Simpson index, Menhinick's richness index, Margalef's richness index, Berger-Parker dominance.

Figure 8A-8E: Comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

Figure 9: Overall comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

Figure 10: Relative abundance scenario of species collected from study area during Pre monsoon season.

Figure 11: Relative abundance scenario of species collected from study area during monsoon season.

Figure 12: Relative abundance scenario of species collected from study area during post monsoon season.

Discussion

This work is consolidated taxonomical work on Family Syrphidae from this protected forest area. Several reseach work have been carried out across different graphic regions of West Bengal previously (Sengupta et al 2018), in this study we consider the dry deciduous forest of Bankura district as a study site.. So, from that point of view, this work carries immense taxonomical importance. Altogether **20** species of hoverflies under **16** genera have been reported. The **20** species which are found are from **2** subfamilies namely Syrphinae and Eristalinae. Subfamily Syrphinae has shown higher abundance than subfamily Eristalinae throughout our survey period.Altogether 7 tribes are reported from the study area of which tribe syrphini has shown the maximum abundance while tribe merodontini the lowest . Among the 16 genera reported *Eristalinus* has shown the Highest abundance while *Dasysyrphus* the lowest

During preceding 3 years (2018-2020), we have surveyed the selected study areas casing pre-monsoon, monsoon and post monsoon season. Further extensive studies throughout all the month should help to construct a clearer cut picture the taxonomical scenario of hoverflies from this protected area with a schematic concept their annual availability. Perhaps such extensive studies and careful attention will be needed to attain far higher counts of this pollinating dipteran insects, although the current taxonomic study has shown a satisfactory result quantitative & qualitatively.

Seasonal variation of the physicochemical circumstances plays an imperative role in syrphid diversity and community structure (Colley *et al.* 2000). Knowledge of seasonal variation, abundance and diversity of syrphid in relation floral abundance and abiotic factors has generally been documented here (Sajjad *et al.* 2010) as it helps their conservation strategies (Mengual, 2010). At the landscape level, positive relationships between the richness and abundance of floral resources and dipteran diversity and activity have been found (Reemer, 2013). But on a micro-scale very little is known about the overall activity patterns of syrphid fly with the distribution of resources. Therefore, to investigate the relation present between seasonal variation and the diversity of syrphid flies in a protected area we have studied here the hoverfly diversity in year-wise collection pattern as well at the seasonal level too. The pattern of seasonal changes in numbers of Syrphidae was similar over the 3-year study period. The species composition was highest during the year 2019 and lowest during 2018. While discussing species abundance, large proportion of species were relatively common while few species were very abundant (Figure 10-12). The most 2 abundant species accounts for nearly 47.5% of total species individuals.

Alpha diversity indices were also calculated. The performance of all species diversity estimators showed remarkable differences between 3 seasons. There is a large super position range in species richness estimates which varied in 3 seasons. Thus, the alpha diversity analysis of this data has shown a consistent pattern of higher diversity at pre monsoon with descending trend at post monsoon and monsoon season

The value of H is higher at pre monsoon rather than monsoon and post monsoon season indicates higher diversity this factor is also supported by higher value of Simpson index of diversity at pre monsoon season. Both Mechinick's and Margalef's richness index are also higher in pre monsoon season. The higher value of Berger Parker index during monsoon season predicts that the community during monsoon season is dominated by few species that is the evenness is lower here compared to the other two seasons where lower value of Berger Parker index attributes to a more even community of hoverfly's population. Although species richness is slightly higher in post monsoon season rather than pre monsoon season while remarkably lower at monsoon season.

The general result of this study suggests that rainfall and temperature play the pivotal role in the hoverfly species composition and relative abundance in the given area, thus the species diversity found to be maximum at pre monsoon season when rainfall was minimum and temperature also in an optimum level comparatively. This prediction has been done based upon the statistical differentiation of the diversity measures, species abundance as well as in the light of species richness estimators

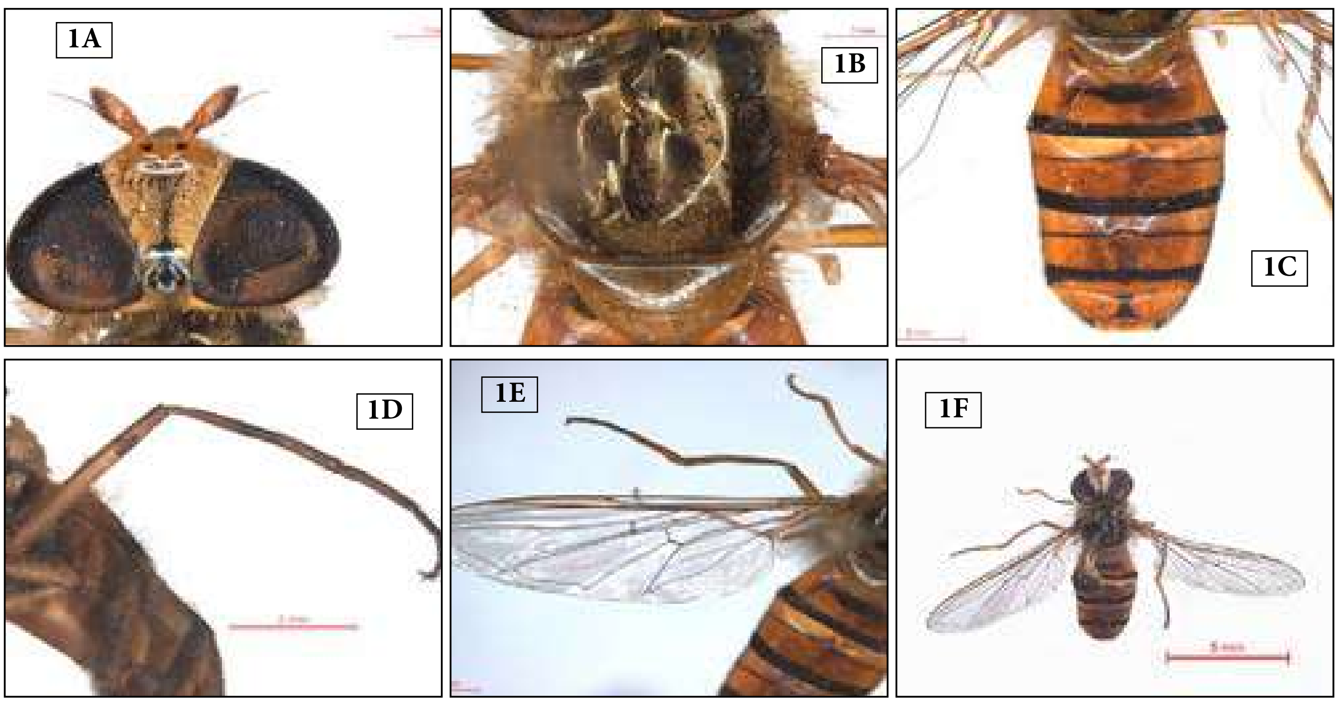
Furthermore, our study suggests that heterogeneity in the dry deciduous forest's hoverfly assemblages occur due to contrasting type of environmental factors, phytophagous nature of feeding, and level of urbanization of the surroundings of forest. Responses to different level of seasonal fluctuation were also found in hoverfly assemblages (Gottschalk *et al.* 2001). Finally considering the availability of feeding and breeding sites, we suggest that such dry deciduous forest ecosystem is acting as sink habitats for hover fly population.

Concluding it can be said Insect abundance in the understory vegetation varies significantly among the habitats. Among these three dominant seasons of our studied area, the pre monsoon season has shown a relatively high abundance of insects. The comparison of the seasonal fluctuations in the insect abundance of the dry deciduous forest revealed that the seasonality of the overall insect population of the understory vegetation is controlled by common micro climatic factors rather than by any habitat specific factors. The factors and process that maintain the numbers of species in a given locality remain unknowing most cases (Whittaker, 1972). Local communities are open, and coupled to broader landscape via movement of flies there by creating a Source Sink system (Amarasekare *et al.* 2001). This effect can increase the species diversity in heterogeneous landscapes shortly. Although this concept of source-sink study needs further scientific attention to get a clearer picture.

Summary

The overall species diversity from Sonamukhi protected forest area depicts altogether 20 species under 16 genera are found. The flies of *Ersistalinus* genus are the most abundant whereas *Dasysyrphus* genus are less abundant in this region. *Episyrphus balteatus* (DeGeer, 1776) is found to be most common and the *Sphaerophoria Indiana* Bigot, 1884 are very rare. Diversity analysis study has revealed that species diversity found to be maximum at pre monsoon season (66.75%) While least during monsoon season (2.5%). Overall collection scenario depicts a positive correlation between seasonal factors (temperature and rainfall) with diversity of pollinating hoverflies.

FIGURE-1



1A. Dorsal view of head of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1B. Dorsal view of thorax of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

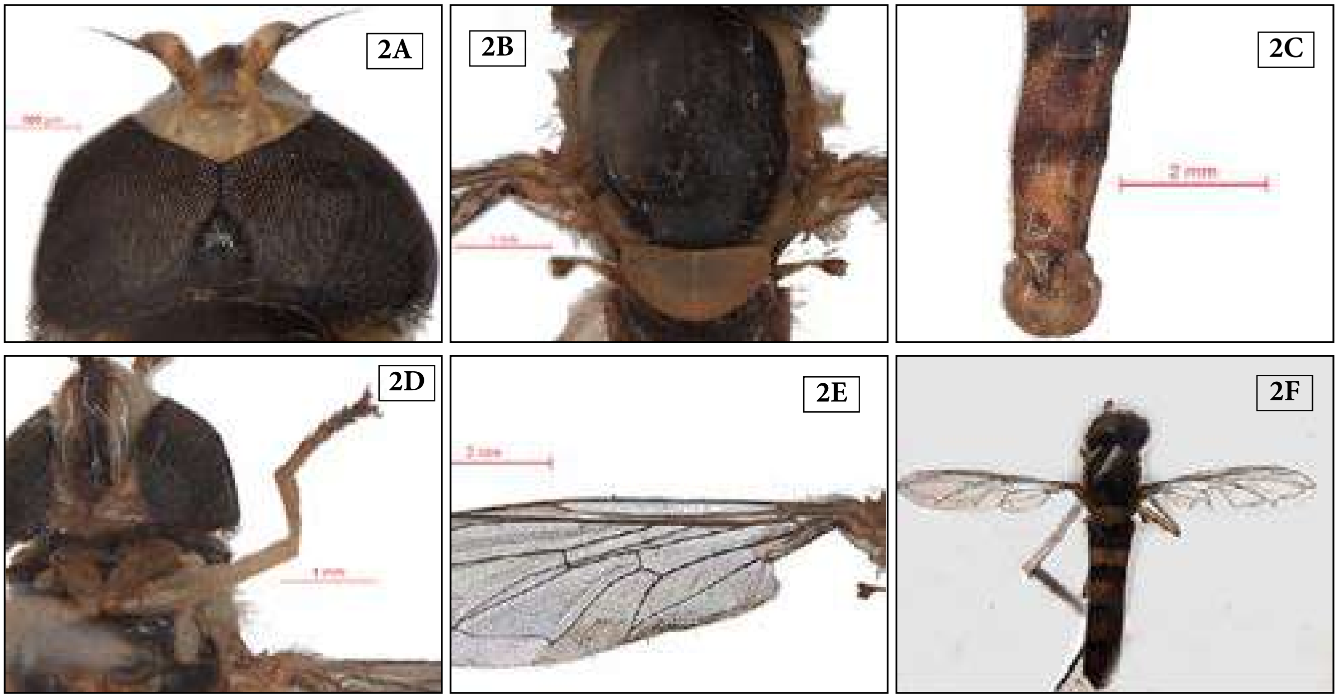
1C. Dorsal view of abdomen of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1D. Dorso lateral view of leg of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1E. Dorso lateral view of wing of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1F. Habitus of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

FIGURE-2



2A. Dorsal view of head of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2B. Dorsal view of thorax of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2C. Dorsal view of abdomen of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2D. Dorso lateral view of leg of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2E. Dorsal view of wing of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2F. Habitus of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

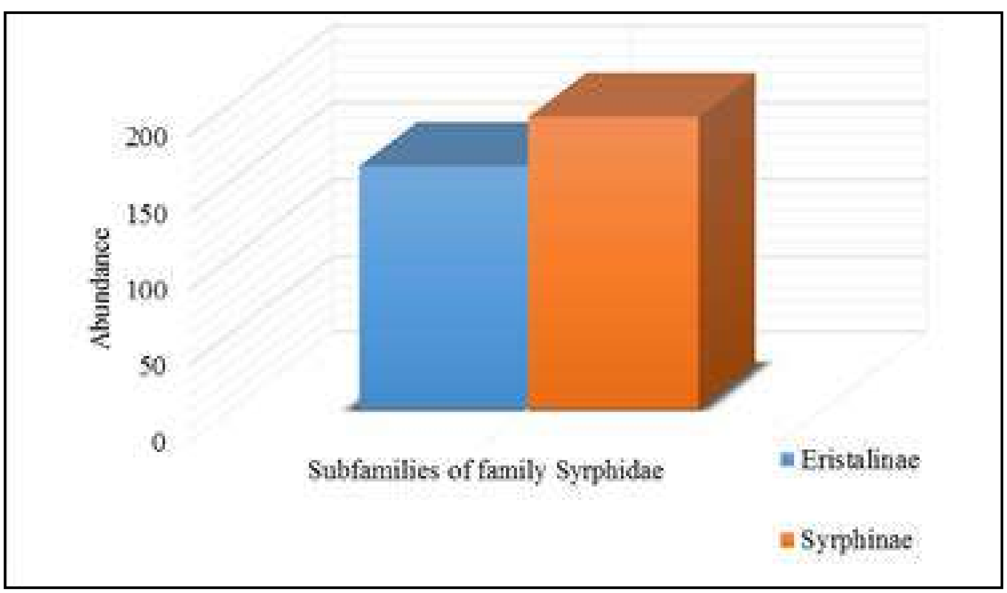


Figure 3: Status of subfamilies of family Syrphidae from Sonamukhi Protected Forest area.

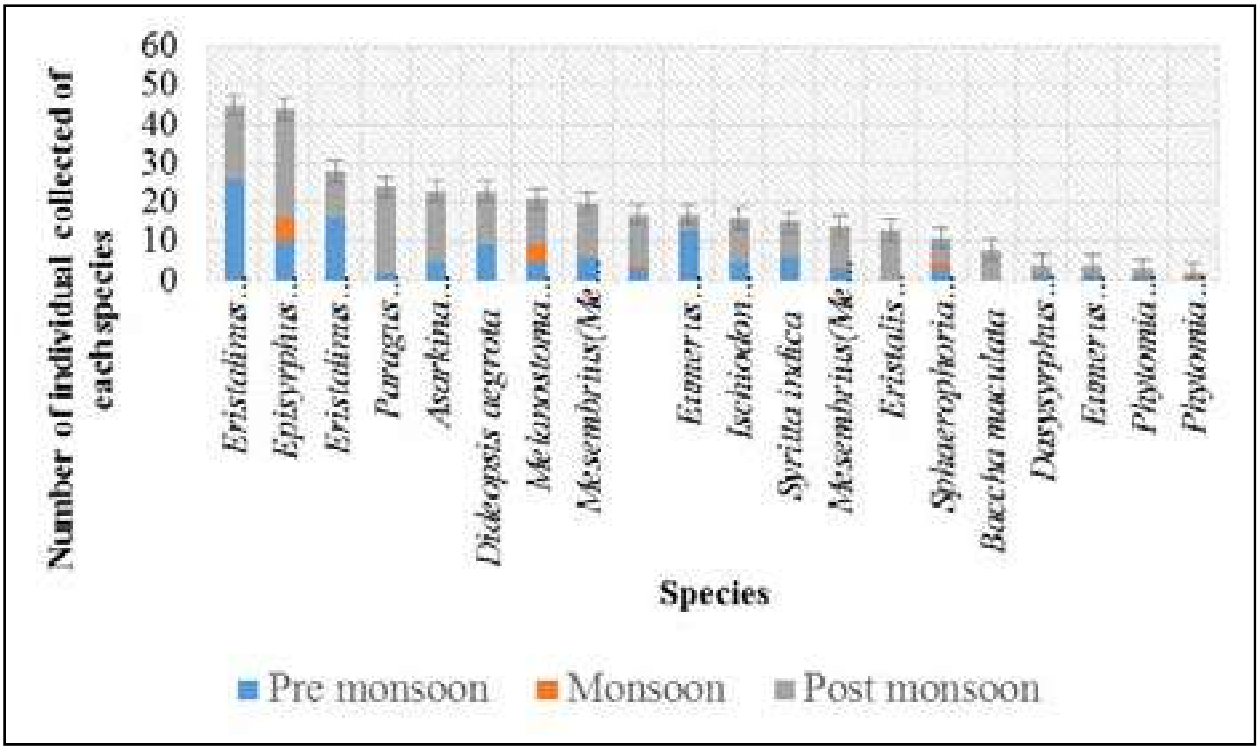


Figure 4: Status of tribes of family Syrphidae from Sonamukhi Protected Forest area.

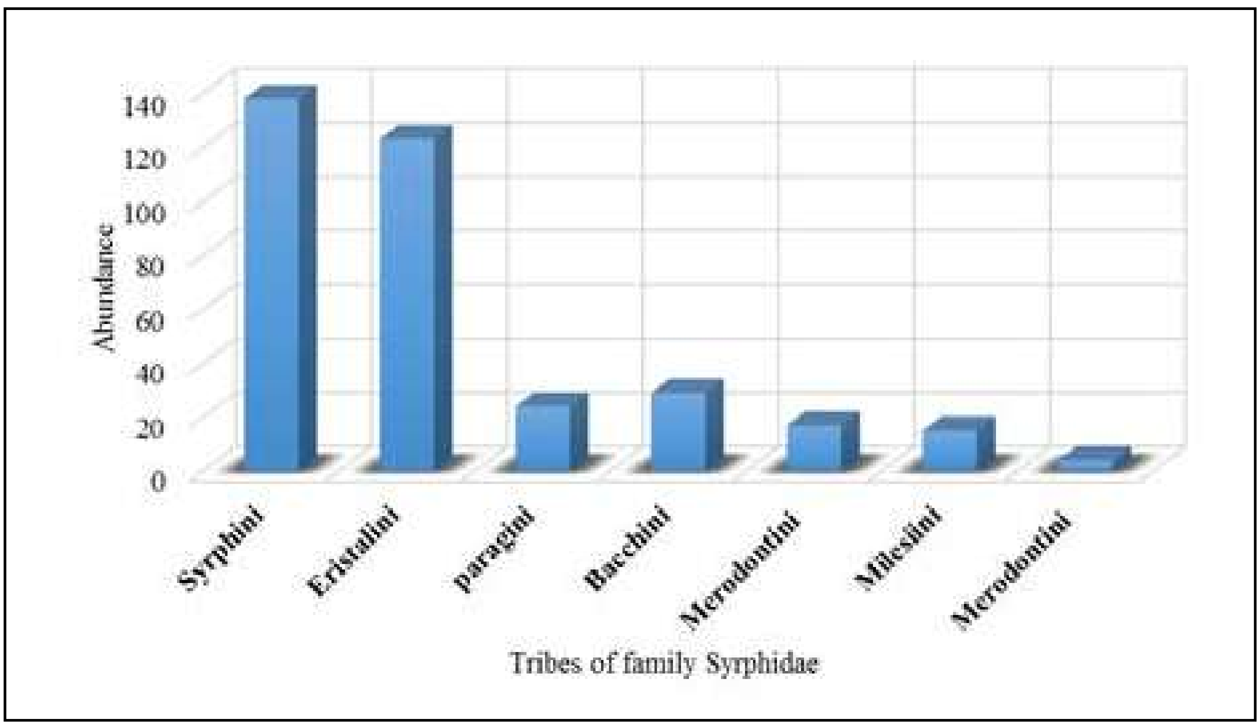


Figure 5: Status of genera of family Syrphidae from Sonamukhi Protected Forest area

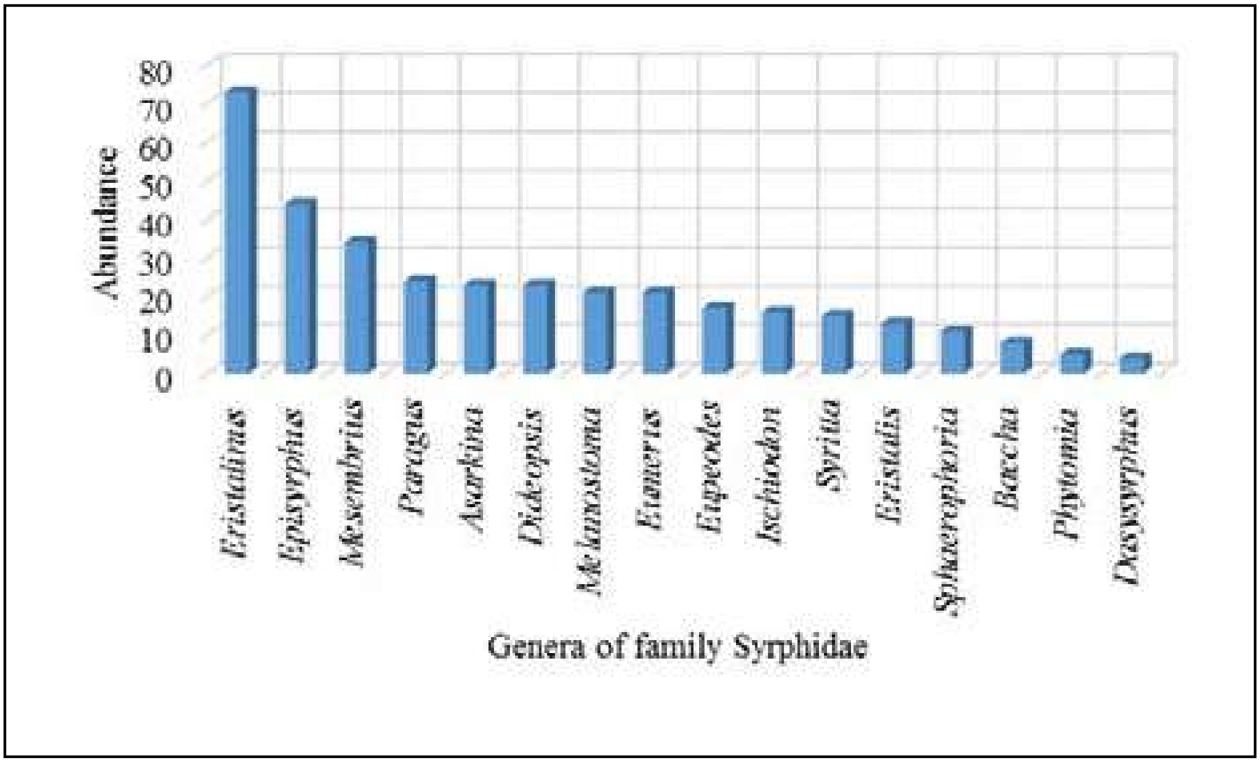


Figure 6: Overall species collection scenario from Sonamukhi Protected Forest area

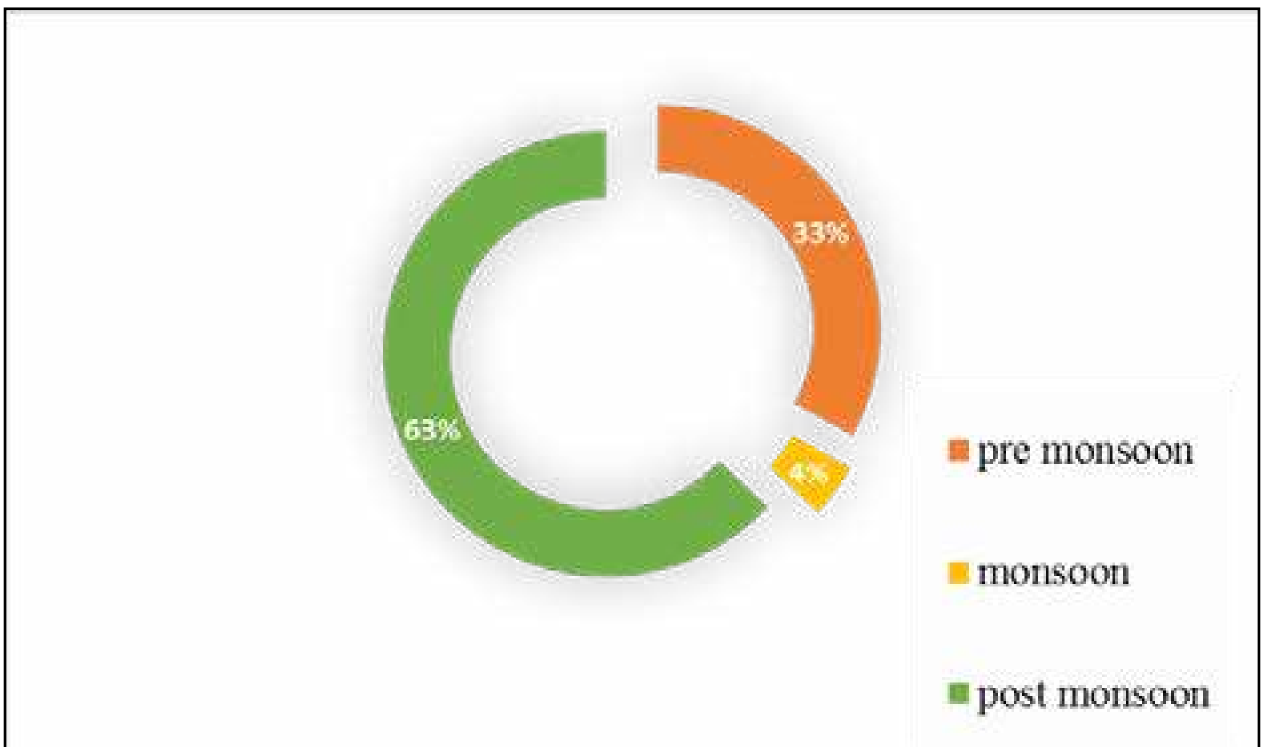


Figure 7: Species collection scenario from Sonamukhi Protected Forest area on seasonal account

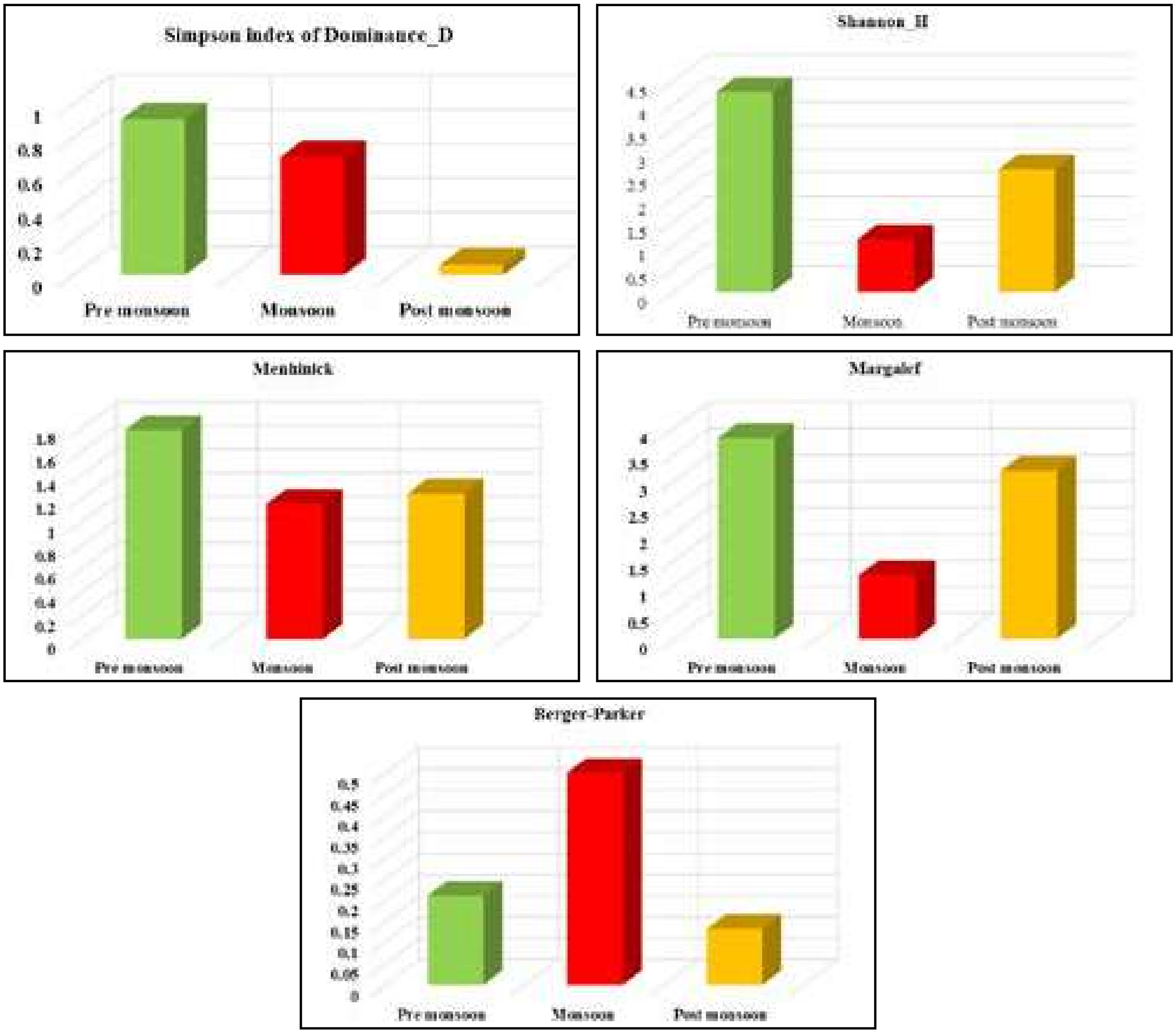


Figure 8A-8E: Comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

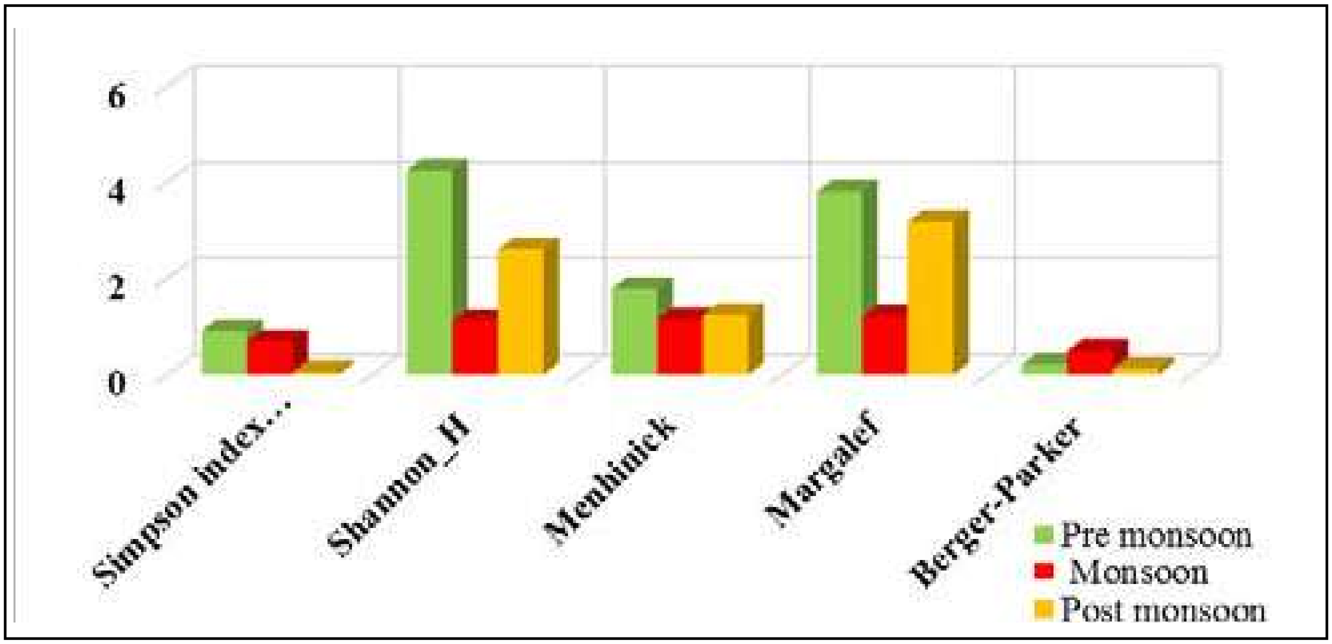


Figure 9: Overall comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

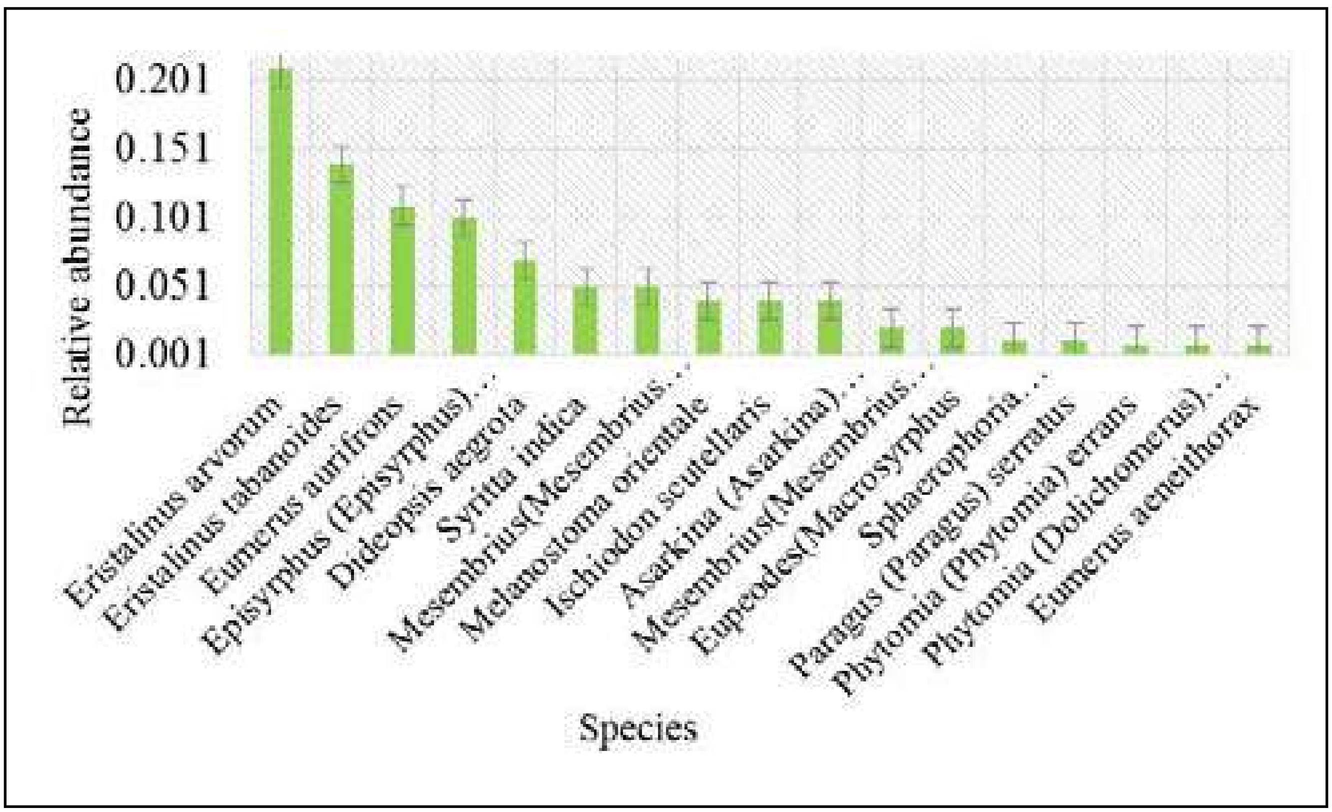


Figure 10: Relative abundance scenario of species collected from study area during Pre monsoon season

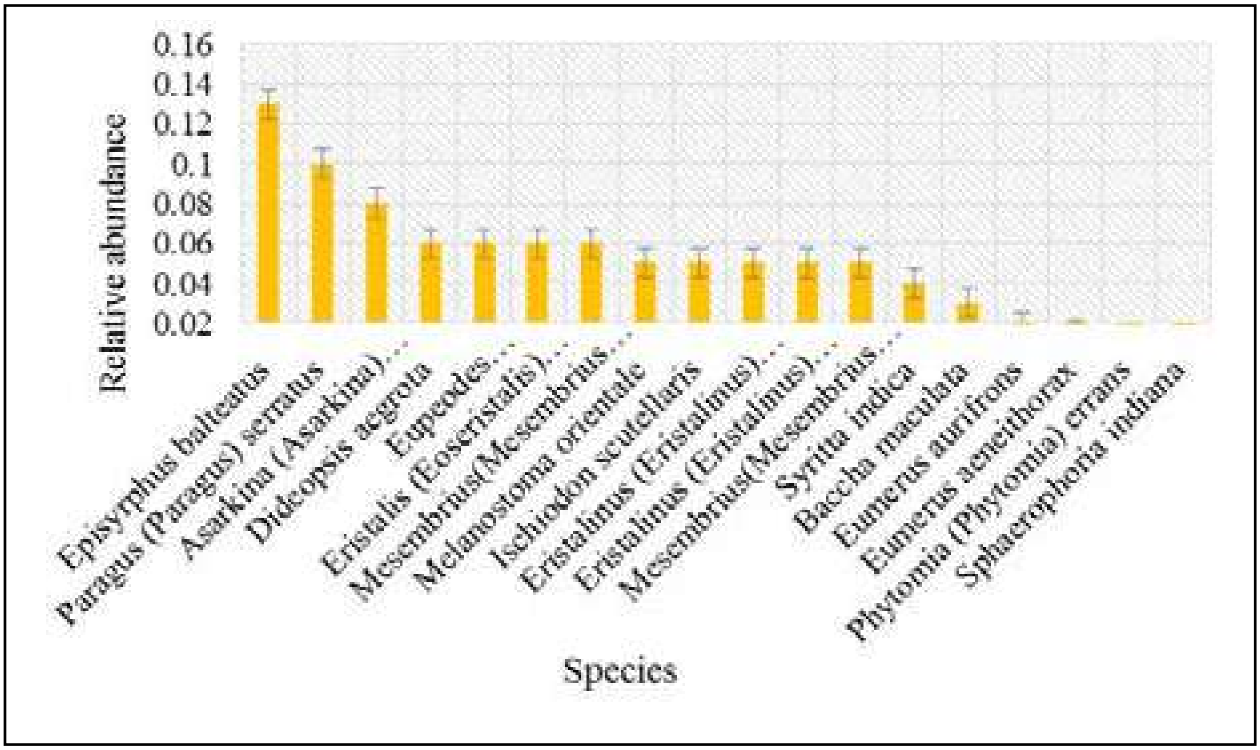


Figure 11: Relative abundance scenario of species collected from study area during monsoon season

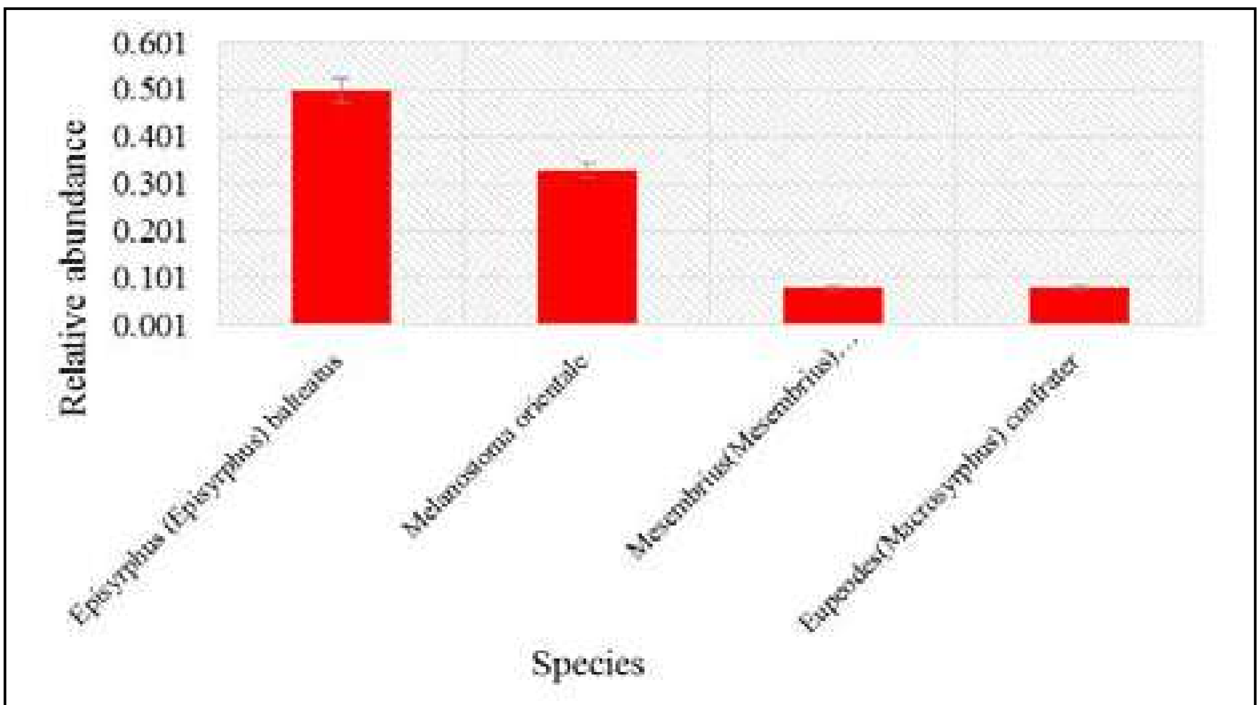


Figure 12: Relative abundance scenario of species collected from study area during post monsoon season

Acknowledgement

We would like to express our gratitude and sincere thanks to Director, Zoological Survey of India, Kolkata, Dr. G.P. Mondal, Scientist- E, H.O. O & Officer in charge, Apterygota division, Dr. Souvik Sen, Scientist- "D", and officer-in- charge, Technical Section, Mr.P.Parui, Retired Scientist and all other members of Diptera Section. The financial assistance under the Junior Research Fellowship (F-2102/2020/Tech./3891) provided by the Zoological Survey of India, Govt. of India is gratefully acknowledged. We also deeply concede the Government of West Bengal and Forest department of West Bengal for the necessary permission for collecting the specimen under their jurisdiction.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

An updated checklist of Indian batoids with new distributional records and conservation status

Bineesh K. K[1]., Ida E. G[1]., Nashad. M[2]., Rajendra Kumar[1]., Rajkumar Rajan[1] and Anil Mohapatra[3]

[1] Marine Biology Regional Centre, Zoological Survey of India, Chennai, Tamil Nadu, India
[2]Fishery Survey of India, Mormugao Zonal Base, Mormugao - 403803, Goa, India
[3]Estuarine Biology Regional Centre, Zoological Survey of India, Ganjam-761002, Odisha, India

Abstract

The present paper is an attempt to provide new information on taxonomy, current distribution, and conservation status of batoids in India. This study is based on the landing site surveys conducted during the years 2017-2022 at major fish landing centres across India. The present study updated the checklist of Indian batoids to 77 valid species. They were caught in commercial and artisanal fisheries of India and several of them were caught as bycatch. Among the deep water batoids, *Dipturus* spp, *Torpedo* spp. and the Dark blind ray *Benthobatis moresbyi* were frequently observed in the deepwater trawl bycatch. Distributions of batoids were highly variable along the Indian coasts. Landing centre survey shows that distribution *of Stripenose guitarfish Acroteriobatus variegatus* is restricted to southern cost of India. Similarly Smoothback guitarfish *Rhinobatos lionotus* is restricted to east coast of India from Kilakarai, Tamil Nadu to Hoogly, West Bengal. In addition, distributional ranges of several batoid species in Indian waters were extended; Brown sting ray *Bathytoshia lata* and Smalleye stingray *Megatrygon microps* are new record to Andaman and Nicobar Islands. Indian Guitarfishes and Wedgefishes are declining drastically due to fishing pressure and habitat destruction, 21% of the species is Vulnerable and 19% are Endangered, 16% are Critically Endangered, and 7% Near Threatened respectively.

Keywords: Rhinopristiformes, species composition, diversity, Indian EEZ, Conservation

Introduction

Skates, rays and guitar fishes collectively known as batoids and they are a significant group of cartilaginous fishes essential for maintaining the balance and health of marine ecosystems (Last *et al.*, 2016). They are commonly caught as bycatch in many parts of the world, especially in trawlers, and they may include commercial and non-commercial species (Blaber *et al.*, 2009; White *et al.*, 2019). Batoid fishes are exploited as targeted and bycatch in its commercial, artisanal and recreational fishing activities of India. Being a leading elasmobranch fishing nation, high fishing pressure over the years as caused steady decline in the population of several batoid fishes in Indian waters (Dulvy *et al.*, 2008; Kyne, 2016; Jabado *et al.*, 2017). Characteristics like low fecundity, later maturity and slow growth efficiency make them highly susceptible to population decline (Jabado, 2019).

Akhilesh *et al.* (2014) carried out an extensive study on Indian elasmobranchs and listed 227 species reported from Indian waters based on the literature survey and listed 169 species as valid from India comprising 79 batoids, 88 sharks and 2 chimaeras (Akhilesh *et al.*, 2023). Kizhakkudan *et al.* (2018) provided an updated list of Indian batoids with updated nomenclature details. However several species mentioned in that checklist have questionable identity and requires immediate validation to address the taxonomic confusion. Present study was carried out to rationalize the valid species of batoids in Indian waters and to map the distribution patterns of commercially important batoid species.

*Author for correspondence : kkbineesh@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Material and Methods

An extensive survey was conducted throughout the major fish landing centres of India including Andaman and Nicobar Islands during the period 2017-2022. Gear wise landings and species composition of batoids were recorded from each centre. Smaller samples are collected from the bycatch or trash and preserved in 10% formalin after taking tissue samples for molecular identification. Larger samples are identified from the harbour and not. Species identification was carried out based on Last *et al.* (2016). The conservation status of these species follows IUCN Red list data (2022) (https://www.iucnredlist.org/).

Results and discussion

Distribution

Distributions of batoids in Indian waters are highly variable and requires species specific management plans as it differs with gears and regions. Present study observed 53 species of batoids belonging to 17 families. Updated checklist of Indian batoids was provided in Table 1. The Short-tail sting ray *Bathytoshia lata* (Garman, 1880) (Figure 1) and Small-eye stingray *Megatrygon microps* (Annandale, 1908) (Figure 2) are new record to Andaman and Nicobar Islands.

Order: Myliobatiformes

Family: Dasyatidae

Bathytoshia lata (Garman, 1880)

Brown sting ray (Figure 1)

Observation/materials. (Not retained) A single male specimen about 122 cm DW were landed as bycatch caught in motorized boat operated off Little Andaman Islands at 50 to 100 m depth and landed at Junglighat fish landing center on 29th December 2019.

Diagnosis: Huge plain coloured ray with characteristic broad and rhombic disc, sharp thorns over disc and tail, elongate and gently tapering tail to caudal sting. Snout short and broadly triangular, tip extended slightly, anterior margin weakly undulate. Eyes very small, length of orbit and spiracle 2.2 in snout length; inter orbital space broad 4.5 times of orbit length. Mouth broad with 4 oral papillae; labial furrows weak and lower jaw weakly convex. Body granular with denser coverage of large thorns centrally. Body uniform greyish brown without diagonal row of white pores on disc. Tail dark before sting and white base ventrally. Ventral surface entirely white.

Order: Myliobatiformes

Family: Dasyatidae

Megatrygon microps (Annandale, 1908)

Smalleye stingray (Figure 2)

Observation/materials. (Not retained) A single female specimen about 122 cm DW were landed as bycatch caught in motorized boat operated off North Sentinel Islands at 50 to 100 m depth and landed at Junglighat fish landing center on 23rd February 2018

Diagnosis: Disc very broad (width more than 1.4 times disc length); outer angles more than 90°; snout rounded, with tip projecting slightly; spiracles large; mouth large, with 5 papillae; disc with numerous stellate-based, enlarged denticles, mostly around snout; tail almost as long as disc, basal portion broad and flat, distal portion slender and round, tapering rapidly beyond sting; ventral cutaneous fold on tail thick and low, originating below spine base; base of tail with enlarged denticles; dorsal surface whitish brown, eyes dark; ventral surface pale (Garman, 1913; Nair & Soundararajan, 1976; Last *et al.*, 2016).

Fig.1. *Bathytoshia lata* (Garman, 1880) landed at Junglighat, South Andaman Islands

Fig.2. *Megatrygon microps* (Annandale, 1908) landed at Junglighat, South Andaman Islands

Geographic distributional range of several species of batoids were extended during the present study: Short tail whip ray *Maculabatis bineeshi* Manjaji-Matsumoto & Last, 2016, Oman numb fish *Narcine atzi* Carvalho & Randall, 2003 and Bigeye numb fish *Narcine oculifera* Carvalho, Compagno & Mee, 2002 were observed in the batoid landings at Tuticorin, Tamil Nadu; Tonkin numb fish *Narcine prodorsalis* Bessednov, 1966 at Chennai, Tamil Nadu. Granulated guitarfish *Glaucostegus granulatus*, Widenose guitarfish *Glaucostegus obstusus* (Müller & Henle, 1841), Giant shovelnose ray *Glaucostegus typus* (Anonymous [Bennett], 1830), Smoothnose wedgefish *Rhynchobatus laevis* (Bloch & Schneider, 1801) and Bowmouth guitarfish *Rhina ancyclostomus* Bloch & Schneider, 1801 are the major species of guitarfishes and wedgefishes contributing to batoids fishery of India and they have wide distribution in both coasts.

Smoothnose wedgefish *Rhynchobatus laevis* (Bloch & Schneider, 1801) is common to West coast of India and they have a distribution from Veraval, Gujarat to Mangalore, Karnataka. However they are not recorded from observed in Southern coasts of India. Bottlenose wedgefish *Rhynchobatus australiae* Whitley, 1939 have wide distribution in West coast of India; they contribute to commercial batoid fishery of Gujarat, Karnataka, Kerala and Andaman and Nicobar Islands. In contrast Smoothback guitarfish *Rhinobatos lionotus* Norman, 1926 is restricted to East coast of India; they have recorded from Kilakarai, Tamil Nadu to Hoogly, West Bengal, but not recorded from both the island groups of India. Annandale's guitarfish *Rhinobatos annandalei* Norman, 1926 is known all along Indian main land (Kizhakkudan *et al.*, 2018). However during the present study it was observed only from Tuticorin, Tamil Nadu to entire west coast. Similarly, Stripenose guitarfish *Acroteriobatus variegatus* (Nair & Lal Mohan, 1973) is also recorded only from Southern coasts of India.

During the present study, potential nursery grounds of four species of batoids namely *G. typus*, *G. obstusus*, *R. australiae* and *A. variegatus* were recorded (Figure 6). *G. typus* have good nursery grounds throughout Andaman and Nicobar Islands and off Chennai, Tamil Nadu. Large number of juveniles of *G. obstusus* was recorded from Central West coast of India and off Kerala. In addition they have good nursery ground off, Odisha. Nursery ground of *R. australiae* was recorded only in North Andaman, Andaman and Nicobar Islands. Whereas nursery ground of *A. variegatus* has been located in south east coast of India.

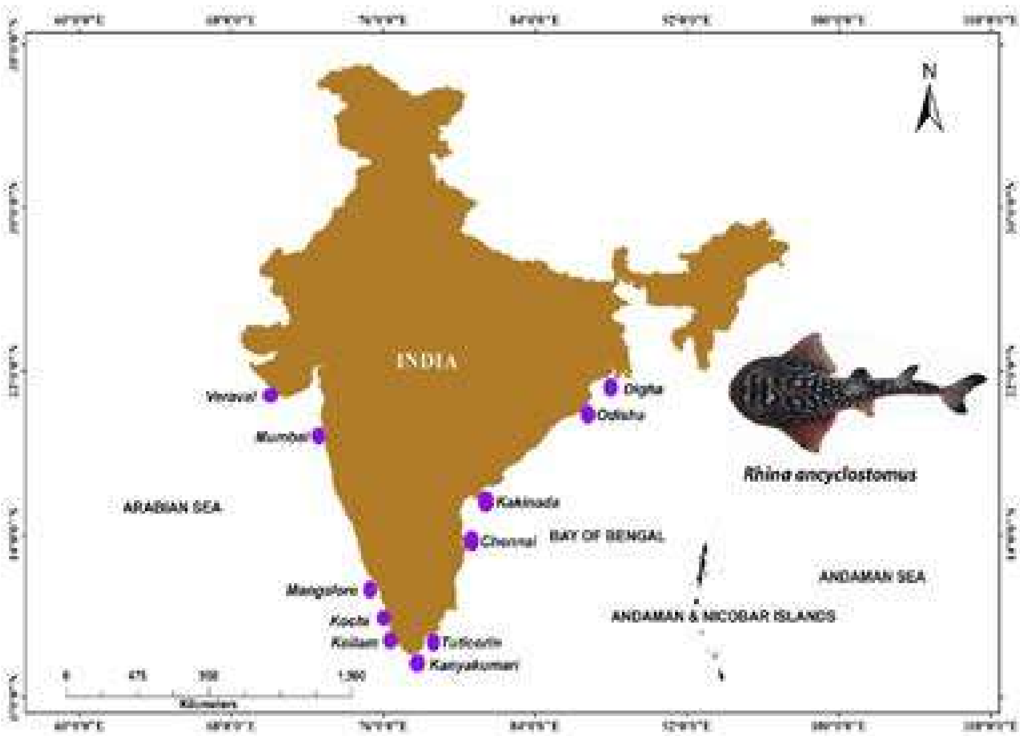

Fig.3 Map showing distribution of *Rhina ancyclostomus* in Indian waters

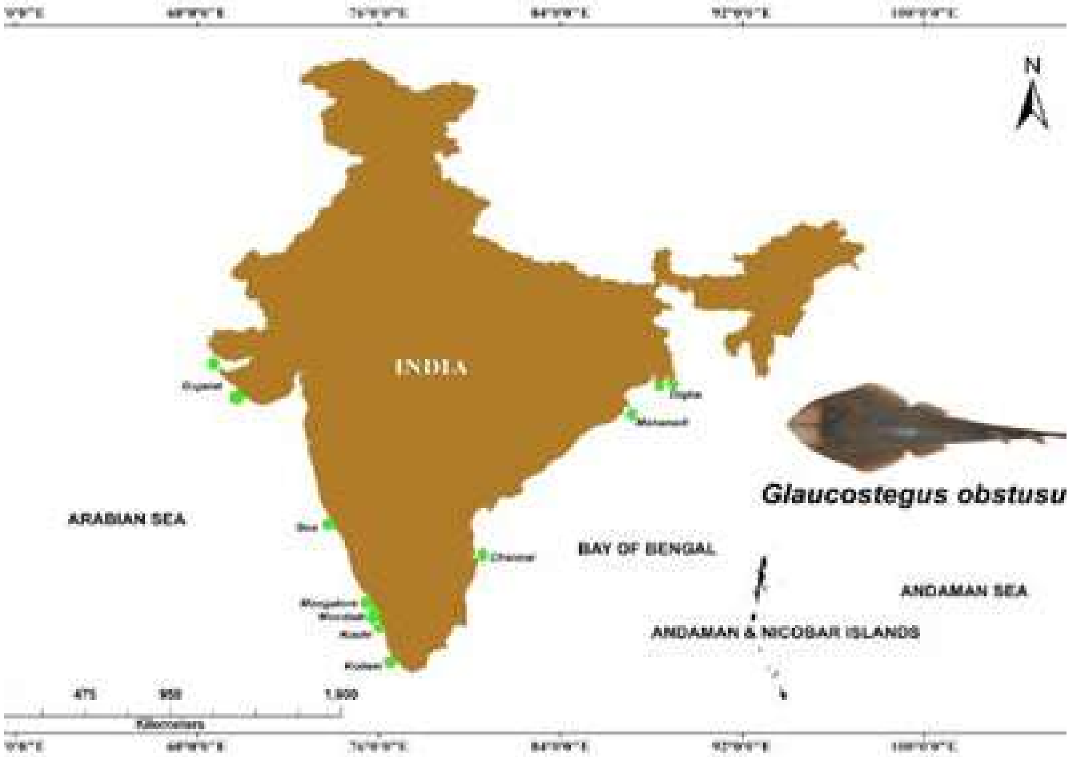

Fig.4 Map showing distribution of *Glaucostegus obtusus* in Indian waters

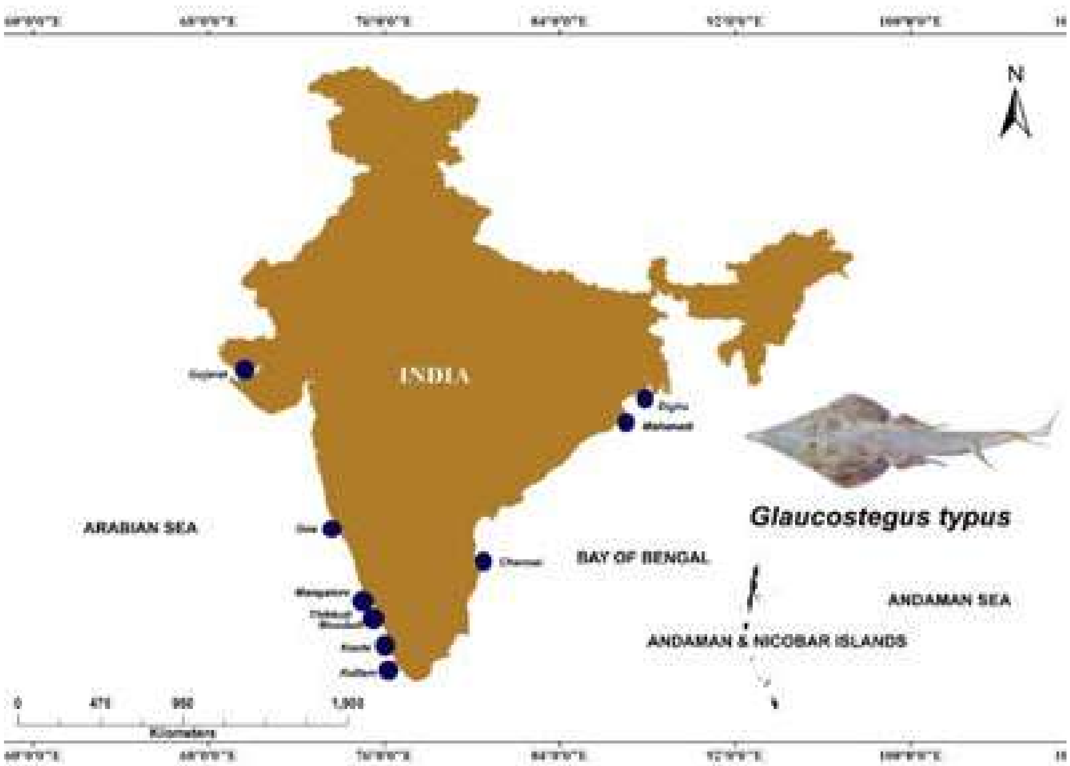

Fig.5 Map showing distribution of *Glaucostegus typus* in Indian waters

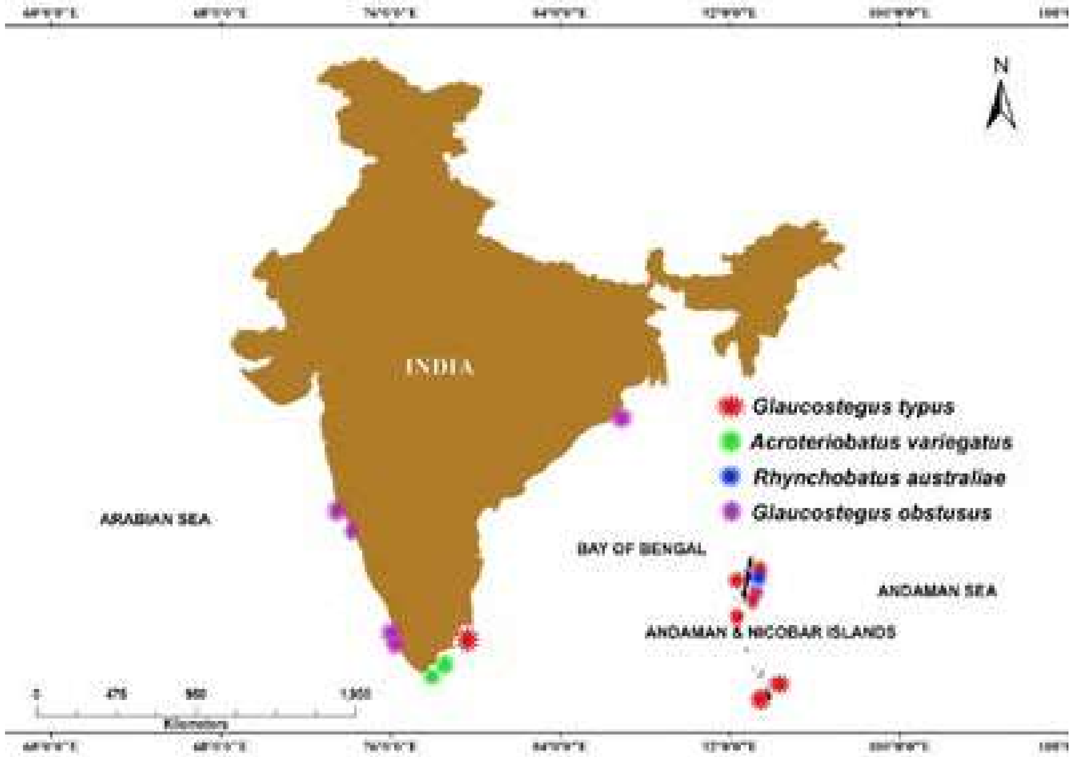

Fig.6 Potential nursery grounds of batoid fishes in Indian waters

Discussion

Batoids are one of the most vulnerable groups of fishes due to their biological characteristics and these apex predators are under intensive fishing pressure and decline of their stocks are a global concern (Stevens *et al.*, 2000; Dulvy *et al.*, 2014). During the present study 77 species of batoids were recorded across Indian coasts, of them 21% of the species are Vulnerable and 19% are Endangered and Data Deficient respectively. Remaining 16% are Critically Endangered, 9% are not evaluated and Least Concern and 7% Near Threatened respectively. Due to the close morphological features between the species within a family, several Indian records of batoids are misidentification and a detailed taxonomic review of Indian batoids is need of the hour to prevent misidentification and confusion. Many species under the genus *Brevitrygon*, *Telatrygon*, *Torpedo Aetobatus*, *Dipturus* and *Benthobatis* requires detailed taxonomic analysis to reveal the accurate species diversity of batoids in India.

Currently 77 valid species of batoids are present in Indian waters; names of several species were changed or synonymised based on the latest taxonomic works. *Torpedo zugmayeri* Engelhardt, 1912 (syn to *Torpedo sinuspersici* Olfers, 1831); *Rhinobatus annulatus* (Müller & Henle, 1841) is restricted to South West Indian Ocean (South Africa) (Last *et al.*, 2016) and it was not recorded during the last decade from Indian waters. Hence it is omitted from the Indian records. Similarly *Dasyatis centroura* (Mitchill, 1815) (syn to *Bathytoshia centroura* (Mitchill, 1815) is also omitted from Indian batoid checklist as it is a Western Atlantic species (Last *et al.*, 2016). Further, batoids like Angel shark *Squatina squatina* (Linnaeus, 1758) and African angel shark *Squatina africana* Regan, 1908 species restricted to Mediterranean waters, Atlantic Ocean (Last *et al.*, 2016) were listed in Indian batoids. Recently, Ambily *et al.* (2018) recorded a specimen of *Squatina africana* from Indian waters based on a single specimen landed at Kochi, Kerala. However multi day liners of Indian origin operating from Northern Kerala will sail beyond Indian EEZ and may catch such species from their habitat. So both the species of *Squatina* were omitted from the updated checklist. Further studies of batoids using integrative taxonomic approach using various molecular markers, focused studies on biology, nursery grounds, critical habitat, current distribution patterns and ecology should be endorsed to strengthen the conservation and management plan of batoids in Indian waters.

Table 1. Updated checklist of batoids reported/listed from Indian waters

Sl No	Family	Species	IUCN Status	WPA	CITES
1	PRISTIDAE	*Anoxypristis cuspidata* (Latham, 1794)	Endangered (EN)	I	I
2		*Pristis clavata* Garman, 1906	Endangered (EN)	I	I
3		*Pristis pristis* (Linnaeus, 1758)	Critically Endangered (CR)	I	I
4		*Pristis zijsron* Bleeker, 1851	Critically Endangered (CR)	I	I
5	RHINIDAE	*Rhina ancylostomus* Bloch & Schneider, 1801	Critically Endangered (CR)	I	II
6		*Rhynchobatus laevis* (Bloch & Schneider, 1801)	Critically Endangered (CR)	I	II
7		*Rhynchobatus australiae* Whitley, 1939	Critically Endangered (CR)	I	II
8		*Rhynchobatus djiddensis* (Forsskal 1775)	Critically Endangered (CR)	I	II
9	RHINOBATIDAE	*Acroteriobatus variegatus* Nair & Lal Mohan, 1973	Critically Endangered (CR)		II
10		*Rhinobatos annandalei* Norman, 1926	Data Deficient (DD)		II
11		*Rhinobatos lionotus* Norman, 1926	Data Deficient (DD)		II
12		*Rhinobatos punctifer* Compagno & Randall, 1987	Near Threatened (NT)		II
13	GLAUCOSTEGIDAE	*Glaucostegus granulatus* (Cuvier, 1829)	Critically Endangered (CR)		II
14		*Glaucostegus obtusus* (Muller & Henle, 1840)	Critically Endangered (CR)	I	II
15		*Glaucostegus thouin* (Anonymous, 1798)	Critically Endangered (CR)	I	II
16		*Glaucostegus typus* (Anonymous [Bennett] 1830)	Critically Endangered (CR)		II
17	NARCINIDAE	*Benthobatis moresbyi* Alcock, 1898	Least Concern (LC)		
18		*Narcine atzi* Carvalho & Randall, 2003	Data Deficient (DD)		
19		*Narcine brevilabiata* Bessednov, 1966	Vulnerable (VU)		
20		*Narcine lingula* Richardson, 1840	Vulnerable (VU)		
21		*Narcine maculata* (Shaw, 1804)	Vulnerable (VU)		
22		*Narcine prodorsalis* Bessednov, 1966	Data Deficient (DD)		
23		*Narcine timlei* (Bloch & Schneider, 1801).	Data Deficient (DD)		
24	NARKIDAE	*Narke dipterygia* (Bloch & Schneider, 1801)	Data Deficient (DD)		
25	TORPEDINIDAE	*Torpedo panthera* Olfers, 1831	Data Deficient (DD)		
26		*Torpedo sinuspersici* Olfers, 1831	Data Deficient (DD)		
27	GURGESIELLIDAE	*Cruriraja andamanica* (Lloyd, 1909)	Data Deficient (DD)		
28		*Fenestraja mamillidens* (Alcock, 1889)	Least Concern (LC)		
29	RAJIDAE	*Dipturus johannisdavisi* (Alcock 1899).	Data Deficient (DD)		

Sl No	Family	Species	IUCN Status	WPA	CITES
30		*Dipturus springeri* (Wallace, 1967)	Least Concern (LC)		
31		*Okamejei powelli* (Alcock, 1898)	Data Deficient (DD)		
32	HEXATRYGONIDAE	*Hexatrygon bickelli* Heemstra & Smith, 1980	Least Concern (LC)		
33	PLESIOBATIDAE	*Plesiobatis daviesi* (Wallace, 1967)	Least Concern (LC)		
34	GYMNURIDAE	*Gymnura poecilura* (Shaw, 1804)	Near Threatened (NT)		
35		*Gymnura zonura* (Bleeker, 1852)	Vulnerable (VU)		
36		*Gymnura tentaculata* (Müller & Henle, 1841)	Data Deficient (DD)		
37	DASYATIDAE	*Brevitrygon imbricata* (Bloch & Schneider, 1801)	Data Deficient (DD)		
38		*Brevitrygon walga* (Müller & Henle, 1841)	Near Threatened (NT)		
39		*Hemitrygon bennetti* (Müller & Henle, 1841)	Vulnerable (VU)		
40		*Himantura leoparda* Manjaji-Matsumoto & Last, 2008	Vulnerable (VU)		
41		*Himantura marginata* (Blyth, 1860)	Data Deficient (DD)		
42		*Himantura tutul* Borsa, Durand, Shen, Alyza, Solihin & Berrebi, 2013	Not Evaluated		
43		*Himantura uarnak* (Forsskål, 1775)	Vulnerable (VU)		
44		*Himantura undulata* (Bleeker, 1852)	Endangered (EN)		
45		*Urogymnus arabica Manjaji-Matsumoto & Last, 2016*	Critically Endangered (CR)		
46		*Maculabatis bineeshi*Manjaji-Matsumoto & Last, 2016	Not Evaluated		
47		*Maculabatis gerrardi* (Gray, 1851)	Endangered (EN)		
48		*Megatrygon microps* (Annandale, 1908)	Data Deficient (DD)		
49		*Neotrygon caerulopunctatus* Last, White & Séret 2016	Not Evaluated		
50		*Neotrygon indica* Pavan-Kumar, Kumar, Pitale, Shen, Borsa 2018	Not Evaluated		
51		*Pastinachus ater*(Macleay, 1883)	Least Concern (LC)		
52		*Pastinachus gracilicaudus* Last & Manjaji-Matsumoto, 2010	Not Evaluated		
53		*Pastinachus sephen* (Forsskål, 1775)	Near Threatened (NT)		
54		*Pateobatis jenkinsii* (Annandale, 1909)	Vulnerable (VU)		
55		*Pateobatis bleekeri* (Blyth, 1860)	Endangered (EN)		
56		*Pateobatis fai* (Jordan & Seale, 1906)	Vulnerable (VU)		
57		*Pteroplatytrygon violacea* (Bonaparte, 1832)	Least Concern (LC)		
58		*Taeniura lymma* (Forsskål, 1775)	Near Threatened (NT)		

Sl No	Family	Species	IUCN Status	WPA	CITES
59		*Taeniurops meyeni* (Müller & Henle, 1841)	Vulnerable (VU)		
60		*Telatrygon crozieri* (Blyth,1860)	Not Evaluated		
61		*Urogymnus asperrimus* (Bloch & Schneider, 1801)	Vulnerable (VU)	I	
62		*Urogymnus granulatus* (Macleay, 1883)	Vulnerable (VU)		
63		*Urogymnus polylepis* Bleeker, 1852	Endangered (EN)	I	
64	**MYLIOBATIDAE**	*Aetomylaeus maculatus* (Gray, 1832)	Endangered (EN)	II	
65		*Aetomylaeus milvus* (Müller & Troschel 1841)	Endangered (EN)	II	
66		*Aetomylaeus nichofii* (Bloch & Schneider, 1801)	Vulnerable (VU)		
67		*Aetomylaeus vespertilio* (Bleeker 1851)	Endangered (EN)	II	
68	**AETOBATIDAE**	*Aetobatus flagellum* (Bloch & Schneider, 1801)	Endangered (EN)		
69		*Aetobatus ocellatus* (Kuhl, 1823)	Vulnerable (VU)		
70	**RHINOPTERIDAE**	*Rhinoptera javanica* Müller & Henle, 1841	Vulnerable (VU)		
71		*Rhinoptera jayakari* Boulenger, 1895	Not Evaluated		
72	**MOBULIDAE**	*Manta alfredi* (Krefft,1868)	Vulnerable (VU)	I	II
73		*Manta birostris* (Walbaum, 1792)	Endangered (EN)	I	II
74		*Mobula kuhlii* (Müller & Henle 1841).	Endangered (EN)		II
75		*Mobula mobular* (Bonnaterre, 1788)	Endangered (EN)		II
76		*Mobula tarapacana* (Philippi 1892).	Endangered (EN)	II	II
77		*Mobula thurstoni* (Lloyd, 1908)	Endangered (EN)		II

Acknowledgments

We express our sincere thanks to the Director, Zoological Survey of India for the support and facilities provided during the study. We are grateful to the Director General, Fishery Survey of India, Mumbai for the support and encouragement during the study

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Biosystematics and Biogeography of Indian Mantodea (Insecta)

Sureshan, P. M.*[1] and Kamila, A.P[2]
Zoological Survey of India, Western Ghat Regional Centre
Kozhikode 673006, Kerala, India.
pmsuresh43@gmail.com [1], kamiii619@gmail.com [2]

Abstract
Praying mantises are always been an attractive insect group. Even though they are charismatic, the studies on them are still untouched in many parts of the world. Here, we are discussing the biosystematics and biogeography of praying mantids of India.

Introduction
The order Mantodea (Insecta) popularly called "Praying mantises", "Preying mantids" etc. includes large predatory insects, distributed in tropical and subtropical habitats of the world. They are small to large, stubby to elongate, rather slow moving insects that are striking in appearance because of their peculiarly modified forelegs. They have a head which is freely movable and they are the only group of insects that can rotate the head to 180 degrees. The size of mantids ranges from 1cm to more than 17cm and females are usually larger than males. Mantids also exhibit interesting behaviour patterns such as camouflage, mimicry and cannibalism. They groom themselves frequently; they wipe their eyes and head using their forelegs, clean their forelegs with the mouth. When faced with danger, most species attempt to run or fly away while some do assume a threatening posture. Mantids remain motionless for hours together, often on a suitable place like flowers that attract insects, with only the head moving to watch approaching insects that serve as their food. Mantids are exclusively carnivorous feeding mainly on other arthropods as well as small vertebrates, thus having a very important ecological role in the suppression of herbivorous insect populations including major agriculture pests (Symondson *et al.*, 2002). Though ecologically important, the studies on preying mantids have been largely ignored and in Indian context the situation is also not encouraging. The present study is the compilation of information from literatures to detail the biosystematics and biogeography of Indian praying mantids.

Biosystematics
The early works on mantid fauna of India were started in the late 1700s. Major studies on Indian Mantodea were undertaken mainly by foreigners like Thunberg, Saussure, Stål, Burmeister, Beier, Uvarov etc. during the pre-independence period. One of the significant contributor on Indian Mantodea was Wood-Mason (1889, 1891), the then curator of Indian Museum, Calcutta. In the early 1930s, Werner made notable contributions to the study of Indian mantid fauna. The contributions by Indian scientists are very negligible during the post-independence period. After the independence, Nadkerny (1965) studied the collections of mantids at Bombay Natural History society. Mukherjee and Hazra (1983-1992) published several papers on Indian Mantodea which included many new taxa. Mukherjee *et al.* (1995) compiled a comprehensive list with a possible dichotomous key up to specific level of Indian mantids which included 162 species under 68 genera and 6 families.

*Author for correspondence : pmsuresh43@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Thereafter some studies on regional mantid fauna of various Indian states are being undertaken by scientists and such studies yielded some new distributional records and few new taxa. In 2014, Mukherjee *et al.* compiled the checklist of Indian Mantodea following the then latest classification by Ehrmann (2002). Accordingly, 169 species under 71 genera and 11 families were listed out from India. The classification of Mantodea was always in a state of flux and the most relevant system of classification of the order were Giglio-Tos (1919), Handlirsch (1930), Chopard (1949), Beier (1964) and Ehrmann (2002). Recently, Schwarz and Roy (2019) provided the latest classification system for Mantodea based mainly on male genital structure supplemented by morphological, chromosomal and molecular data. Accordingly, more than 2500 species of mantids belonging to 436 genera under 31 families are known worldwide (Anderson, 2022) out of which 169 species under 69 genera in 13 families and 7 superfamilies are known from the country (Kamila and Sureshan, 2022b). The contribution of Indians towards the enrichment of Indian mantid fauna is only 2 genera and 20 species since the late nineties to till date. Recently, two species from Southern Western Ghats were newly described (Kamila and Sureshan, 2022a; Sureshan *et al.,* 2023).

The Indian families and subfamilies present in the order Mantodea are given below (Kamila and Sureshan, 2022b).

CLASS INSECTA

ORDER MANTODEA

I. Superfamily METALLYTICOIDEA Giglio-Tos, 1917

1. Family Metallyticidae Giglio-Tos, 1917

II. Superfamily EREMIAPHILOIDEA Saussure, 1869

2. Family Eremiaphilidae Saussure, 1869

Subfamily: Eremiaphilinae
Iridinae
Parathespinae

3. Family Rivetinidae Ehrmann & Roy, 2002

Subfamily: Deiphobinae
Rivetininae

4. Family Toxoderidae Saussure, 1869

Subfamily: Oxyothespinae
Toxoderinae

III. Superfamily GONYPETOIDEA Westwood, 1889

5. Family Gonypetidae Westwood, 1889

Subfamily: Gonypetinae
Iridopteryginae

IV. Superfamily HAANIOIDEA Giglio-Tos, 1915

6. Family Haaniidae Giglio-Tos, 1915

Subfamily: Caliridinae
Haaniinae

V. Superfamily HYMENOPOIDEA Giglio-Tos, 1915

7. Family Empusidae Burmeister, 1838

Subfamily: Blepharodinae
Empusinae

8. Family Hymenopodidae Giglio-Tos, 1915

Subfamily: Acromantinae
Hymenopodinae
Oxypilinae
Phyllothelyinae

VI. Superfamily MANTOIDEA Latreille, 1802

9. Family Deroplatyidae Westwood, 1889

Subfamily: Deroplatyinae

10. Family Mantidae Latreille, 1802

Subfamily: Choeradodinae
Hierodulinae
Mantinae
Tenoderinae

VII. Superfamily NANOMANTOIDEA Brunner De Wattenwyl, 1893

11. Family Amorphoscelidae Stål, 1877

Subfamily: Amorphoscelinae

12. Family Leptomantellidae Schwarz & Roy, 2019

13. Family Nanomantidae Brunner De Wattenwyl, 1893

Subfamily: Nanomantinae
Tropidomantinae

The diversity of mantid fauna of Maharashtra, Kerala, Tamil Nadu, Uttar Pradesh and West Bengal are better documented when compared to the other parts of the country (Table-1). The ecological regions of deserts and semi-arid areas, Andaman and Nicobar Islands, North-East India, Gangetic plains, Central India and major parts of the Deccan plateau are very poorly explored for mantid collections. Studies on the ecology, biology, ethology and phylogeny of this interesting group of insects are also greatly neglected in India.

Table- 1. The state-wise status of mantid fauna.

States/ Union-territories	Number of genera	Number of species
Andhra Pradesh	25	31
Arunachal Pradesh	14	21
Assam	23	27
Bihar	17	20
Chhattisgarh	26	33
Gujarat	8	9
Goa	8	9
Haryana	0	0
Himachal Pradesh	14	21
Jharkhand	7	7
Karnataka	29	39
Kerala	41	68
Madhya Pradesh	18	27
Maharashtra	29	55
Manipur	8	9
Meghalaya	17	25
Mizoram	0	0
Nagaland	4	4
Odisha	19	27
Punjab	4	4
Rajasthan	10	11
Sikkim	10	17
Tamil Nadu	34	53
Telangana	5	6
Tripura	1	1
Uttar Pradesh	28	49
Uttarakhand	1	1
West Bengal	29	45

States/ Union-territories	Number of genera	Number of species
Andaman & Nicobar	8	12
Chandigarh	2	2
Dadra Nagar Haveli, Daman & Diu	1	1
Delhi	0	0
Jammu & Kashmir	4	4
Ladakh	0	0
Lakshadweep	1	1
Puducherry	3	3

Biogeography

The biogeography of world Mantodea has not been much studied until the 21st century. There have been several publications dealing with the biogeography of praying mantids of different areas. They are; Rivera and Cobián (2017) on Peruvian mantids, Ursani *et al.* (2017) on mantids of Punjab, Pakistan, Okely *et al.* (2020) on Egyptian mantids. The main biogeographic works on single taxa are; Rivera *et al.* (2011) on the genus *Pseudopogonogaster* Beier, 1942; Shcherbakov (2017) on the genus *Parapsychomantis* Shcherbakov, 2017; Rivera (2017) on Neotropical polymorphic earless praying mantises.

Mantodea is generally assumed to be poor dispersers (non-migrants) (Johnson 1969). However, the ootheca of mantids are resistant to all kinds of harsh conditions and this allows for an easy distribution of species via floating driftwood or human dispersal (Salt and James, 1947; Ehrmann 2002). It is also assumed that several interesting disjunctive distributions among extant and fossil Mantodea worldwide may be due to the same reasons. The most comprehensive study on the biogeography of Mantodea was published by Svenson and Whiting (2009) based on molecular data.

The studies on the mantid fossils indicate that mantids originated in the early Jurassic period and most modern mantises originated on Gondwana in the Cretaceous (Svenson and Whiting, 2009). Mantid fauna of the Oriental region shows close affinity with that of the Afrotropical and Australasian regions. Neotropical and Nearctic elements are very rarely reported from the region. The occurrence of a Neotropic Subfamily Choeradodinae represented by the genus *Asiadodis* in the Oriental region is an example of disjunctive distribution. As per the classification of Schwarz and Roy (2019), three families (Metallyticidae, Leptomantllidae and Haaniidae) and seven subfamilies (Tropidomantinae, Iridopteryginae, Deiphobinae, Parathespinae, Iridinae, Phyllothelinae and Deroplatyinae) are endemic to the Oriental region. The other families occurring in the Oriental region are Gonypetidae, Hymenopodidae, Mantidae, Deroplatyidae, Rivetinidae, Toxoderidae, Empusidae, Eremiaphilidae, Amorphoscelidae and Nanomantidae. An analysis of the distributional data of Indian taxa shows that the mantid fauna of India is mainly composed of Oriental elements at the generic level. Among the 69 genera reported from the country 57 are distributed only in the oriental region and out of which 7 genera endemic to India (*Dysaulophthalma, Pararivetina*, *Cotigaonopsis*, *Indothespis*, *Toxodanuria, Indomenella* and *Parananomatis*). Four genera (*Amorphoscelis*, *Iris, Blepharopsis* and *Empusa*) are common in the Oriental and Afrotropical regions. The genera *Mantis* and *Tenodera* have a wider distribution and are common in the Oriental, Afrotropical, Palearctic and Australian regions. The genera *Nanomantis*, *Acromantis*, and *Tamolanica* are common in the Oriental and Australasian regions while the genera *Toxomantis* and *Euthyphleps* are common in the Oriental and Palearctic regions. The genus *Statilia* occur in Oriental, Afrotropical and Australasian regions and the genus *Hierodula* occur in Oriental, Palearctic and Australaisan regions.

The analysis of the available data shows that some species of *Mantis, Statilia, Tenodera, Hierodula*, *Humbertiella*, *Eomantis* and *Amorphoscelis* are widely distributed in the country. Species like *Didymocorypha lanceolata* (Fabricius, 1798), *Schizocephala bicornis* (Linnaeus, 1758), *Gongylus gongylodes* (Linnaeus, 1758), *Creobroter apicalis* Saussure, 1869 and *Ephestiasula rogenhoferi* (Saussure, 1872) were reported from almost all parts of the country. The species of family Eremiaphilidae is restricted to the semi-arid area of the country. Twelve species of mantids are so far reported from Andaman and Nicobar Islands including an endemic species viz. *Acromantis nicobarica* Mukherjee, 1995 while only one species (*Hierodula tenuidentata* Saussure, 1869) is reported from Lakshadweep Islands which is probably an introduced species. The records of some species from the island ecosystems may be due to introduction from the main land. The fauna of South and North Eastern India appears richer than other parts of the country indicated by the occurrence of rare taxa. More interesting taxa of mantids will be discovered from the tropical rainforests of Western Ghats and North east India if serious field explorations are undertaken in these regions. Because of the incompleteness in the field explorations and collection of specimens throughout the country, it is very difficult to make a general statement on the distributional patterns of mantids at species level.

Discussion

Though order Mantodea is considered an economically important group of insects, the group has been greatly neglected for biosystematics from India. Taxonomic revisions of mantid taxa supplemented by the modern tools of molecular studies are very essential. Due to the incompleteness of field studies and poor documentation of diversity, it is not possible to predict a pattern of distribution for Indian Mantodea. Being a less studied group of insects, taxonomic research in the group has to be promoted in order to understand the mantid biodiversity of the country and utilizing them for biological control programmes against agricultural pests. Detailed studies on the life history, ecology, ethology, phylogeny or any other facet of mantid life will also be highly rewarding in entomological science.

Acknowledgment

We are thankful to the Director, Zoological Survey of India, Kolkata for giving the opportunity and facilities. We are also grateful to the Officer-in-Charge, WGRC, Zoological Survey of India, Kozhikode for the support and encouragement. The second author is thankfully acknowledges University of Calicut for giving the opportunity to do the Ph.D., and University Grand Commission for the funding.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Occurrence of Soil-Inhabiting Nematoda (Dorylaimida and Tylenchida) in Some Protected Areas and Tea Estates of Assam with Four New Records of Dorylaimida from India

Debabrata Sen and Samprit Deb Roy
Zoological Survey of India, M-Block
New Alipore, Kolkata- 700053

Abstract

During a survey in 2018, soil samples were collected to explore the occurrence and diversity of soil-inhabiting nematode in some of the districts of Assam state including several protected areas and Tea Estates/gardens which have immense economic importance. The soil samples were processed by Cobb's Sieving and Decantation Method and the extraction of nematodes was done by modified Baerman Funnel Technique. 25 Nematodes have been reported from several conservation areas and Tea gardens. Among these, 21 species belong to the order Dorylaimida and 4 to the order Tylenchida. Out of these nematodes, 15 species are reported as new distributional records from Assam. Four species, *Mesodorylaimus bastiani* (Butschli, 1873) Andrassy, 1959, *Aporcelaimellus taylori* Yeates, 1967, *Makatinus punctatus* Heyns, 1965 and *Nygolaimus macrobrachyurus* (Heyns, 1968) Thorne, 1974 are recorded for the first time from India. The nematodes reported exhibited various feeding habits like omnivore, herbivore, predatory & predatory- omnivore.

Keywords: Soil-inhabiting Nematoda, Assam, Protected areas, Tea gardens, New records, Trophic groups.

Introduction

A survey was conducted in different districts of Assam in 2018. Soil samples were collected to explore the occurrence and diversity of soil-inhabiting nematode fauna from several protected areas and Tea Estates/gardens having immense economic importance. Soil samples were collected from Pobitora Wildlife Sanctuary, Morigaon district; Nameri forest range of Nameri National Park and Bhomoraguri Reserve Forest, Shonitpur district; Jeypore Forest Range of Dehing-Patkai Wildlife Sanctuary and Mariani Forest Range of Hollongapar Gibbon Wildlife Sanctuary, Jorhat district along with Panbari Tea Estate, Golaghat district; Experimental garden of Tocklai Tea Research Institute and Holangooree Tea Estate, Jorhat district; Burrapahar Tea Estate, Nawgaon district.

Nematodes are important for their significant role, both beneficial and harmful, in soil ecosystem as well as for their agricultural importance from economic point of view as they are responsible for crop loss. These micro-organisms are significantly important for decomposition in soil ecosystem (Yeates and Coleman, 1982) and are responsible for nitrogen mineralization and nutrient cycling in soil micro-habitat. They are bio-indicators of soil health because of their presence in all possible habitats and diverse feeding habits (Bongers and Bongers, 1998; Neher, 2001).

Literature review revealed significant works on soil and phytonematodes from Assam although the reports from protected areas are meagre. Das (1958) first reported the occurrence of *Meloidogyne hapla*, *Meloidogyne incognita* and *Pratylenchus* sp. from the soil of tea seedlings from Tocklai experimental station, Jorhat district, Assam. Jairajpuri (1964a, b, c) described *Basirotyleptus basiri*, *Dorylaimellus curvatus* and reported *Tyleptus striatus*, *Nygellus clavatus*, *Belondira ortha* from the soil around tea plantations and sugarcane of Jorhat district. *Paratylenchus pseuduncinatus* was described and *Hoplolaimus indicus* was reported by Phukan and Sanwal (1979, 1980) from the soil associated with tea plant in Jorhat district. Ahmad and Jairajpuri (1987) reported *Oriverutus sundarus* from TTRI in Jorhat district. Saha *et al.* (2000) described *Helicotylenchus assamensis*

*Author for correspondence : debabrata.zsi@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

from Assam. Mushtaq *et al.* (2006) reported *Mylodiscus nanus* Thorne, 1939, Ahmad *et al.* (2010) described a new genus *Rhinodorylaimus* to accommodate a new species *Rhinodorylaimus kazirangus*, Baniyamuddin and Ahmad (2011) described two new species along with one known species from Kaziranga National Park. In recent times, significant contributions to the study of soil-inhabiting nematodes were done by Deuri *et al.* (2016), Das *et al.* (2016), Jena *et al,* (2017) and Khan *et al.* (2017).

Distribution of twenty-five species of soil-inhabiting Nematodes from the above mentioned conservation areas and Tea gardens along with their distribution in forest ecosystem and agro-ecosystem were observed (Table 1, Fig. 1, 2 & 3). Among these twenty-one species belong to the order Dorylaimida and four to the order Tylenchida. Fifteen species are reported as new distributional record from Assam (Table 1). Four species have been recorded for the first time from India. In the present study, nematodes with various feeding habits like omnivore, herbivore, predatory & predatory-omnivore exhibiting different trophic levels were observed (Table 1, Fig. 4 & 5).

Materials and Methods

For the present study, soil samples were collected from rhizosphere of various plants from forest ecosystem (conservation areas) and agro-ecosystem (agricultural fields in the buffer zone of protected areas and tea gardens) with the help of a hand-shovel. At the time of collection, the collection data were kept and the geographical position of a particular sampling site was recorded by a GPS. The collected soil samples were processed by 'Cobb's sieving and decantation technique' (Cobb, 1918) followed by 'modified Bearmann's funnel technique' (Christie and Perry, 1951) to extract the nematodes. The extracted nematodes were killed and fixed instantly in their characteristic body posture by Seinhorst's method in hot Formaldehyde-acetic acid solution (FA) solution. These were preserved in the same solution with appropriate labels. The specimens were transferred in cavity blocks containing glycerine-alcohol and were kept in a desiccator for 3 to 6 weeks. After complete dehydration of the specimens, permanent slides were prepared by using anhydrous glycerine as a mountant medium. Permanent slides were prepared by the wax ring method. The nematodes were observed and studied under a Nikon eclipse Ni DIC microscope (model YTV55) for taxonomic studies and identification. Photomicrographs were taken with the digital camera, attached with the same microscope.

Systematic Account of the New Records from India

Phylum NEMATODA Rudolphi, 1808 (Lankester, 1877)

Order DORYLAIMIDA Pearse, 1942

Suborder DORYLAIMINA Pearse, 1936

Superfamily DORYLAIMOIDEA De Man, 1976

Family DORYLAIMIDAE De Man, 1976

Subfamily LAIMYDORINAE Andrássy, 1969

Genus *MESODORYLAIMUS* Andrassy, 1959

1. ***Mesodorylaimus bastiani*** (Butschli, 1873) Andrassy, 1959

Family APORCELAIMIDAE Heyns, 1965

Subfamily APORCELAIMINAE Heyns, 1965

Genus *APORCELAIMELLUS* Heyns, 1965

2. ***Aporcelaimellus taylori*** Yeates, 1967

Genus *MAKATINUS* Heyns, 1965

3. ***Makatinus punctatus*** Heyns, 1965

Suborder NYGOLAIMINA Ahmad & Jairajpuri, 1979

Superfamily NYGOLAIMOIDEA Thorne, 1935

Family NYGOLAIMIDAE Thorne, 1935

Subfamily NYGOLAIMINAE Thorne, 1935

Genus *NYGOLAIMUS* Cobb, 1913

4. ***Nygolaimus macrobrachyurus*** (Heyns, 1968) Thorne, 1974

Genus *MESODORYLAIMUS* Andrassy, 1959
Mesodorylaimus bastiani (Butschli, 1873) Andrassy, 1959
(Plate 1: A- G; Table 2)

Material examined: 2 females, 2 males. India, Assam, Morigaon dist., Pobitora Wild Life Sanctuary, Lat 26°14.534N and long 092°02.926E, 31-i-2018, coll. D. Sen (Reg. No. ZSI/WN2239/2).

Diagnosis: Female: Body slender, slightly ventrally curved on fixation. Cuticle smooth, thicker on tail. Lip region almost continuous or slightly offset by weak depression, lips amalgamated. Odontostyle about 1.5 times the labial diameter, its aperture occupying 33.3 – 35.7% or about one-third of odontostyle length. Guiding ring single, 0.9 – 1.1 lip region-width from anterior end. Odontophore straight, 1.4 times the odontostyle length. Nerve ring 11 – 11.1 labial diameters from anterior end or at 32.0 - 33.6% of the pharyngeal length. Reproductive system amphidelphic. Vulva transverse, pre- to slightly post-equatorial. Vagina extending inward more than half (54 – 61%) of the corresponding body width. Posterior gonad and ovary longer than the anterior. Prerectum 3.8 – 4.0, rectum 0.8 – 1.3 anal body-widths long. Tail straight, elongated, consisting of an anterior convex-conoid portion followed by a slender portion, narrowing on both sides, tapering continuously to an acute or finely rounded terminus. Posterior narrow portion of tail longer than anterior conical portion, 2.2 – 2.6 times of the anterior wide part.

Males: Similar to female in general body shape and morphology except reproductive system and tail shape. Supplements consist of 14 – 16 regularly spaced ventromedians and an adanal pair. Spicules 1.6 anal body-widths long. Lateral guiding piece about one-third to one-fourth of spicule length. Prerectum 4.1 – 4.2 and rectum about 1.0 anal body-widths long. Tail short, rounded, slightly concave ventrally.

Habitat: Soil around the roots of unidentified wild plant.

Distribution in world: Holland, Germany, Sweden, Poland, Austria, United States, Mexico, Australia, Czechoslovakia, Hungary, Yugoslavia, Spain, France, Italy, Russia, Ukraine, Estonia, Latavia, Lithuania, Georgia, Armenia, Uzbekistan, Morocco, Cameroon, Tanzania, Zaire, South Africa, Mauritius, Java, Sumatra .

Remark: Mesodorylaimus bastiani can be distinguished in having elongated tail consisting of a conical part followed by a slender portion which tapers to an acute or finely rounded tip in female. The present specimens of *Mesodorylaimus bastiani* (Butschli, 1873) Andrassy, 1959, reported from India, agree well with the type and other reported specimens of the species except the number of ventromedian supplements in males (number of supplements in type species is 9 – 13 and 8 – 11 in the specimens reported from Spain by Pena-Santiago *et al.*, 2000 *vs.* 14 – 16 in the present specimens). Since the morphology and all other morphometric measurements show similarities with the previously reported specimens, the difference in the number of supplements may be considered as an intraspecific variation for the specimens reported from India. Yeates (1993) categorized *Mesodorylaimus* as an omnivore. The predatory behaviour of M. *bastiani* was observed on bacterial feeder, other predatory groups and on the phytonematodes of different feeding habits (Bilgrami, 1995; Bilgrami *et al.* 2001). This is the first record of the species from India.

Genus *APORCELAIMELLUS* Heyns, 1965

Aporcelaimellus taylori Yeates, 1967

(Plate 2: A – H; Table 3)

Material examined: 2 females, 1 juvenile. India, Assam, Nawgaon district: Burrapahar: Rangalu Paharguri village, Lat 26°34.541N and long 093°01.007E, 04-ii-2018, coll. D. Sen (Reg. No. ZSI/WN2467).

Diagnosis: Female: Body ventrally curved on fixation, the posterior portion in particular in one specimen, slightly tapering towards anterior end. Cuticle distinctly in two layers, thick near labial region at the level of odontostyle and on tail. Lip region clearly set off by constriction, almost same or slightly wider than adjoining body, 16.5 – 17.0mm wide or about 1/3.5 of body width at neck base. Amphids stirrup-shaped. Odontostyle 1.1 – 1.2 times the labial diameter, its aperture slightly more than half or occupying about 57.5 – 57.8% of odontostyle length. Guiding ring 0.5 – 0.6 lip region-width from anterior end. Odontophore rod-like, 1.7 – 1.8 times the odontostyle length. Nerve ring 9.1 – 11.1 labial diameters from anterior end or at 27.0 - 33.4% of the pharyngeal length. Expanded part of pharynx about half or 49.8 – 51.5% of the pharyngeal length. Thin cardiac disc present, cardia conoid, about one-third or 1/2.7 – 1/3.4 neck base width long. Vulva transverse, post-equatorial. Vagina extending inward about half or 46.7 – 49.2% of the corresponding body width (length of *pars proximalis* vagina 21.0 – 17.6mm, *pars refringens* 5.0 – 7.0mm and combined width (CW) 9.0 – 10.0mm and *pars distalis* 3.0mm), distally sclerotized. Female genital system amphidelphic, both ovaries reflexed, both the gonads equally developed. Prerectum 2.4 – 3.5 and rectum 1.2 – 1.4 anal body diameters long. Tail short, 0.9 – 1.0 anal body diameter long, convex and uniformly conoid ending in a rounded terminus.

Male: Not found.

Juvenile: Morphologically similar to female with a shorter body length and some relevant differences in morphometric measurements, shown in table 3.

Habitat: Soil around the roots of paddy (*Oryza sativa*).

Distribution in world: New Zealand, U.S.A, Pakistan.

Remark: Aporcelaimellus taylori can be recognized by the thick cuticle near the head and uniformly conoid tail. Yeates (1967) described the species from New Zealand. Thorne (1974) reported this species from USA. Álvarez-Ortega *et al.* (2012) proposed a new combination of the species as *Aporcella taylori* (Yeates, 1967) Álvarez-Ortega, Subbotin

& Peña-Santiago, 2012. The present female specimens of *Aporcelaimellus taylori* Yeates, 1967, reported from India, agree well morphologically with the type and other reported specimens of the species except some minor morphometric variations (in the type specimen tail is longer evident from 'c' value. c = 46 in type *vs.* 60.9 – 73.5 in the present specimens. In the reported specimens prerectum slightly longer than body diameter *vs.* 2.4 – 3.5 anal body diameter in the present specimens). This is the first record of the species from India.

Genus *MAKATINUS* Heyns, 1965
Makatinus punctatus Heyns, 1965
(Plate 3: A-F; Table 3)

Material examined: 1 female. India, Assam, Golaghat dist., Bokakhat, Panbari Tea Estate, Lat 26°37.385N and long 093°31.559E, 04-ii-2018, coll. D. Sen (Reg. No. ZSI/WN2403).

Diagnosis: Female: Body ventrally curved on fixation, particularly the posterior portion, slightly tapering towards anterior end. Cuticle in two layers, thicker on tail. Lip region set off by weak constriction, its width about one-fifth of body width at neck base. Amphids funnel-shaped. Odontostyle strong and wide, ventral arm with thick wall, length equal to labial diameter, aperture more than half or occupying about 62% of odontostyle length. Guiding ring about half lip region-width from anterior end. Odontophore about twice the odontostyle length. Nerve ring 8.6 labial diameters from anterior end. Pharynx muscular, expanded part of pharynx slightly more than half or 52.5% of the pharyngeal length. Vulva transverse, heavily sclerotized distally, post-equatorial. Vagina extending inward little less than one-third or 36.5% of the corresponding body width (length of *pars proximalis* vagina 42mm, *pars refringens* 16mm and combined width (CW) 18mm and *pars distalis* 2.0mm). Female reproductive system amphidelphic. Prerectum 2.8 and rectum 0.8 anal body diameters long. Tail short, convex both dorsally and ventrally 0.4 anal body diameter long, conically ending in a small hyaline projection of digitate terminus.

Male: Not found.

Habitat: Soil around the roots of tea plant (*Camellia sinensis*).

Distribution in world: South Africa, U.K., USA, California, Hawaii, Netherland, Venezuela.

Remark: Makatinus punctatus can be characterized by its tail conically ending in a small hyaline projection of digitate terminus. Heyns (1965) described the species from South Africa. Pena-Santiago and Varela (2017) reviewed the genus *Makatinus* Heyns, 1965 and observed that *Makatinus punctatus* perfectly agrees with the characteristics of the genus and the species differs from all other species of genus by its typical conical tail shape with a small digitate terminal hyaline projection. The present single female specimen of *Makatinus punctatus,* reported from India, shows clear affinity and similarity to the type specimens in general morphology having some variation in morphometric measurements (in female type specimens L = 2.40 - 3.17mm, a – 36 – 42, b = 4.2 – 4.4, c = 84 – 99, $c^{/}$ = 0.7, odontostyle = 25 - 27mm). This is the first report of the species from India.

Genus *NYGOLAIMUS* Cobb, 1913
Nygolaimus macrobrachyurus (Heyns, 1968) Thorne, 1974
(Plate 4: A-H; Table 2)

Material examined: 1 female, 1 male. India, Assam, Jorhat dist., Meleng: Holongapar Gibbon WLS: Mariani Forest Range, Lat 26°40.989N and long 094°21.063E, 26-x-2018, coll. D. Sen (Reg. No. ZSI/WN2624/1); India, Assam, Majuli dist., Majuli island: Chitadarsuk village, and Lat 26°59.507N and long 094°09.070E, 27-x-2018, coll. D. Sen (Reg. No. ZSIWN2625/1).

Diagnosis: Large nematode, Body ventrally curved upon fixation, cylindrical. Cuticle thick on tail. Lip region elevated, minutely angular, distinctly set off from body by deep constriction, slightly wider than adjoining body, lips amalgamated. Amphids not clearly visible. Mural tooth deltoid, linear, little more than half or 0.55 labial diameter long. Expanded portion of pharynx occupies more than half (67.2%) of total pharyngeal length. Nerve ring 8.8 labial diameters from anterior end. Cardia tongue-shaped, 10.0mm long, surrounded by three vertically oval glands present at the pharyngo-intestinal junction. Vulva transverse, post-equatorial. Vagina extending inward little more than half or 54.2% of the corresponding body width. Reproductive system amphidelphic. Distinct sphincter present at uterus-oviduct junction. Prerectum short, 1.1 anal body diameter and rectum about one anal body diameter long. Tail short, convex-conoid with rounded terminus, 0.8 anal body diameter long.

Male: Similar to female in general body shape and morphology except reproductive system and tail shape. Supplement consists of a single rudimentary ventromedian and an adanal pair. Spicules 1.2 anal body diameter long. Prerectum 0.8 and rectum about 1.0 anal body-widths long. Tail short, rounded.

Habitat: Soil around the roots of unidentified grass (from Jorhat dist.) and fern (from Majuli dist.)

Distribution in world: The Netherlands, U. S. A.

Remark: Nygolaimus macrobrachyurus can be distinguished by its longer body length and a single rudimentary ventromedian supplement in addition to the adanal pair in male. Heyns (1968) described the species under the subgenus *Nygolaimus* as *Nygolaimus (Nygolaimus) macrobrachyuris*. Thorne (1974) reported the species from South Dakota, U.S.A. and renamed the species as *Nygolaimus macrobrachyurus* with a new rank. The present female and male specimens of *Nygolaimus macrobrachyurus*, reported from India, are longer and body to pharyngeal length ratio (b) is more than in the type specimens, yet they show very close morphological similarities with those of the type specimens except some morphometric variations (in the female holotype, L = 3.49mm, b = 3.2 – 3.6; in male paratypes L = 2.73 – 2.84mm, b = 3.7, spicule length in male = 45 - 46mm; In the specimen reported from USA, L = 3.5mm). This is the first record of the species from India.

Discussion

Total twenty-five species of soil-inhabiting Nematodes belonging to 9 families and 14 genera under the orders Dorylaimida and Tylenchida have been reported from the conservation areas and tea gardens and their distributions in forest ecosystem and agro-ecosystem were observed (Fig. 2). Seventeen species were reported from conservation areas and 10 species from the agricultural system and among these, 4 species, *Laimydorus multialaeus*, *Aporcelaimellus chauhani*, *Aporcelaimellus baqrii* and *Xiphinema gracilicaudatum* were found to occur either in more than one conservation areas and tea gardens or in both (Table 1). Among these 25 species, 63% species was found to occur from conservation areas and 37% from the soils of tea gardens with the repetition of some species either in protected areas or in tea gardens or in both (Fig. 1). Again, 56% species was found in forest ecosystem and 44% species in agro-ecosystem (Fig. 2). Maximum and minimum number of occurrence of different species and their distribution in different protected areas and tea gardens has been observed (Table 1, Fig. 3). Yeats (1971) studied the Feeding types and feeding groups in plant and soil nematodes and their trophic groups can be categorized as omnivorous, plant feeders or herbivorous, fungal feeders, bacterial feeders, predators, predatory-omnivore etc. (Yeates *et al.*, 1993). In the present study, nematodes of different trophic groups depending on their feeding habits were observed. The reported nematode species were found to belong to four trophic groups, 10 species (40%) are herbivores, 09 species (36%) are predatory omnivorous, 5 species (20%) are omnivorous and 1 species (4%) is predatory (Fig. 4 & 5).

Table-1. Distribution of dorylaimid and tylenchid nematodes in some protected areas and tea estates of Assam

Protected Area / Tea Estate	Species	Locality with Geographic coordinate	Habitat	Trophic group (Feeding habit)	New record Status
Pobitora Wild Life Sanctuary	1. ***Laimydorus multialaeus*** (Khera, 1970) Baqri, 1985	Lat 26°14.534N & long 092°02.926E, Pobitora Wild Life Sanctuary, Morigaon dist.	Forest Ecosystem	Omnivorous	First report from Pobitora WLS
	2. ***Mesodorylaimus bastiani*** (Butschli, 1873) Andrassy, 1959	Lat 26°14.534N & long 092°02.926E, Pobitora Wild Life Sanctuary, Morigaon dist.	Forest Ecosystem	Predatory omnivore	New Record from India
	3. ***Aporcelaimellus chauhani*** Baqri & Khera, 1975	Lat 26°14.534N & long 092°02.926E, Pobitora Wild Life Sanctuary, Morigaon dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	4. ***Aporcelaimellus heynsi*** Baqri & Jairajpuri, 1968	Lat 26°14.534N & long 092°02.926E, Pobitora Wild Life Sanctuary, Morigaon dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	5. ***Lindseyus indicus*** Dhanachand & Jairajpuri, 1980	Lat 26°14.534N & long 092°02.926E, Pobitora Wild Life Sanctuary, Morigaon dist.	Forest Ecosystem	Omnivorous	New distributional record from Assam
Nameri forest range, Nameri National Park	1. ***Laimydorus multialaeus*** (Khera, 1970) Baqri, 1985	26°56.565N & long 092°50.770E and 26°56.324N & long 092°50.577E, Nameri forest range, Nameri N. P., Shonitpur dist.	Forest Ecosystem	Omnivorous	First report from Nameri N. P.
	2. ***Aporcelaimellus amylovorus*** (Thorne & Swanger, 1936) Heyns, 1965	Lat 26°56.565N & long 092°50.770E, Nameri Forest Range, Nameri N. P., Shonitpur dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	3. ***Aporcelaimellus baqrii*** Ahmad & Jairajpuri, 1982	Lat 26°56.565N & long 092°50.770E, Nameri forest range, Nameri N. P., Shonitpur dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	4. ***Xiphinema insigne*** Loos, 1949	Lat 28°41.522N & long 080°01.686E, Nameri forest range, Nameri N. P., Shonitpurdist,	Forest Ecosystem	Herbivorous	First report from Nameri N. P.
	5. ***Hoplolaimus imphalensis*** M. L Khan & S. H. Khan, 1985	Lat 26°55.418N & long 092°49.642E, Potashali village, buffer zone of Nameri N. P. Shonitpur dist.	Forest Ecosystem	Herbivorous	New distributional record from Assam

Protected Area / Tea Estate	Species	Locality with Geographic coordinate	Habitat	Trophic group (Feeding habit)	New record Status
Jeypore Forest Range, Dehing-Patkai Wildlife Sanctuary	1. ***Laimydorus siddiqii*** Baqri & Jana, 1983	Lat 26°15.235N & long 092°02.482E,Jeypore village, Jeypore Forest Range, Buffer zone of Dehing-Patkai WLS, Dibrugarh dist.	Agro-ecosystem	Omnivorous	New distributional record from Assam
	2. ***Sectonema procta*** Jairajpuri and Baqri, 1966	Lat 27°14.932N & long 095°25.694E, beside Namchang road, Jeypore forest range, DehingPatkai WLS, Dibrugarh dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	3. ***Xiphinema elongatum*** Schuurmans-Stekhoven & Teunissen, 1938	Lat 27°14.932N & long 095°25.694E, beside Namchang road, Jeypore forest range, Dehing Patkai WLS, Dibrugarh dist.	Forest Ecosystem	Herbivorous	New distributional record from Assam
	4. ***Xiphinema gracilicaudatum*** (Singh & Khan, 1997) Ganguly *et al.*, 2000	Lat 27°14.932N & long 095°25.694E, Jeypore Forest Range, Namchang road, Dehing-Patkai WLS, Dibrugarh dist., Assam	Forest Ecosystem	Herbivorous	New distributional record from Assam
	5**. *Xiphinema manasiae*** Sen, Chatterjee & Manna, 2010	Lat 27°15.836N & long 095°23.900E, buffer zone of Jeypore forest range, Dehing Patkai WLS, Jeypore, Dibrugarh dist.	Agro-ecosystem at the buffer zone of Dehing-Patkai WLS	Herbivorous	New distributional record from Assam
Bhomoraguri Reserve Forest	1. ***Aporcelaimellus baqrii*** Ahmad & Jairajpuri, 1982	Lat 26°37.072N & long 092°51.208E, Bhomoraguri Reserve Forest, Tezpur,Shonitpur dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	2**. *Dorylaimoides (Digidorylaimoides) micoletzkyi*** (De Man, 1921) Thorne & Swanger, 1936	Lat 26°37.072N & long 092°51.208E, Bhomoraguri Reserve Forest, Tezpur, Shonitpur dist.	Forest Ecosystem	Omnivorous	New distributional record from Assam
Mariani Forest Range, Hollongapar Gibbon Wildlife Sanctuary	1. ***Aporcelaimellus chauhani*** Baqri & Khera, 1975	26°40.732N & long 094°21.226E, Mariani Forest Range, Hollongapar Gibbon WLS, Jorhat dist.	Forest Ecosystem	Predatory omnivore	New distributional record from Assam
	2. ***Paralongidorus sali*** Siddiqi, Hooper & Khan, 1963	Lat 26°40.989N & long 094°21.063E, Holongapar Gibbon WLS, Mariani Forest Range, Jorhat dist.	Forest Ecosystem	Herbivorous	First report from Hollongapar Gibbon WLS
	3. ***Nygolaimus macrobrachyurus*** (Heyns, 1968) Thorne, 1974	Lat 26°40.989N & long 094°21.063E, Holongapar Gibbon WLS, Mariani Forest Range, Jorhat dist.	Forest Ecosystem	Predator	New Record from India

Protected Area / Tea Estate	Species	Locality with Geographic coordinate	Habitat	Trophic group (Feeding habit)	New record Status
Panbari Tea Estate	1. ***Aporcelaimellus chauhani*** Baqri & Khera, 1975	Lat 26°37.385N & long 093°31.559E, Panbari Tea Estate, Bokahat, Golaghat dist.	Agro-ecosystem	Predatory omnivore	New distributional record from Assam
	2. ***Makatinus punctatus*** Heyns, 1965	Lat 26°37.385N & long 093°31.559E, Panbari Tea Estate, Bokakhat, Golaghat dist.	Agro-ecosystem	Predatory omnivore	New Record from India
	3. ***Xiphinema gracilicaudatum*** (Singh & Khan, 1997) Ganguly *et al.*, 2000	Lat 26°37.385N & long 093°31.559E, Panbari Tea Estate, Bokakhat, Golaghat dist.	Agro-ecosystem	Herbivorous	New distributional record from Assam
	4. ***Helicotylenchus assamensis*** Saha, Lal, Singh, Kaushal & Sharma, 2000	Lat 26°37.385N &long 093°31.559E, Panbari Tea Estate, Bokahat, Golaghat dist.	Agro-ecosystem	Herbivorous	First report from Panbari Tea Estate
Experimental garden of TTRI	1. ***Aporcelaimellus coomansi*** Baqri & Khera, 1975	Lat 26°43.807N & long 094°13.779E, Experimental garden, TTRI, Jorhat dist.	Agro-ecosystem	Predatory omnivore	New distributional record from Assam
Burrapahar Tea Estate	1. ***Oriverutus sundarus*** (Williams, 1964) Siddiqi, 1971	Lat 26°34.534N & long 093°09.789E, Burrapahar Tea Estate, Nawgaon dist.	Agro-ecosystem	Not determined	Ahmed & Jairajpuri,1987 reported from TTRI
	2. ***Hoplolaimus indicus*** Sher, 1963	26°34.534N & long 093°09.789E, Burrapahar Tea Estate, Nawgaon dist.	Agro-ecosystem	Herbivorous	First report from Burrapahar Tea Estate
Holangooree Tea Estate	1. ***Xiphinema brasiliense*** Lordello, 1951	Lat 26°39.442N & long 094°23.095E, Holangooree Tea Estate, Jorhat dist.	Agro-ecosystem	Herbivorous	New distributional record from Assam
	2. ***Xiphinema gracilicaudatum*** (Singh & Khan, 1997) Ganguly *et al.*, 2000	Lat 26°39.442N & long 094°23.095E, Hoolangooree Tea Estate., Jorhat dist.	Agro-ecosystem	Herbivorous	New distributional record from Assam
	3. ***Axonchium (Axonchium) nitidum*** Jairajpuri, 1964	Lat 26°39.442N & long 094°23.095E, Holangooree Tea Estate, Jorhat dist.	Agro-ecosystem	Predatory omnivore	Jairajpuri, 1964 reported from Jorhat and Sibsagar dist.
	4. ***Hoplolaimus pararobustus*** (Schuurmans-Stekhoven & Teunissen, 1938) Sher, 1963	Lat 26°39.442N & long 094°23.095E, Holangooree Tea Estate, Jorhat dist.	Agro-ecosystem	Herbivorous	New distributional record from Assam

Table – 2: Morphometric measurements of *Mesodorylaimus bastiani* & *Nygolaimus macrobrachyurus* (All measurements are in µm except the total length, L in mm.)

Characters	Mesodorylaimus bastiani				Nygolaimus macrobrachyurus	
	Female (n=2)		Male (n=2)		Female (n=1)	Male (n=1)
	Min	Max	Min	Max		
L	1.73	1.77	1.56	1.74	3.97	3.28
a	46.8	49.1	48.8	51.4	56.8	42.1
b	5.0	5.2	4.8	4.8	5.0	4.0
c	15.6	18.4	60.1	67.2	99.4	93.9
c'	3.9	5.3	1.0	1.0	0.8	0.6
V/T %	46.8	51.4	67.6	71.2	54.3	61.6
G_1 %	11.0	13.0	-	-	12.0	-
G_2 %	13.8	15.3	-	-	11.8	-
Length of odontostyle	14.0	15.0	15.0	16.0	-	-
Width of odontostyle	2.0	2.5	2.0	2.5	-	-
Length of odontostyle aperture	5.0	5.0	5.0	5.0	-	-
Length of odontophore	20	22	20	21	-	-
Guiding ring from anterior end	9.0	11.0	-	-	-	-
Length of mural tooth	-	-	-	-	13.0	15.0
Maximum body width	36.0	37.0	32.0	34.0	70.0	78.0
Length of Pharynx	330.0	353.0	322.0	360.0	781.0	815.0
Length of expanded pharynx	165.0	201.0	166.0	254.0	525.0	508.0
Cardiac Glands	-	-	-	-	5.5-7.5 x 6.5-8	7.5-10.0 x 5.5-6.5
Nerve ring from anterior end	111.0	113.0	83.0	111.0	207.0	238.0
Lip height	4.0	4.5	4.0	4.5	6.5	6.5
Lip width	10.0	10.5	10.5	11.0	23.5	24.0
Neck base width	34.0	35.0	30.0	32.0	67.0	74.0
Body width at vulva	36.0	37.0	-	-	70.0	-
Lip adjoining body width	11.0	11.5	12.5	13.0	22.0	25.0
Cuticle anterior end	1.0	1.0	1.0	1.0	4.5	5.0
Cuticle at mid body	1.0	1.5	2.0	2.0	5.0	5.0
Cuticle on tail	2.0	2.5	2.0	2.0	11.0	11.0

Characters	Mesodorylaimus bastiani				Nygolaimus macrobrachyurus	
	Female (n=2)		Male (n=2)		Female (n=1)	Male (n=1)
Vulva from anterior end	814.0	901.0	-	-	2165.0	-
Length of vagina	20.0	22.0	-	-	38.0	-
Length of anterior gonad	191.0	246.0	-	-	480.0	-
Length of uterus	44.0	58.0	-	-	156.0	-
Length of oviduct	90.0	104.0	-	-	125.0	-
Length of ovary	57.0	84.0	-	-	199.0	-
Length of posterior gonad	240.0	272.0	-	-	472.0	-
Length of uterus	45.0	63.0	-	-	132.0	-
Length of oviduct	119.0	123.0	-	-	162.0	-
Length of ovary	76.0	86.0	-	-	178.0	-
Tail length	94.0	113.0	26.0	26.0	40.0	35.0
Length of anterior convex part of tail	29	31	-	-	-	-
Length of posterior narrow part of tail	65.0	82.0	-	-	-	-
Anal body diameter	21.0	24.0	25.0	26.0	46.0	55.0
Length of prerectum	86.0	93.0	105.0	108.0	51.0	48.0
Length of rectum	20.0	29.0	27.0	28.0	46.0	57.0
Length of testes	-	-	1115.0	1182.0	-	2027.0
Number of ventromedian supplements	-	-	12	15	-	1 + (1 adanal)
Length of spicule	-	-	41.0	43.0	-	69.0

Table – 3: Morphometric measurements of *Aporcelaimellus taylori* and *Makatinus punctatus* (All measurements are in µm except the total length, L in mm.)

Characters	Aporcelaimellus taylori			Makatinus punctatus
	Female (n=2)		Juvenile (n=1)	Female (n=1)
	Min	Max		
L	2.35	2.37	1.65	3.54
a	37.7	37.9	33	21.5
b	4.1	4.3	3.4	3.9
c	60.9	73.5	57.0	122.0
c'	0.9	1.0	0.9	0.4
V %	53.5	53.8	-	56.4
G_1 %	14.0	16.7	-	16.1
G_2 %	13.5	13.7	-	12.9
Length of odontostyle	19.0	21.0	17.0	29.0
Length of odontostyle aperture	11.0	11.5	10.0	18.0
Length of odontophore	36.0	36.0	31.0	63.0
Width of odontostyle	3.5	3.5	2.5	6.0
Guiding ring from anterior end	10.0	11.0	-	14.0
Maximum body width	62.0	63.0	50.0	164.0
Length of Pharynx	550.0	572.0	480.0	893.0
Length of Expanded Pharynx	274.0	295.0	253.0	469.0
Length of cardia	17.0	22.0	10.0	-
Nerve ring from anterior end	155.0	184.0	103.0	250.0
Lip height	5.0	6.0	5.0	9.5
Lip width	16.5	17.0	14.0	29.5
Neck base width	59.0	60.0	48.0	160.0
Body width at vulva	62.0	63.0	-	164.0
Lip adjoining body width	17.0	18.0	15.0	31.0
Cuticle anterior end	3.0	3.5	2.0	5.0
Cuticle at mid body	2.5	3.0	2.0	6.0
Cuticle on tail	6.5	7.0	4.0	10.0
Vulva from anterior end	1260.0	1280.0	-	2000.0

Characters	Aporcelaimellus taylori			Makatinus punctatus
	Female (n=2)		Juvenile (n=1)	Female (n=1)
Length of vagina	29.0	31.0	-	60.0
Length of *Pars distalis* vagina	3.0	3.0	-	2.0
Length of *Pars refringens* (CW)	5.0x9.0	7.0x10.0	-	16.0x18.0
Length of *Pars proximalis* vagina	21.0	21.0	-	42.0
Length of anterior gonad	330.0	399.0	-	571.0
Length of uterus	51.0	83.0	-	130.0
Length of oviduct	138.0	151.0	-	259.0
Length of ovary	141.0	165.0	-	182.0
Length of posterior gonad	320.0	327.0	-	457.0
Length of uterus	51.0	52.0	-	94.0
Length of oviduct	116.0	128.0	-	202.0
Length of ovary	148.0	152.0	-	161.0
Tail length	32.0	39.0	29.0	29.0
Anal body diameter	35.0	39.0	30.0	65.0
Length of prerectum	97.0	124.0	97.0	187.0
Length of rectum	47.0	51.0	40.0	53.0

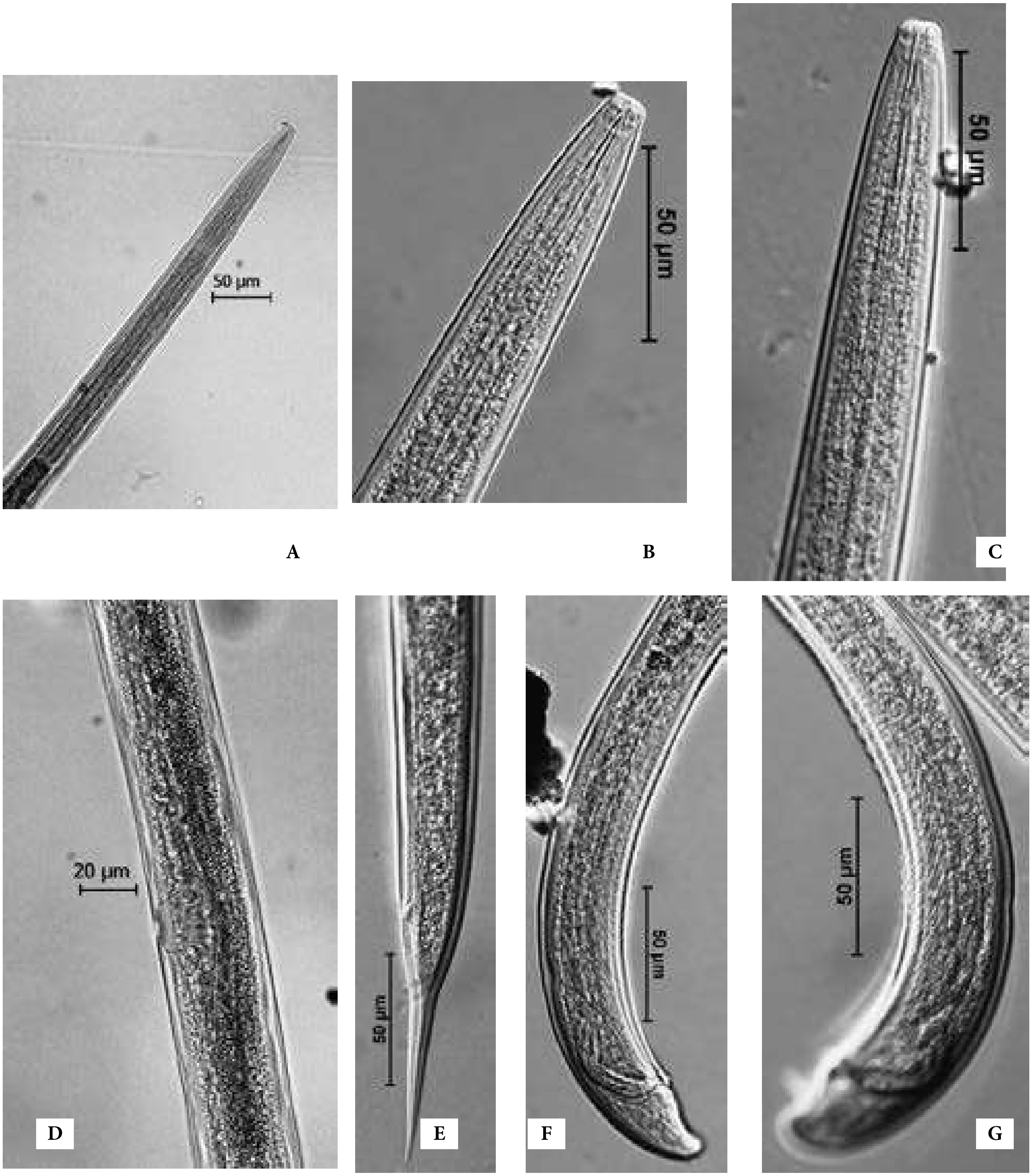

Plate 1 (A - G): Photomicrographs of *Mesodorylaimus bastiani* (Butschli, 1873) Andrassy, 1959. **A. Pharynx of Female, , B. Odontostyle of Female, C. Odontostyle of Male, D. Vulva, E. Posterior end of female showing tail, F & G. Posterior end of male showing ventromedian supplements, spicule & tail**

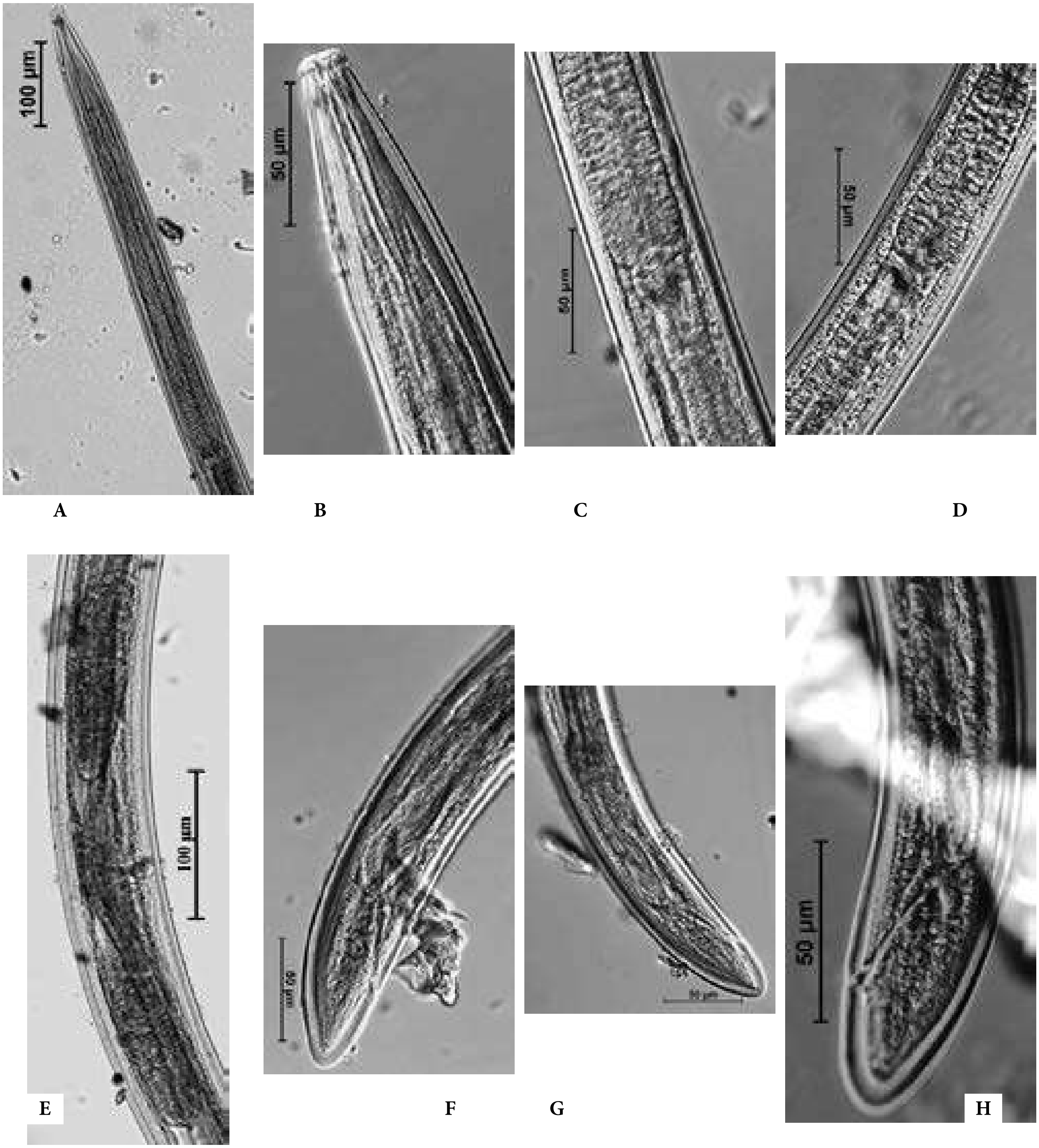

Plate 2 (A - H): Photomicrographs of *Aporcelaimellus taylori* Yeates, 1967. **A. Pharynx of Female, B. Odontostyle of Female, C. Pharyngo-intestinal junction of Female, D. Pharyngo-intestinal junction Juvenile, E. Gonads, F & G. Posterior end of female showing variation in tail terminus, H. Posterior end of Juvenile**

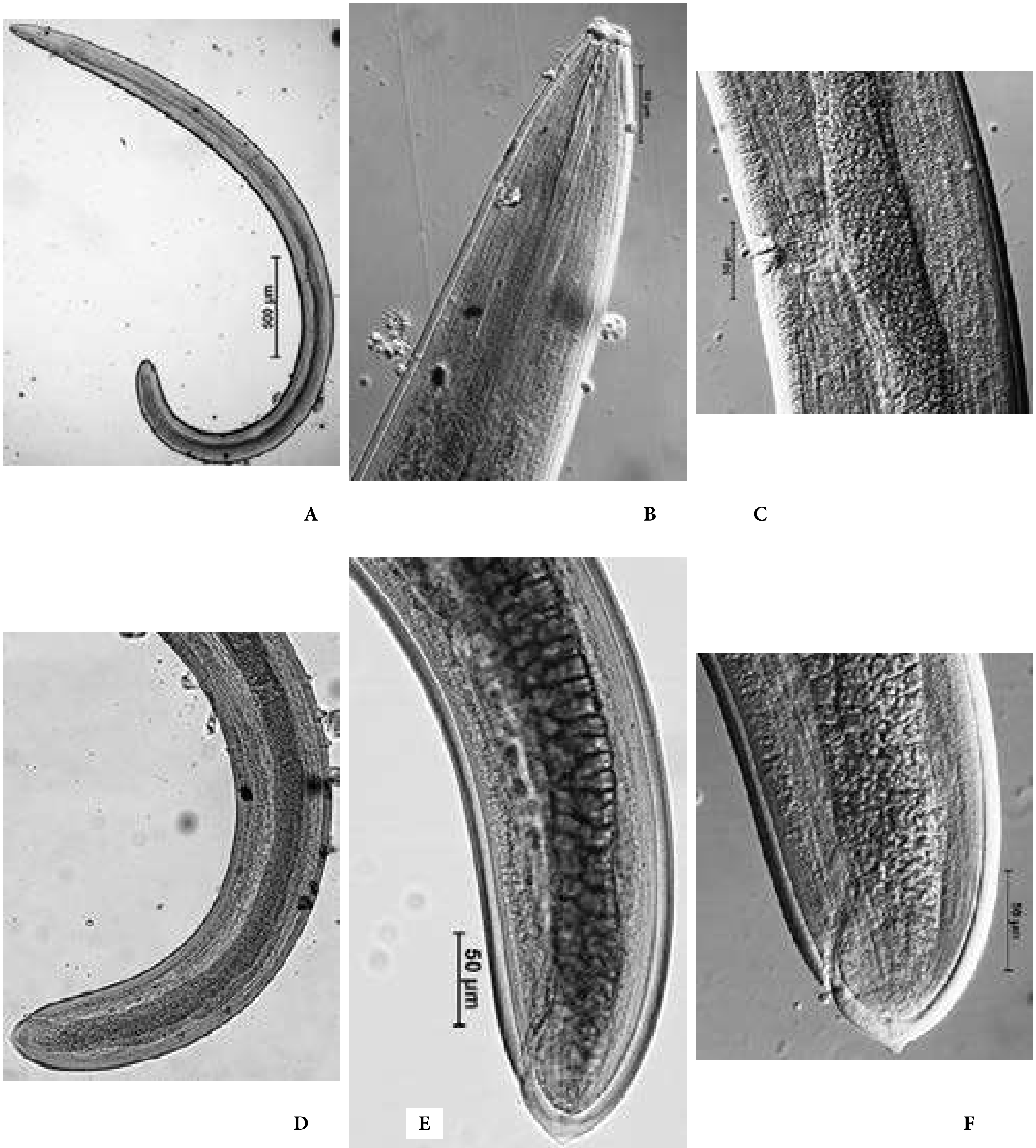

Plate 3 (A - F): Photomicrographs of *Makatinus punctatus* Heyns, 1965 **A. Entire Female, B. Odontostyle, C. Vulva, D. Posterior end, E & F. Tail End**

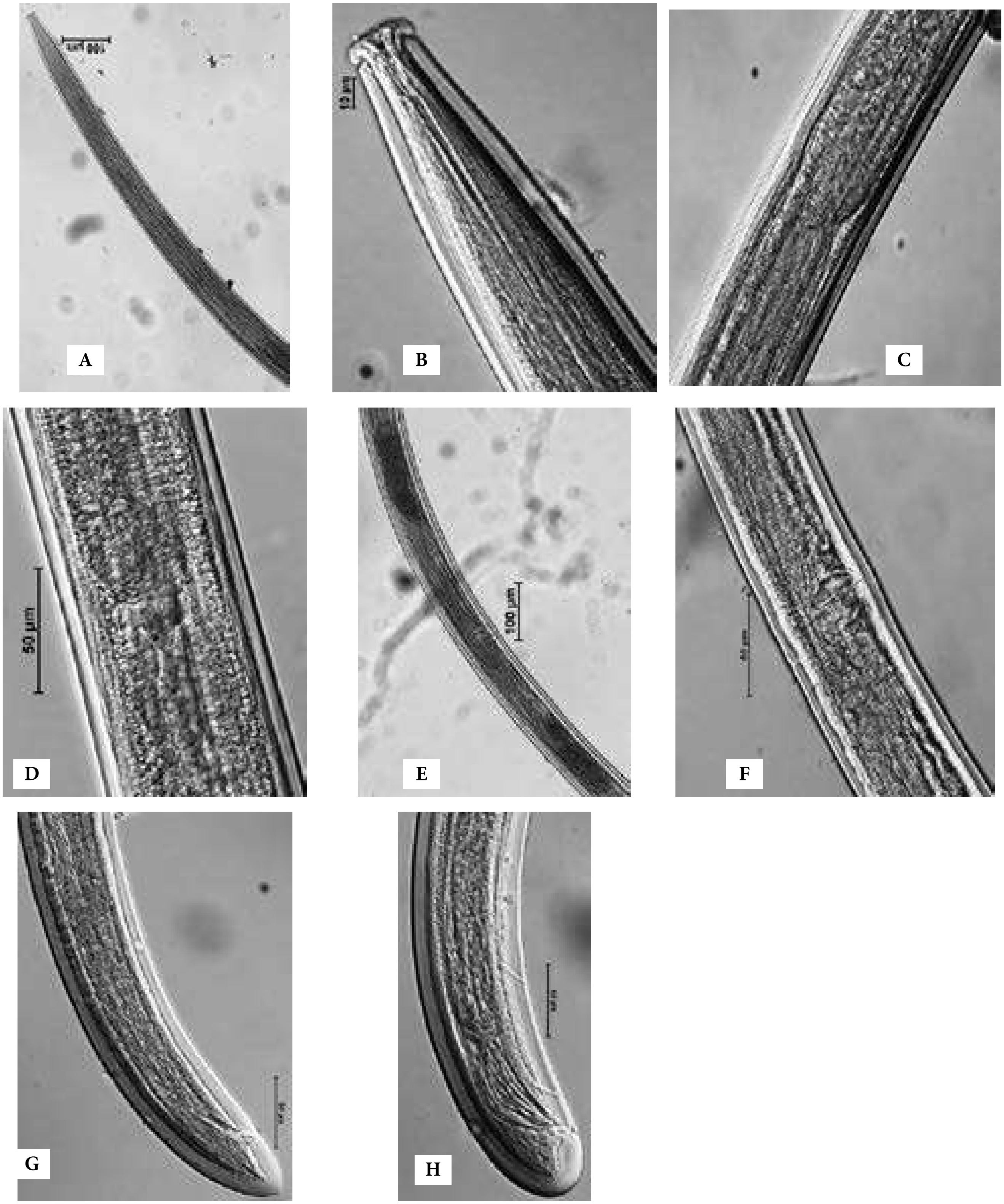

Plate 4 (A - H): Photomicrographs of *Nygolaimus macrobrachyurus* (Heyns, 1968) Thorne, 1974 **Pharynx of female, B. Mural tooth of female, C. Cardiac glands of female, D. Cardiac glands of male, E. Gonads of female, F. Vulva, G. Posterior end of female, H. Posterior end of male showing spicule, single ventromedian supplemnent and tail**

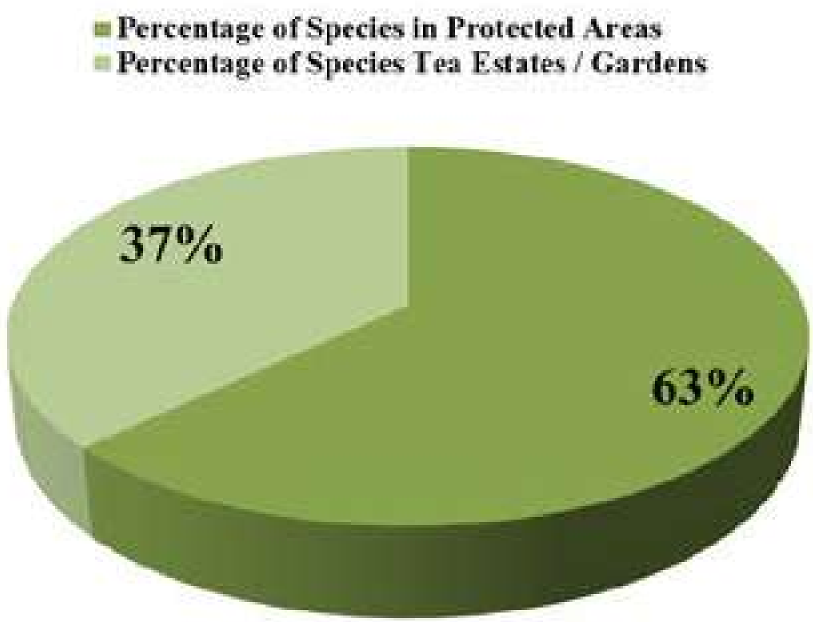

Figure 1. Percentage of nematode Species in Protected Areas and Tea Estates/ Gardens

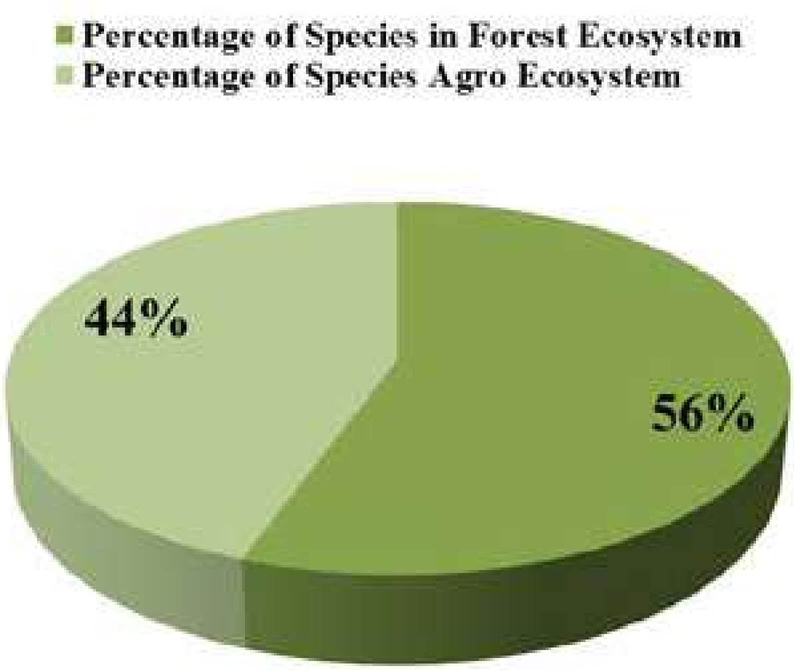

Figure 2. Percentage of Nematode species in Forest Ecosystem and Agro-Ecosystems

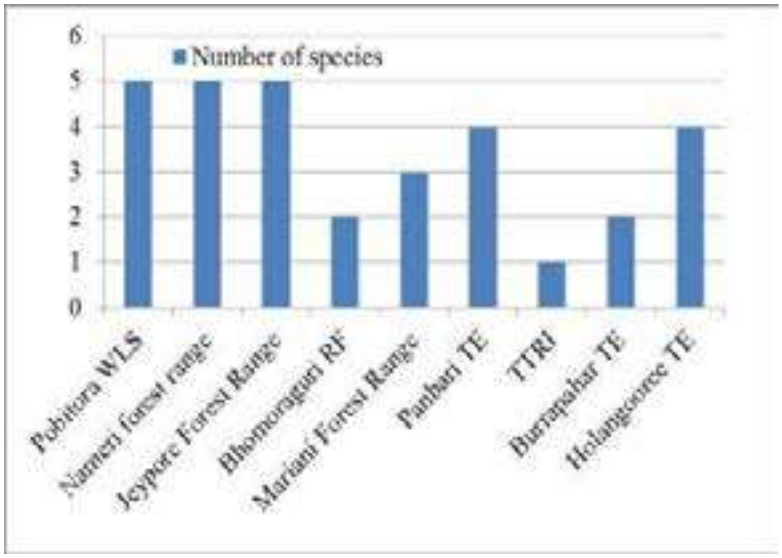

Figure 3. Number of species present in different protected areas and tea estates

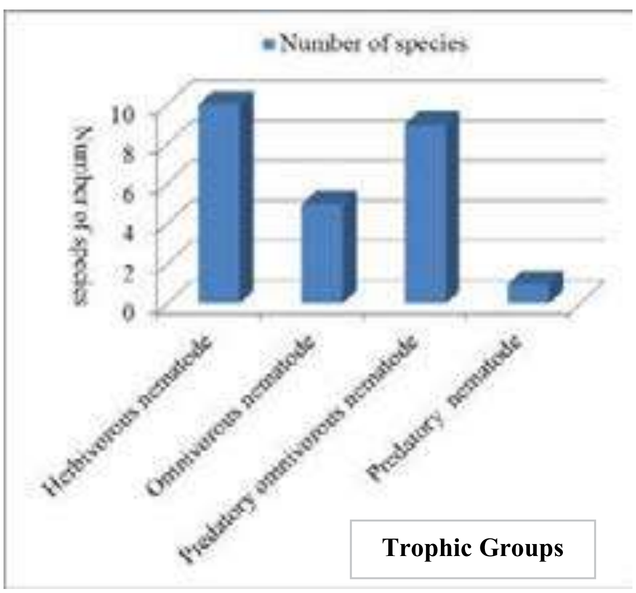

Figure 4. Number of species under different trophic groups of nematodes

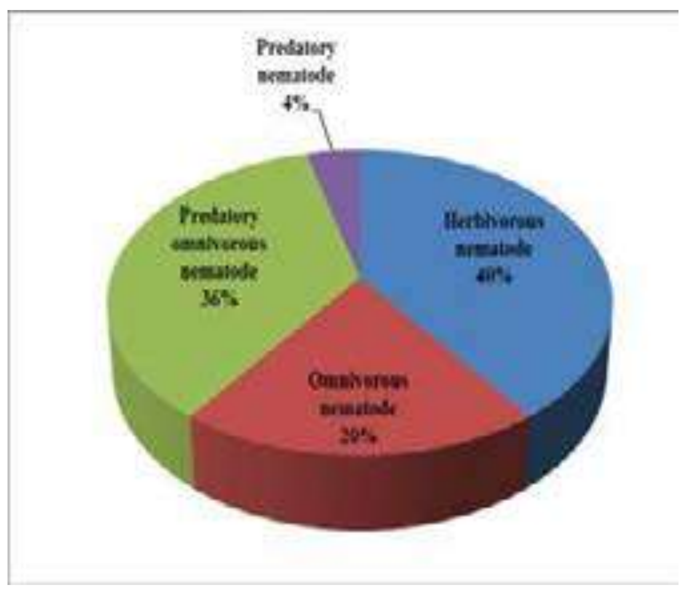

Figure 5. Percentage of nematode species under different trophic groups

Acknowledgements

Authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India for providing all sorts of facilities to carry out the work, to publish the result and for her constant inspiration during the work.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Biological Assessment of Major Water Bodies of Metropolitan Region Kolkata

Subhadip Ghosh[1,2], Shaheen Akhtar[1] and Dr. Kanchan Kumari[1*]

[1]CSIR-National Environmental Engineering Research Institute (NEERI) Kolkata Zonal Center, Kolkata-700 107, West Bengal
[2]Maulana Abul Kalam Azad University of Technology, West Bengal, Haringhata - 741249
**Email: onlinekanchan1@gmail.com/k_kumari@neeri.res.in*

Abstract

Benthic macroinvertebrate monitoring or biological monitoring is use of biological responses for populations and communities of certain indicator organisms to evaluate anthropogenic environmental changes. Biomonitoring is a special way of assessing water quality using macroinvertebrates to find the Saprobic score and Diversity score to indicate the level of pollution as well as to assess the biological quality of water. It entails the use of indicator species, generally, benthic macroinvertebrates/ fish and algae communities as well as certain aquatic plant species are also used. From several studies, benthic macro-invertebrate populations have been regarded as the most acceptable biological parameter to assess the quality of water out of all the biotic components. The mapping based on bio-monitoring has been proven as a powerful tool for the preparation of future action plans to control water pollution and improve the water quality of water bodies. The present study has been conducted in four major water bodies of city, Kolkata (West Bengal) using benthos monitoring to understand the prevailing scenarios.

The benthos samples were collected from all the four water bodies selected for study, sieved, washed, and transferred into a large tray for identification purposes and classified according to their taxa. As per the score obtained, most of the sampling sites were found to be moderately polluted. Gastropods, annelids, crustacea, and insects made up the majority of the benthic macro-invertebrate species that were collected. The various opportunities and lessons learned from past experiences of monitoring of different water bodies have also been included in this study. The details and significance of the work have been discussed in the full paper.

Keywords: Biomonitoring, Benthos, Water Quality, Pollution, Diversity

Introduction

The basic concept of using benthic macroinvertebrates in biological water quality monitoring as indicator species is of central importance nowadays (Rout, 2010). Various procedures are available to assess the quality of water of both lotic (flowing waters such as streams) and lentic (still waters such as lakes) waterbodies; among which physicochemical parameters such as temperature, Dissolved oxygen (DO), Chemical oxygen demand (COD), Biochemical oxygen demand (BOD), pH, chlorides, alkalinity of waterbodies are mostly prioritized. The physicochemical parameters routinely practiced, however only provide a quick snap-shot of the condition of a waterbody. These cannot detect the impacts of toxicants that are dynamic in nature, failing to give a comprehensive assessment of the state of waterbodies at times, and thus inappropriately identifying contaminated waters (United States Environmental Protection Agency, USEPA, 2005). Biomonitoring using benthic macroinvertebrates provides a detailed, comprehensive assessment of the health of a waterbody over a long period of time (Karr,1999). Therefore, biological objectives can be added to supplement the physicochemical parameters while assessing the quality of a waterbody (Yoder and

*Author for correspondence : Dr. Kanchan Kumari, Principal Scientist, CSIR-NEERI, Kolkata-700107
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Rankin, 1998; Karr, 1995; Yoder, 1995). As 98% of animal species are invertebrates in the animal kingdom, benthic macroinvertebrates, which are small aquatic invertebrate animals and the aquatic larval stages of insects (including dragonfly and stonefly larvae, snails, worms, beetles, etc.), are majorly used in biomonitoring to determine the biological water quality in terms of the Saprobic and Diversity score. From several studies, benthic macro-invertebrate populations have been regarded as the most acceptable biological parameter to assess the quality of water. The ubiquitous and sedentary nature of benthic macroinvertebrates (Rosenberg and Resh, 1993), their cumulative response to stress, the length of their life cycles, and their long-term exposure to toxic substances (Rossaro *et al.*, 2011; Szivák, and Csabai, 2012) collectively favors their utilization as an important bio-indicator within the environmental policies (Yoder and Rankin, 1998). Moreover, adapting biological monitoring using benthic invertebrates can be efficient, simple to grasp, and cost-effective. The benthic macroinvertebrates usually live in inmate contact with the sediments, which enhances their interaction with various pollutants, and thus their community structures are influenced by the level of exposure to pollutants (Bhadrecha *et al.* 2016; Khatri *et al.* 2020). In India, various studies have been conducted on river using benthic macroinvertebrates (Singh *et al.*, 2019), Recently, CPCB has conducted a study on River Ganga using benthic macroinvertebrates (CPCB, 2017). Changes in distribution patterns of macroinvertebrates due to anthropogenic activities are recorded in rivers Teesta and Ganga (Bhatt & Pandit 2010; Nautiyal, 2010). In 2015, a study was conducted on benthic macroinvertebrates in river Mahi and it was reported that the water was polluted (Khatri *et al.*, 2021). For stream benthic macroinvertebrate monitoring, a survey was conducted by USA state agencies (Carter & Resh, 2001). Different types of biomarkers based on their effectiveness, suitability, specificity to certain pollutants, their ability to detect different chemicals, ecological relevance have also been used according to their suitability while lot many more biomarkers are still under trial to be included in the water monitoring programme (Kumari and Khare, 2018). Indices based biomonitoring approach has been exploited internationally to assess the status of water bodies, for example in ETHbios is such biomonitoring tool developed for assessing streams and rivers in Ethiopia (Mezgebu, A., 2022). The use of benthic macroinvertebrates increased dramatically in the past few decades in both North America and Europe in the biological assessment of water quality in lakes and streams (Rosenberg, and Resh, 1993; Tampo et al, 2021). However, such monitoring reports are scarcely available for the major water bodies of Kolkata and therefore the present study was undertaken to comprehend the present scenario of the biological water quality status.

Materials and Methods

Sampling Sites: Four sampling sites were selected in and around Kolkata, West Bengal (**Figure 1**) based on reconnaissance survey conducted in January, 2023 followed by detailed study in the month of February and March, 2023. These water bodies were Rabindra Sarovar (S-1), Subhash Sarovar (S-2), Santragachi Jheel (S-3), and East Kolkata Wetlands (S-4).

Rabindra Sarovar Lake (S- 1) (Coordinates- 22.5121°N, 88.3637°E) is a 72-acre artificial lake located near Dhakuria with a length of 1770 m and a width of 206 m. It is a rain-fed water body (Khan & Sinha, 2002) and is majorly used for recreational activities. Subhas Sarovar Lake (S-2) (Coordinates- 22.5684°N, 88.4007°E) is also a manmade artificial lake located at Beleghata covering an area of approximately 39 acres. It is 366 m in width at its broadest point and 533.3 m in length where moderate human intervention such as bathing, washing clothes, dumping food leftovers, etc. takes place. Santragachi Jheel (S- 3) (Coordinates- 22.5813°N, 88.2841°E), locally known as 'Makal Jheel' is an important urban wetland of Howrah, West Bengal, India. It is spread over an area of almost 31.57 acres with a length and width of 915 m and 305 m respectively. It is locally regarded as a bird sanctuary as it draws prominent migratory birds in the winter season. East Kolkata Wetland (S- 4) (Coordinates- 22.5528°N, 88.4501°E), is one of the largest assemblages of sewage-fed fish ponds located in the Eastern region of Kolkata. It covers an area of nearly 30888.173 acres and consists of 37 mouzas of South and North 24 Parganas district and Kolkata district (Ghosh and Das, 2020). It is an important Ramsar site and is known to be one of the largest waste waters fed aquaculture systems in the world. This wetland is also called the "Kidney of East Kolkata" as it has a crucial role in purifying sewage water (Ghosh *et al.*, 2018).

Collection, Identification, and Preservation of Benthic macroinvertebrates: Benthic samples were primarily collected from three separate points of each sampling site, and the invertebrates were sampled both qualitatively and quantitively for the saprobic and diversity scoring. Standard protocol for benthic invertebrates sampling techniques was followed (CPCB, 2017) where hand nets were used to collect the samples from the substratum, a 0.6 mm pore-sized sieve was used to collect the benthic invertebrates directly from the roots of aquatic plants and a shovel to collect the benthic samples from mud, clay, and sandy substratum. After collection, the organisms were washed and transferred into collection bottles for further identification (taxonomical groups) and scoring purposes.

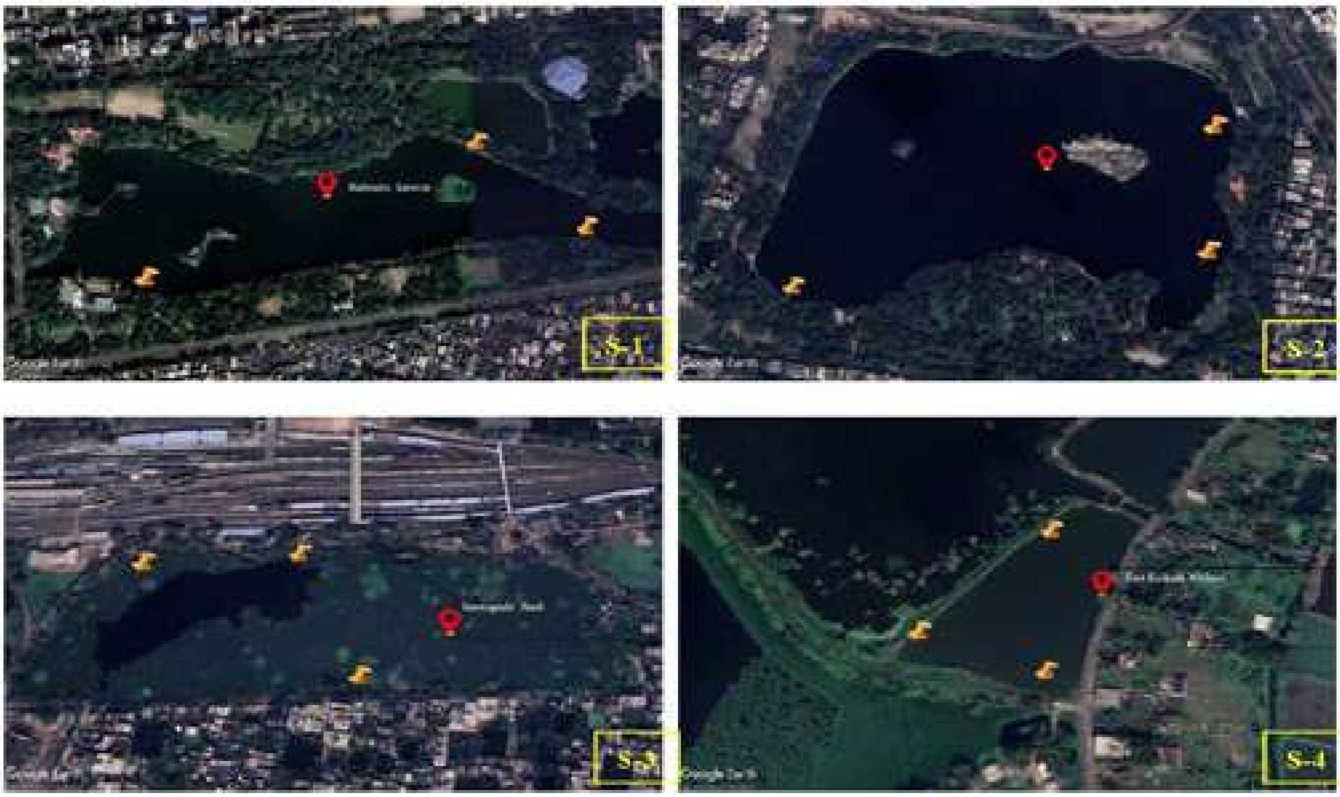


Figure 1: Satellite image of all the four sampling locations i.e. S-1: Rabindra Sarovar, S-2: Subhash Sarovar, S-3: Santragachi Jheel and S-4: East Kolkata Wetlands. [Legends: - Sampling site, - Sampling point.]

Calculation of Saprobic and Diversity Score

The saprobic score and the diversity score of each sampling site (Khatri *et al.*, 2021; Varnosfaderany *et al.*, 2010; Armitage *et al.*,1983) were determined using the following formulas given in standard operating procedures (SOPs) of CPCB:

$$\text{Saprobic Score} = \frac{\text{Grand total of multiplied score}}{\text{Grand total of number of families encountered}}$$

$$\text{Diversity Score} = \frac{\text{Total number of runs}}{\text{Total number of organisms}}$$

The saprobic score [Biological Monitoring Working Party (BMWP] shows the presence of benthic macro invertebrate's up to the family level with relation and accuracy up to genus level of taxonomic precision. All the families are classified here with scale between 0-10 according to their preference for saprobic water quality. The families that are most sensitive to pollution are placed at the top of the table and get the highest score of 10 while the species that are tolerant to pollution gets score of 1 and 2. The other species that are intermediate gets score between 10-1.

The diversity Score is the ratio of the total of different animals found (runs) with the total number of organisms encountered. The ratio of diversity score has a value between 0 and 1.

On the basis of the range of saprobic score and diversity score the biological water quality criteria (BWQC) has been derived by CPCB for evaluating the water quality (Table-4).

Water samples were also collected from each site and physical parameters such as water depth, temperature, pH, dissolved oxygen (DO), and flow rate were measured (Table 1) following the Standard Methods (APHA,1989).

Results and Discussion

The benthic macroinvertebrate samples, collected from 4 sites were identified according to their taxonomical groups, classes, families, and order with the help of identification keys. The identified species mostly consisted of Gastropods, Annelids and Crustacea (Table 2). Furthermore, the presence or absence of anthropogenic intervention at each site influenced the thriving of the benthic species and thus were also simultaneously correlated with the reported invertebrates. At S-1, there were no sewage discharges found; the main source of water was runoff water which was mostly used for recreational purposes. Moderate macrophyte growth was found in the littoral area of the lake at the time of sampling. Notable invertebrates that were recorded from S-1 included Gastropoda, family Viviparidae, Thiaridae, and Lymneidae; Annelida, family Salifidae (*Barbronia weberi*) and Crustacea, family Atyidae and Palaemonidae. Also, species belonging to the order Odonata consisting of family Libellulidae, and Coenagrionidae, the order Coleoptera consisting of the family Hydrophilidae, the order Hemiptera consisting of the family Belostomatidae, and the order Lepidoptera consisting of the family Pyralidae were found (Plate 1). Fishes like *Glossogobius giuris* and *Tilapia sparrmanii* were also present in the samples collected. S-2, also a rainwater-fed ecosystem where moderate human activities like bathing, washing clothes and utensils, dumping food leftovers, fishing, etc. were noted having moderate macrophytes growth in its vicinity. Samples collected from S-2 included Gastropods of the family Viviparidae, Thiaridae, Lymneidae, and Planorbidae, two families of Crustacea (Atyidae and Palaemonidae), two families of Hemiptera (Nepidae and Belostomatidae), three families of Odonata (Libellulidae, Coenagrionidae, and Aeshnidae), and one family of Coleoptera (Hydrophilidae) (Plate 2). S-3 was surrounded on almost all sides by human settlements, shops, railway quarters, etc. The jheel received sewage wastes from cattle sheds, domestic waste materials, and sewage from roadside shops (Patra *et al.*, 2011) and so a dense growth of macrophytes (mainly water hyacinth) covering the jheel was noted. Gastropods of the family Viviparidae, Thiaridae, Lymneidae, and Planorbidae, and Annelids of the family Nereididae Namalycastis sp were recorded in S-3 samples. The order Odonata, represented by the family Libellulidae and Coenagrionidae, two families of Hemiptera (Nepidae and Belostomatidae), one family of Coleoptera (Curculionidae), and the family Chironomidae (*Chironomus sp.*) of the taxonomical group Diptera were also identified (Plate 3). S-4 is a wetland and an assemblage of sewage-fed shallow ponds, mostly used for pisciculture and thus a little growth of macrophyte vegetation was noted. Human interference like bathing and washing clothes was also noticed during sampling. Species identified from the S-4 samples included the family Viviparidae, Thiaridae, Lymneidae, and Planorbidae of Mollusca. Among them, Lymneidae was abundant in number. Three families of Hemiptera (Nepidae, Belostomatidae, and Notonectidae), and one family of Oligochaeta (Lumbricidae) were also detected (Plate 4).

Following the identification an evaluation of the biological water quality was done where the BMWP, the saprobic and the diversity scores were calculated (CPCB, 2017; Khatri *et al.*, 2021; Varnosfaderany *et al.*, 2010; Armitage *et al.*,1983). Table 3 presents that, with the decrease in BMWP score, the pollution tolerance of species is increasing (CPCB 2017) i.e. more BMWP-scored species are less pollution tolerant. The presence of Viviparidae excessively in every site is a direct indication of the mesotrophic condition of water bodies (Rout,2011; Kumar and Bohra, 1999). The presence of Lumbricidae (*Lumbricus terrestris*) in S-4 indicates sewage discharge from surrounding polluted areas. Also, the detection of the family Chironomidae (*Chironomus* *sp.)* and Nereididae (*Namalycastis sp.)* in S-3 samples, strongly indicated the eutrophic condition of the water body. Combining the Saprobic score (1 – 10) and Diversity score (0 - 1), prescribed in Biological Water Quality Criteria (BWQC) (Table 4), the biological water quality class was also determined (Table 5).

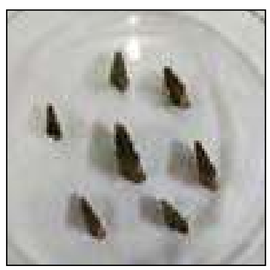
Table 1 – Results of Field measurements performed at the four sampling sites

Location	**Code**	**General Water Quality Parameters**					**Human Activity**
		Temperature (°C)	**pH**	**DO (mg/l)**	**Flow rate (m/sec)**	**Depth (meter)**	
Rabindra Sarovar	S-1	25	8.46	10.54	0.01	7.5	Recreational activities, Morning walk
Subhas Sarovar	S-2	27	8.66	6.6	0.030	12	Fishing, Bathing
Santragachi Jheel	S-3	26	8.43	2.8	0.81	2	Waste dumping, cloth washing, cattle washing
East Kolkata Wetlands	S-4	30	8.89	11.94	0.030	1	Pisciculture, bathing

Plate 1 – Representative species collected from all four sites.

Family: Libellulidae
Pantala flavescens

Family:Palaemonidae
Macrobrachium equidens

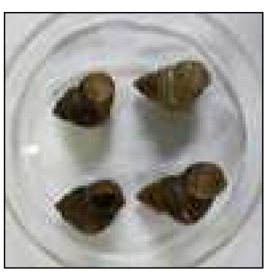


Family: Thiaridae
Melanoides tuberculata

Family:Chironomidae
Chironomus sp.

Family:Lumbricidae
Lumbricus terrestris

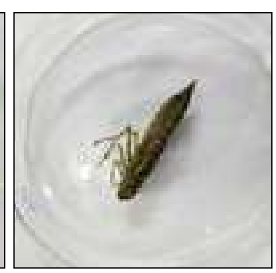
Family:Belostomatidae
Diplonychus rusticus



Family: Viviparidae
Filopaludina bengalensis

Family: Coenagrionidae
Agrocnemis sp.

Family: Nepidae
Ranatra sp.



Family: Aeshnidae
Aeshna sp.

Table 2- Identified families and genera of Benthic macro- invertebrates of Rabindra Sarovar, Subhas Sarovar, Santragachi Jheel and East Kolkata Wetlands

Sl No.	Taxonomical group	Family	Genus/Subfamily	Rabindra Sarovar (S-1)	Subhas Sarovar (S-2)	Santragachi Jheel (S-3)	East Kolkata Wetlands (S-4)
1.	Mollusca	Viviparidae	*Filopaludina bengalensis*[a]	+	+	+	+
2.	Mollusca	Thiaridae	*Melanoides tuberculata*[a]	+	+	+	+
3.	Mollusca	Lymnaeidae	*Lymnaea accuminata*[a]	+		+	+
4.	Mollusca	Planorbidae	*Indoplanorbis exustus*[a]		+	+	+
5.	Odonata	Aeshnidae	*Aeshna sp*[a]		+		
6.	Odonata	Libellulidae	*Orthetrum albistylum*[a]	+	+	+	
7.	Odonata	Coenagrionidae	*Agriocnemis sp.*[a]	+	+		
8.	Odonata	Libellulidae	*Pantala flavescens*[b]		+		
9.	Coleoptera	Hydrophilidae	*Hydrophilus sp.*[b]	+	+		
10.	Coleoptera	Dytiscidae	*Dytiscus sp.*[a]	+			
11.	Hirudinea	Salifidae	*Barbronia weberi* [a]	+			
12.	Crustacea	Palaemonidae	*Macrobrachium equidens*[a]	+	+		
13.	Crustacea	Atyidae	*Caridina peninsularis*[a]	+	+		
14.	Hemiptera	Nepidae	*Ranatra sp.*[a]		+	+	+
15.	Hemiptera	Belostomatidae	*Diplonychus rusticus*[a]	+	+		
16.	Hemiptera	Notonectidae	*Anisops sp.*[a]				+
17.	Hemiptera	Nepidae	*Laccotrephes sp*[a]				+
18.	Odonatan	Coenagrionidae	*Enallagma sp.*[b]		+	+	
19.	Lepidoptera	Pyralidae	*Pyralis sp.*[a]	+			
20.	Oligochaeta	Lumbricidae	*Lumbricus terrestris*[a]				+
21.	Polychaeta	Nereididae	*Namalycastis sp.*[a]			+	
22.	Diptera	Chironomidae	*Chironomus sp.*[a]			+	

Sources: [a]Akolkar, P. (2017). Benthic Macro-Invertebrates of River Ganga. CPCB, [b]Srivastava & Sinha, 1993, Ghosh and Nilsson, 2012

Table 3 : Site-wise availability of Taxonomical families.

BMWP Score	Taxonomical Families	Site-1	Site-2	Site-3	Site-4	Pollution tolerance
8	Libellulidae	+	+	+		Increasing Pollution Tolerance
	Aeschnidae		+			
6	Viviparidae	+	+	+	+	
	Thiaridae	+	+	+	+	
	Atyidae	+	+			
	Palaemonidae	+	+			
	Coenagrionidae	+	+	+		
	Nereididae			+		
5	Balostomatidae	+	+	+	+	
	Hydrophilidae	+	+			
	Dytiscidae	+				
	Pyralidae	+				
	Notonectidae				+	
	Nepidae		+	+	+	
3	Salfidae	+				
	Lymnaeidae	+		+	+	
	Planorbidae		+	+	+	
2	Chironomidae			+		
1	Lumbricidae				+	

Table 4: Biological Water Quality Criteria (BWQC) developed by Central Pollution Control Board.

Range of Saprobic Score	Range of Diversity Score	Water quality Class	Water Quality	Indicating Colour
7 and more	0.2 – 1	A	Clean	Blue
6 – 7	0.5 – 1	B	Sight Pollution	Light Blue
3 – 6	0.3 – 0.9	C	Moderate Pollution	Green
2 – 5	0.4 - less	D	Heavy Pollution	Orange
0 – 2	0 – 0.2	E	Severe Pollution	Red

Table 5: Results of Biological Water Quality Class of four sampling sites as per CPCB criteria

Name of the sites	Station Code	Range of Saprobic Score (0-10)	Range of Diversity Score (0-1)	Biological Water Quality	Biological Water Quality Class	Indicator Colour
Rabindra Sarovar	S-1	5.33	0.440	Moderate Pollution	C	Green
Subhas Sarovar	S-2	5.82	0.620	Moderate Pollution	C	Green
Santragachi Jheel	S-3	5.40	0.643	Moderate Pollution	C	Green
East Kolkata Wetlands	S-4	4.25	0.571	Moderate Pollution	C	Green

Conclusion

Biomonitoring of water bodies based on the saprobic and diversity index can be a useful tool to assess the water quality status of different aquatic ecosystems of the country The results of present study based on saprobic and diversity score indicates that all four sites selected for the study namely Ravinder Sarovar, Subhash Sarovar, Santragachi Jheel and East Kolkata Wetlands were moderately polluted during the sampling period due to many anthropogenic activities and non-point sources of pollution. A total of 11 taxonomical groups comprising of 19 different families with total of 609 individual organisms were accounted during the study. Among all the groups, members of group odonata, hemiptera and molluscs were found in abundance. Species like *Chironomus sp.* and *Lumbricus terrestris* reveal the organic pollution in Santragachi Jheel and East Kolkata Wetland respectively. Assessment of biological water quality from all the sampling stations revealed that the water is unfit for potable use and requires proper conventional treatments. All four sites therefore need proper maintenance along with environmentally sound management of sewage effluents presently mixing with the water of aquatic ecosystem selected for study in order to make the water ecologically appropriate. If proper management practices are not adopted in near future, it can be detrimental to the aquatic life of all four water bodies.

Acknowledgements

The authors are thankful to Director, CSIR-NEERI, Nagpur, and Head, CSIR-NEERI, Kolkata Zonal Centre for providing all necessary facilities to complete this work (CSIR-NEERI/KRC/2023/JUNE/KZC/1). We also extend our gratitude to KMDA (Kolkata Metropolitan Development Authority) for giving permission to conduct sampling work in both Rabindra Sarovar and Subhas Sarovar.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Spider richness in Kuttanad, a major low-lying rice agroecosystem in Central Kerala, India

Nishi Babu and G. Prasad

Department of Zoology
University of Kerala, India

Abstract

This study focused on the spider fauna of the rice agroecosystem around Kuttanad's paddy fields and proximate areas. The spider richness, abundance, and species composition between the rice agroecosystem and nearby surroundings were assessed from July 2021 to April 2022. Pitfall trap and sweeping net were used to conduct monthly collection in six sites: Edthuva, Champakulam, Veeyapuram, Kainakary, Moncompu, and Karuvatta. We collected only adult spiders for identification. Edthuva represented the highest number of specimens, followed by Champakulam, Moncompu, Karuvatta, Kainakary, and Veeyapuram. Representatives from 16 families were obtained, with Salticidae, Araneidae, and Tetragnathidae being the most prevalent. Also, it was noted that the spider species in rice fields were typical, and statistical analysis revealed a substantial variation in species composition between paddy fields and their nearby areas. In addition to the species diversity, a closer look at the vertical distribution pattern of orb-web weavers belonging to Tetragnathidae and Araneidae in paddy fields were also observed. The diversity indices indicate that the Edthuva and Champakulam rice agroecosystem spider communities are more diversified than those in other locations.

Keywords: Spider fauna, Paddy fields, Kuttanad, Biocontrol, Paddy pest

Introduction

Scientists have recently focused on studying biological diversity in agroecosystems to create sustainable ecosystems. Additionally, monitoring a few ecologically significant species is an intuitively appealing way to assess the sustainability of that ecosystem. One such agroecosystem is the cultivation of rice, which is the most ancient form of intensive agriculture in Kuttanad, a low-lying fragile wetland ecosystem in the south Indian state of Kerala, which consists of approximately eight agroecosystem zones. Paddy cultivation has been the primary livelihood in Kuttanad. According to Roger (1996), the rice crop and associated ecosystems constitute a rich mosaic of habitats that preserve high biological diversity. Therefore, increasing the yield and protecting it from pest attacks are necessary.

Moreover, the use of pesticides may reduce not only pest species but also their natural enemies. Other than the use of chemicals, the most effective pest management strategy is the promotion of biological control. As biocontrol provides self-perpetuating control at little to no ongoing expense, it is both economically and environmentally favourable since it reduces the non-target effects and environmental damage caused by many synthetic inputs (Bale *et al.*, 2008). Since spiders are one of the natural enemies that help to reduce the pest populations, their diversity and density are crucial in any attempt to use them as biocontrol agents. Also, they exhibit high diversity and are dominant insectivores in many terrestrial ecosystems. Research has shown that spiders can be effective predators in reducing the numbers of planthoppers and leafhoppers in rice fields (Hamamura 1969; Gavarra and Raros 1973; Samal and Misra 1975;

*Author for correspondence : nishibabu510@gmail.com.
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Kobayashi 1977; Chiu 1979; Holt *et al.*, 1987; Tanaka 1989). Dispersal by running and ballooning allows spiders to quickly establish colonies in agricultural fields following disturbance from agricultural techniques. Lee *et al.* (1997) showed that spiders represent more than 90% of the natural enemies of brown planthoppers living in paddy fields. Because of this, most studies on the biological control of planthoppers have focused on spiders. As a result, studies on the diversity of spiders in agroecosystems are important to monitor how these predators affect herbivorous pests (Maloney *et al.*, 2003) and to understand how environmental changes affect spider colonization. (Oberg, 2007).

Spiders utilize various techniques to capture their food, and it has been noted that orb-web spiders may trap more insects than they consume (Tahir *et al.*, 2009). In the present study, Tetragnathidae and Araneidae are the two orb-web weavers most frequently found in the paddy fields of Kuttanad. This work aims to assess the species composition and vertical stratification of these Tetragnathidae and Araneidae spiders in paddy fields and adjacent areas. Also, this study intends to propagate the knowledge that spiders are a common and influential group of natural predators that are thought to be effective in the biocontrol of significant paddy pests in agroecosystems.

Materials and Methods Study Area

Kuttanad Wetland is a low-lying area located between 9°15' N to 9°33' N latitudes and 76°19' E to 76°34' E longitudes, with backwaters, canals and stream networks located in the southern end of India's largest Ramsar site, the Vembanad-Kole wetlands. This wetland is a deltaic trough-like formation shaped by the confluence of four major rivers of the state, the Meenachil, the Manimala, the Pampa, and the Achenkovil, flowing towards the north-western direction and debouching into the Vembanad Backwater. Kuttanad has an area of approximately 874 km^2 and covers three districts of Kerala: Pathanamthitta, Alappuzha, and Kottayam, each contributing nearly 20 percent of Kerala's total rice production. It is therefore acknowledged as the "Rice Bowl of Kerala." The Food and Agriculture Organization of the United Nations recognises the Kuttanad wetland farming system as "unique", saying it is the "only system in India that favours rice cultivation below sea level". The sites selected for the present study were in Champakulam, Edathua, Veeyapuram, Kainakary, Karuvatta, and Moncompu, situated at 9.41°N, 76.4 °E; 9.36°N, 76.45°E; 9.30°N, 76.46°E, 9.48°N, 76.37°E, 9.311 °E;76.43°N and 9.44°E; 76.42°N respectively. Edathua and Champakulam are organic farms that do not employ chemical fertilizers. Farmers in Karuvatta and Moncompu use weedicides to control insect attacks, while those in Veeyapuram and Kainakary use pesticides.

Study Period

The study was conducted from July 2021 to April 2022, in paddy fields and their proximate areas at six stations located at Edathua, Champakulam, Kainakary, Veeyapuram, Moncompu, and Karuvatta. The period of each paddy's cultivation is four months, with two seasons, Rabi and Kharif. Sampling was conducted in these two seasons: Rabi, which is characterised by heavy rain (South-West Monsoon) and high humidity, and Kharif, which is characterized by low rainfall and dry weather (Menon *et al.*, 2000).

Sampling

The sampling was done for each season once in a month. The paddy fields were selected and divided into 10 quadrants of 1m x 1 m. The specimens were collected from each quadrant using a visual search and sweeping method between 6am to 9am. The collected specimen were preserved in 70% alcohol and transported to the laboratory.

Sample identification

A detailed examination of each spider was done using a stereo zoom microscope (Magnus, MS 24). The epigynum of female adult spider was cleared in 10% KOH, and mounted on a temporary slide, and observed under a compound microscope (Leica DM1000 LED) to study the internal structures. Adult male spiders are identified by observing their palp. Measurements of the legs and pedipalps are taken using the Leica S8APO version 4.2. The specimens were identified using literature. All the collected specimens were preserved and deposited in the Zoological Museum of the Department of Zoology, University of Kerala, Kariavattom.

Vertical stratification

We conducted field observations on the spiders belonging to the families Tetragnathidae and Araneidae based on their distribution in different strata of the paddy crop. The vertical stratification of the spider species is related to the height of the rice plant (Babu and Prasad, 2022).

Data Analysis

Spider diversity of paddy fields and proximate regions of each station was analysed using R Core Team (2022). Other indices such as the Shannon-Weiner index (H'), Simpson's Dominance index, Margalef's species richness, and Evenness were analysed using the *vegan* package in R. To estimate the possible reach of spider fauna in both paddy and proximate regions of each station, a species accumulation curve was done using *vegan* package in R. To observe the patterns of community structure in the study area, a

Non-metric Multidimensional Scaling (NMDS) ordination was performed using the *vegan* package in R.

Results and Discussion

Sampling yielded a total of 3569 individuals of 80 species representing 16 families and 57 genera (Table 1). The dominant group of families has 24 species of Salticidae, 14 species of Araneidae, and nine species of Tetragnathidae. The analysis of diversity patterns of the spider community in both paddy and proximate areas of each study area is represented in Tables 2 and 3. The rice agroecosystem of Champakulam has the highest species diversity, with H' of paddy fields is 2.88 and proximate is 3.86, and also having lowest dominance and highest evenness. Followed by Edthuva with H' of paddy fields is 2.81 and its adjacent area is 3.95. The lowest diversity of spiders was observed in Veeyapuram *i.e.,* in paddy fields it is 2.37 and in proximate areas the value is 3.09. In Kainakary also the same H' value has been reported for paddy fields but in the proximate area the value is 3.48, a higher value than that of Veeyapuram. The highest evenness index was observed in the paddy fields of Champakulam and proximate regions of the Karuvatta rice agroecosystem with values of 0.85 and 0.69 respectively. Species richness measured using Margalef's index had maximum value in rice fields and proximate region Champakulam, whereas minimum value was observed in Veeyapuram. The species accumulation curve of each site is also given in Figure 1 (paddy fields) and Figure 2 (proximate areas), indicating that sampling was almost complete. The species accumulation curve was computed as a qualitative measure of species richness, with Shannon-Weiner and Simpson's diversity being higher in Edathua and Champakulam due to higher species richness. And, the curves may indicate stabilization in the estimated number of species.

The NMDS scatter plot indicates significant values of spider assemblage of the sampling sites (Figure 3). Higher spider diversity in Champakulam and Edathua suggested a favourable habitat for spiders. The vertical stratification of spiders *Tetragnatha mandibulata*, *T. javana*, *T. keyserlingi*, *Tylorida striata*, *Leucauge granulata,* and *Glenognatha dendata* belonging to the families Tetragnathidae and *Neoscona theisi*, *N. nautica*, *Argiope catenulata* and *Araneus ellipticus* representing the family Araneidae observed during the study is presented in Table 4. Most of the tetragnathids and araneids were reported from the upper layer of the rice plant. The present study documented species diversity and assemblage in selected rice fields and their adjacent areas of Kuttanad. According to the findings, more species are reported in paddy fields of Edathua and Champakulam (organic farms) than in other farms in Kuttanad. Overall, species richness is the most widely adopted diversity measure, which examines the number of species occurring in a habitat (Sudhikumar *et al.*, 2005). The organic farms obtained the highest species richness value in the present study. The highest evenness index obtained resulted in the conclusion that all species in that site are equally abundant. It is possible that the excessive usage of chemical fertilizers is responsible for the lower diversity in the fields of Veeyapuram and Kainakary. The rice agroecosystems in Karuvatta and Moncompu, which used weedicides, displayed greater diversity than pesticide-affected fields but had a different species composition from organic farms. As a result, it can be assumed that spiders can serve as indicators of an ecosystem's health.

According to Tahir *et al.* (2012), orb-weaving spiders utilize the vertical stratification method of niche portioning and do not actively compete with one another. Orb-web weavers can efficiently reduce niche overlap by capturing different prey at different heights due to differences in the web structure. Araneids and some tetragnathids were seen foraging at the upper layer of the rice plants in the current investigation. *Glenognatha dentata* dominated the plant's basal region. Therefore, spiders can form several guilds based on the prevalence of pests, the microhabitat, and feeding strategies and coexist depending on the plant structure for their preferred habitat.

Table 1. Checklist of spiders recorded in the study

I.	**Family Araneidae** **Clerck, 1757**
1.	Anepsion maritatum (O. Pickard-Cambridge, 1877)
2.	Araneus ellipticus (Tikader & Bal, 1981)
3.	Argiope catenulata (Doleschall, 1859)
4.	Argiope anasuja Thorell, 1887
5.	Chorizopes khanjanes Tikader, 1965
6.	*Cyclosa confraga* (Thorell, 1892)
7.	Cyclosa neilensis Tikader, 1977
8.	Cyrtophora citricola (Forsskål, 1775)
9.	Eriovixia laglaizei (Simon, 1877)
10.	Gasteracantha geminata (Fabricius, 1798)
11.	*Guizygiella* sp.
12.	Herennia multipuncta (Doleschall, 1859)
13.	Neoscona nautica (L. Koch, 1875)
14.	Neoscona theisi (Walckenaer, 1841)
II.	**Family Clubionidae** **Wagner, 1887**
15.	Clubiona drassodes O. Pickard-Cambridge, 1874
16.	Clubiona filicata O. Pickard-Cambridge, 1874
17.	Clubiona tridentata Dhali, Roy, Saha & Raychaudhuri, 2016
III.	**Family Corrinidae** **Karsch, 1880**
18.	Castianeira zetes Simon, 1897
19.	Corinnomma severum (Thorell, 1877)
IV.	**Family Eresidae** **C. L. Koch, 1845**
20.	Stegodyphus sarasinorum Karsch, 1892
V.	**Family Hersiliidae** **Thorell, 1869**
21.	Hersilia savignyi Lucas, 1836
22.	Hersilia tibialis Baehr & Baehr, 1993
VI.	**Family Lycosidae** **Sundevall, 1833**
23.	Pardosa pseudoannulata (Bösenberg & Strand, 1906)
24.	Pardosa sumatrana (Thorell, 1890)
VII.	**Family Oxyopidae** **Thorell, 1869**
25.	Oxyopes javanus Thorell, 1887
26.	Oxyopes birmanicus Thorell, 1887
27.	Oxyopes shweta Tikader, 1970
28.	Peucetia viridana (Stoliczka, 1869)
VIII.	**Family Philodromidae** **Thorell, 1869**
29.	Psellonus planus Simon, 1897
IX.	**Family Pholcidae** **C. L. Koch, 1850**
30.	Pholcus sp.
X.	**Family Pisauridae** **Simon, 1890**
31.	Dendrolycosa gitae (Tikader, 1970)
XI.	**Family Salticidae** **Blackwall, 1841**
32.	Asemonea tenuipes (O. Pickard-Cambridge, 1869)
33.	Bianor angulosus (Karsch, 1879)
34.	Brettus cingulatus Thorell, 1895
35.	Carrhotus viduus (C. L. Koch, 1846)
36.	Curubis tetrica Simon, 1902
37.	Epocilla aurantiaca (Simon, 1885)
38.	Hyllus semicupreus (Simon, 1885)
39.	Icius vikrambatrai Prajapati, Malamel, Sudhikumar & Sebastian, 2018
40.	Indomarengo chavarapater Malamel, Prajapati, Sudhikumar & Sebastian, 2019
41.	Indopadilla insularis (Malamel, Sankaran & Sebastian, 2015)
42.	Marengo Sachintendulkar Malamel, Prajapati, Sudhikumar & Sebastian, 2019
43.	Menemerus bivittatus (Dufour, 1831)
44.	Myrmaplata plataleoides (O.P.-Cambridge, 1869)
45.	Phintelloides undulatus (Caleb & Karthikeyani, 2015)
46.	Phintella vittata (C. L. Koch, 1846)
47.	Plexippus petersi (Karsch, 1878)
48.	Plexippus paykulli (Audouin, 1826)
49.	Rhene flavicomans Simon, 1902
50.	Rhene flavigera (C.L. Koch, 1846)
51.	Rhene rubrigera (Thorell, 1887)

52. Siler semiglaucus (Simon, 1901)
53. Telamonia dimidiata (Simon, 1899)
54. Thiania bhamoensis Thorell, 1887
55. Thyene bivittata Xie & Peng, 1995

XII. Family Sparassidae Bertkau, 1872

56. Heteropoda venatoria (Linnaeus, 1767)
57. *Olios* sp.
58. Olios milleti (Pocock, 1901)
59. Thelcticopis moolampilliensis Jose & Sebastian, 2007

XIII. Family Tetragnathidae Menge, 1866

60. *Glenognatha dentata* (Zhu & Wen, 1978)
61. *Leucauge granulata* (Walckenaer, 1841)
62. *Tetragnatha javana* (Thorell, 1890)
63. *Tetragntha keyserlingi* Simon, 1890
64. *Tetragnatha mandibulata* Walckenaer, 1841
65. *Tetragnatha* sp.
66. *Tetragnatha viridorufa* Gravely, 1921
67. *Tylorida striata* (Thorell, 1874)
68. *Tylorida ventralis* (Thorell, 1874)

XIV. Family Theridiidae Sundevall, 1833

69. Meotipa argyrodiformis (Yaginuma, 1952)
70. Meotipa picturata Simon, 1895
71. Nihonhimea indica (Tikader, 1977)
72. *Theridion* sp.
73. Theridion manjithar Tikader, 1970

XV. Family Thomisidae Sundevall, 1833

74. Camaricus formosus Thorell, 1887
75. Indoxysticus minutus (Tikader, 1960)
76. Thomisus projectus Tikader, 1960
77. Thomisus pugilis Stoliczka, 1869

XVI. Family Uloboridae **Thorell, 1869**

78. Philoponella feroka (Bradoo, 1979)
79. *Philoponella* sp.
80. Zosis geniculata (Olivier, 1789)

Table 2: Diversity indices of spiders from the selected paddy fields of Kuttanad

	Karuvatta	Moncompu	Edathua	Champakulam	Veeyapuram	Kainakary
Dominance_D	0.08214	0.07772	0.06192	0.06045	0.09801	0.09861
Simpson_1-D	0.9179	0.9223	0.9381	0.9336	0.902	0.9014
Shannon_H	2.583	2.62	2.879	2.816	2.374	2.374
Evenness_e^H/S	0.8277	0.8581	0.8086	0.8597	0.8259	0.8265
Margalef	1.917	1.94	2.598	2.631	1.549	1.569

Table 3: Diversity indices of spiders from the **proximate areas of the selected paddy fields of Kuttanad.**

	Karuvatta	Moncompu	Edathua	Champakulam	Veeyapuram	Kainakary
Dominance_D	0.02531	0.0303	0.03097	0.0237	0.05351	0.03898
Simpson_1-D	0.9747	0.9697	0.969	0.9763	0.9465	0.961
Shannon_H	3.847	3.699	3.861	3.948	3.091	3.481
Evenness_e^H/S	0.6994	0.652	0.6015	0.656	0.647	0.5804
Margalef	7.477	7.128	8.701	8.865	4.071	6.661

Table 4. Vertical stratification of tetragnathid and araneid spiders in rice fields from soil level

Sl. No.	15-20cm	20-50cm	50-80cm	>80cm	Tip of the leaf
1.	*Glenognatha dentata*	*Glenognatha dentata*	Araneus ellipticus	*Tylorida striata*	*Tetragnatha mandibulata*
2.			*Leucauge granulata*	*Glenognatha dentata*	*Tetragnatha javana*
3.			*Argiope catenulata*	*Araneus ellipticus*	*Tetragnatha keyserlingi*
				Neoscona theisi	
				N. nautica	
				Argiope catenulata	

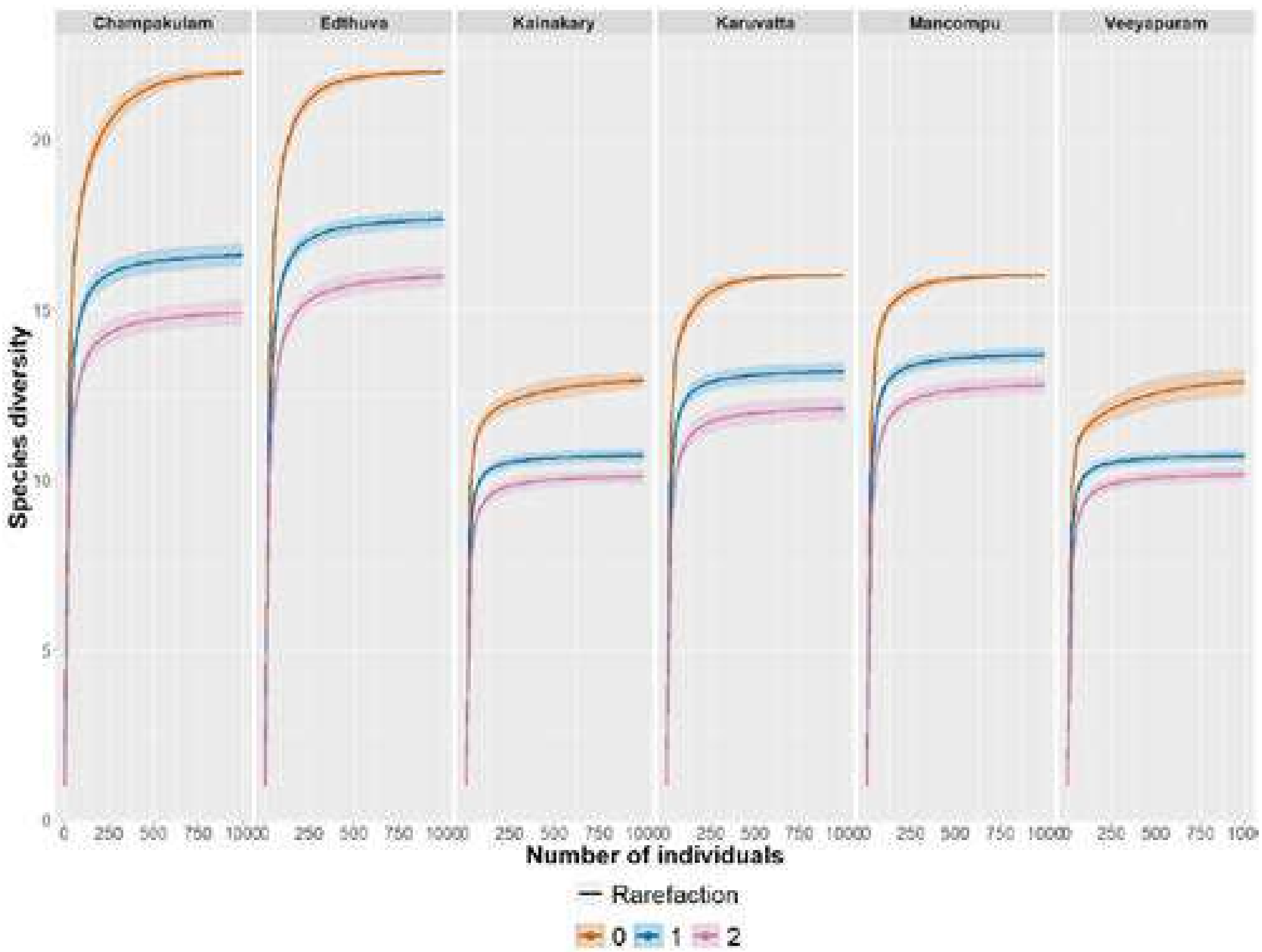

Fig.1. Species accumulation curve of selected paddy fields of Kuttanad. 0-Richness, 1-Shannon diversity, and 2-Simpson diversity.

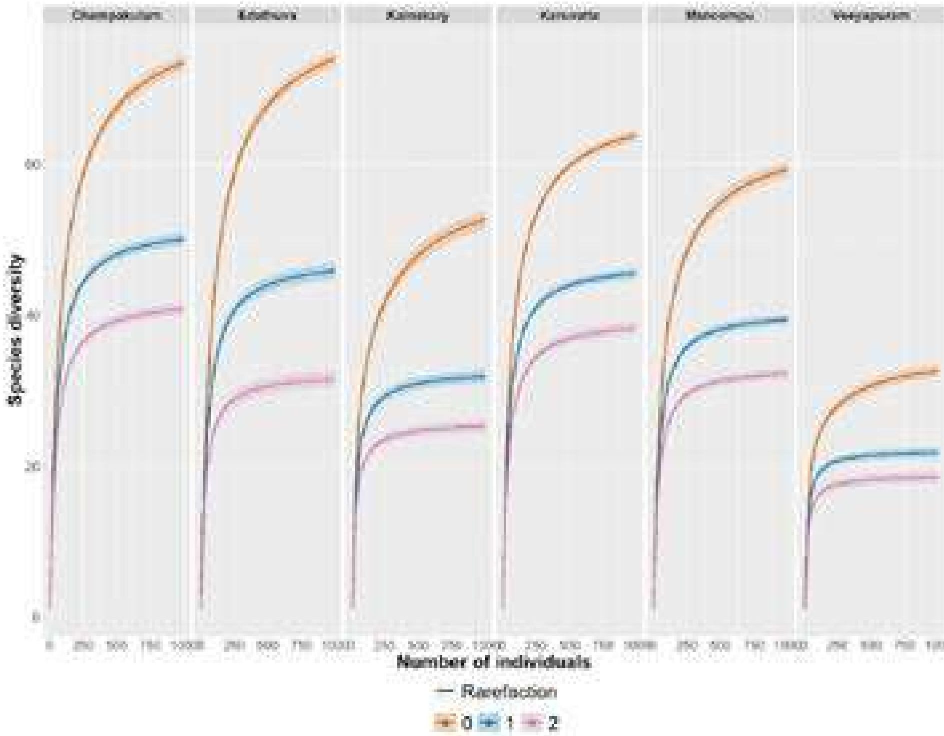

Fig.2. Species accumulation curve of proximate regions of selected paddy fields of Kuttanad. 0-Richness, 1- Shannon diversity and 2- Simpson

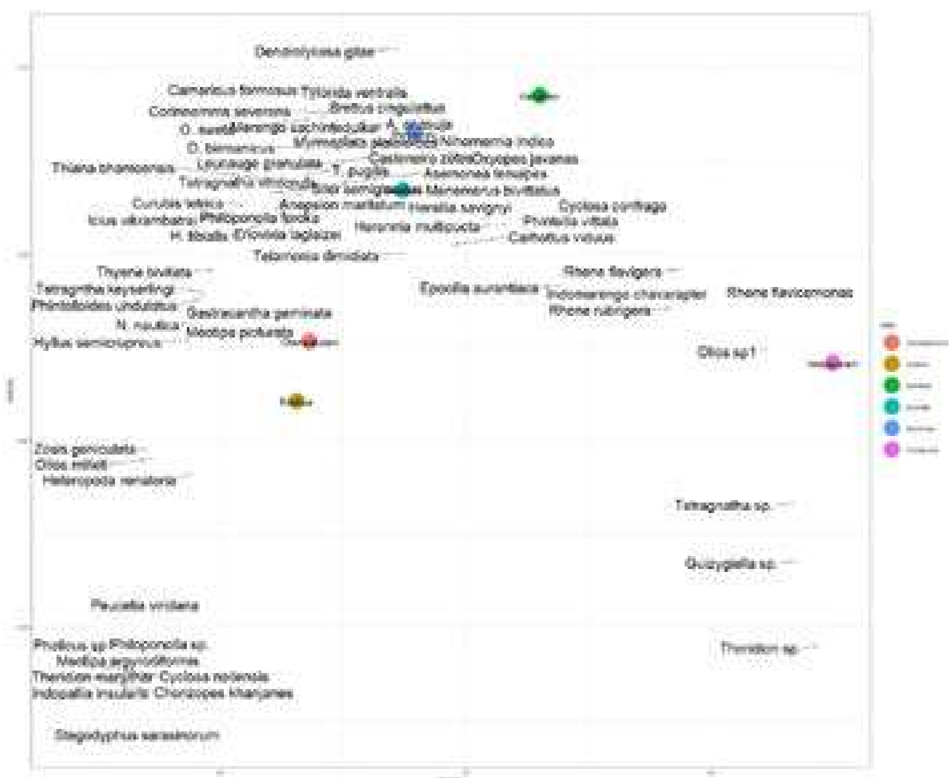

Fig.3. NMDS: Distribution of species in different sites.

Acknowledgements

Nishi Babu (NB) acknowledges the financial assistance received from the University Grants Commission (UGC), New Delhi. Dr. G. Prasad appreciates the University of Kerala for providing financial support for the study through the project fund of the university. The farmers, Mr. Jacob Sebastian, Thomas Mathew, Mathew Thomas, and Girish V., are thanked by the authors for providing the facilities required for the fieldwork. NB would like to extend her gratitude to Ms. Kripa Mariam Mammen and Merin Elizabeth George for their assistance and continual support throughout the field collections and lab work. Also, NB likes to thank Mr. Binish Roopas for his aid and support. We would like to thank an anonymous reviewer for the constructive suggestions.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Osteology of incomplete lateral lined schisturid loaches of Meghalaya: a comparative account

Wimarithy K. Marak & Yumnam Lokeshwor Singh*
Department of Zoology, Assam Don Bosco University, Tapesia Garden, Kamarkuchi, Assam, India, 782402
Email: wimmarak@gmail.com

Abstract

The present study is based on the comparative osteology among *Schistura* fishes with incomplete lateral line found in Meghalaya. Six species are studied for osteology, three already described ones and three unknown species. The clearing and staining of this species group showed variations and similarities in their neurocranium structure, ceratobranch structure, air bladder capsule structure, vertebrae number, fin insertions and caudal vertebrae complex in all cases. The study revealed that *Schistura fasciata* has a total of 37 vertebrae, *S. reticulofasciata* with 35–36, *S. syngkai* with 34–35, *S.* sp. 1 with 35, *S.* sp. 2 with 37 and *S.* sp. 3 with 32 vertebrae.

Keywords: *Schistura*, Nemacheiline fish, comparative osteology, Meghalaya

Introduction

Nemacheiline fishes of the genus *Schistura* McClelland, 1838, are highly diversified predominantly small and colourful fishes with mouth moderately arched, lower lip with a median interruption, no formation of two lateral triangular pads, and lips smooth to strongly furrowed. Some of them have feebly to well develop processus dentiformis while it is absent in some. *Schistura* have diverse colour pattern usually with bars, split in many, basicaudal black bars with complete or dissociate. Their caudal fins are slightly emarginated to fork (Vishwanath *et al*., 2014).

Meghalaya is drained by two drainage system i.e., Brahmaputra River drainage and Barak-Surma-Meghna River drainage system. Khynriam & Sen (2014) listed 12 species of *Schistura* from Meghlaya viz., *Schistura beavani* (Gunther, 1868), *S. cinticauda* (Blyth, 1860), *S. devdevi* (Hora, 1935), *S. multifasciata* (Day, 1878), *S. papulifera* Kottelat *et al*., 2007, *S. prashadi* (Hora, 1921), *S. reticulofasciata* (Singh & Bănărescu, 1981), *S. rupecula* McClelland, 1838, *S. scaturigina* McClelland, 1839, *S. sijuensis* (Menon, 1987), *S. sikmaensis* (Hora, 1921) and *S. vinciguerrae* (Hora, 1935). Out of these, the occurrence of five species viz., *S. cinticauda, S. rupecula, S. prashadi, S. sikmaensis* and *S. vinciguerra* are doubtful due to their original type locality and may possibly be the misidentification of the specimens. After a thorough investigation on the available *Schistura* species in Meghalaya, nine species of *Schistura* including three unknown species are with incomplete lateral lined viz., *S. devdevi, S. fasciata* Lokeshwor & Vishwanath, 2011, *S. larketensis* Choudhury *et al.,* 2017, *S. papulifera, S. reticulofasciata, S. syngkai* Choudhury *et al.,* 2019, *S.* sp. 1, *S.* sp. 2 and *S.* sp. 3.

Comparative osteology is one of the tools of taxonomy in systematic study of species within the genus or family. Proper osteological study of fish species from Meghalaya has not been carried out. Out of the six studied herein, three species are already named and three are unknown. The clearing and staining of *Schistura devdevi, S. larketensis* and *S. papulifera* were not carried out due to the unavailability of specimens in the museum and could not find them during survey. The studies have revealed the structural similarities and variations amongst the *Schistura* species group with incomplete lateral line in their neurocranium, ceratobranch,

*Author for correspondence : lokeshwor.singh@dbuniversity.ac.in
Article Received on: 02.04.2023 Accepted on: 24.04.2023

air bladder capsule, vertebrae counts, fin insertions and caudal vertebrae complex.

Materials and Methods

Specimens were collected from different parts of Meghalaya from both drainage systems i.e., Brahmaputra River drainage and Barak-Surma-Meghna River drainage. Collected specimens were preserved in 10% formalin buffer solution in translucent bottle. General counts and measurements follow Kottelat (1990). Point to point measurements has been done by using dial caliper nearest to 0.1 mm unit. Measurements of body parts are expressed in percentage of Standard Length (SL) and subunits of head parts are expressed as percentage of Lateral Head Length (LHL). Clearing and double staining of bones follow Taylor & Van Dyke (1985) with necessary modifications according to size of the fish. Identification of bones follows Sawada (1982) and Prokofiev (2010). Data from Kottelat *et al.,* 2007 for *Schistura papulifera* and data from Hora, 1935 for *Schistura devdevi* were used in the absence of comparative materials. The museum specimens of *Schistura larkentesis* have been observed from Guwahati University Museum of Fish (GUMF). The clearing and staining of *Schistura devdevi* (Hora, 1935), *S. larketensis* Choudhury *et al.,* 2017, and *S. papulifera* Kottelat *et al.,* 2007 was not be able to carried out due to the unavailability of specimens.

Result

The recent survey on various river systems of Meghalaya revealed nine loach species having incomplete lateral line under genus *Schistura* and family Nemacheilidae. Table 1 shows the distribution and status of *Schistura* with incomplete lateral line in the two drainage system in Meghalaya i.e. The Brahmaputra drainage system and the Barak-Surma – Meghna drainage system. The highest assemblage of this species group is found in Brahmaputra drainage system with 8 species viz., *Schistura devdevi, S. larketensis, S. papulifera, S. reticulofasciata, S. syngkai, S.* sp. 1, *S.* sp. 2 and *S.* sp. 3. Barak-Surma-Meghna drainage system is inhibited by 3 species viz., *Schistura fasciata, S. reticulofasciata* and *S. syngkai*. There are 4 species viz., *Schistura fasciata, S. reticulofasciata,* and *S. syngkai* have been reported from both the drainage systems *i.e*., from Bahmaputra and Barak-Surma-Meghna drainage systems. Among them *S. papulifera* and *S. larketensis* are found in cave and *S. papulifera* is under critically endangered according to IUCN (2010).

Systematic Accounts:

Schistura devdevi (Hora, 1935)

(Fig. 1 A)

Nemacheilus devdevi Hora, 1935: 54, pl. 3 (Type locality: Eastern Himalayas; small streams below Darjeeling and Sikkim, India).

Material examined: ZSI/VF/ERS 2076, 31.1 mm SL; India: Assam: Dhemanji district: Subansiri River at Padomukh (Brahmaputra River system); Coll. R. Mathew & party, 03-ii-2006. ZSI/VF/ERS 2495, 34.2 mm SL; India: Arunachal Pradesh: Subansiri district: Sippi River (Brahmaputra River system); Coll. R. Mathew & party, 05-vi-2007.

Diagnosis: Body with 4–6 dark broad saddles on dorsum, 7–8 irregular bars on flanks; basicaudal bar fragmented with a short dark brown bar on ventral portion and a short faintly mark spot on dorsal portion; 7½ branched dorsal-fin rays, pelvic fin with 6 rays, caudal fin slightly emerginate with 8+7 branched rays; lateral line incomplete with 54 pores terminating above vertical to anal-fin origin.

Distribution: India: Arunachal Pradesh, Meghalaya, Sikkim.

Schistura fasciata Lokeshwor & Vishwanath, 2011

(Fig. 1 B)

Schistura fasciata Lokeshwor & Vishwanath, 2011: 1514–1519 (Type locality: Barak River at the western side of Maram Hill, Senapati District, Manipur, India)

Material examined: ADBU-MF/1000/1–5, 5 exs., 55.9–66.0 mm SL; Sohra, East Khasi Hills, Meghalaya, India; Daphisha Pala, 05-x-2022.

Diagnosis: Body with 11-13 dark brown transverse bars, bars arranged regularly, often fused on mid-dorsal line, width of bar broader than interspace; moderately high adipose crest on dorsal and ventral sides of caudal peduncle; lateral line incomplete, reaching vertical to posterior end of anal-fin base; three black spots on base of dorsal-fin; dorsal-fin with 8½ branched rays; processus dentiformis large.

Distribution: Barak River, Maram Hill, Senapati District, Manipur and Sohra, East Khasi Hills, Meghalaya, India.

Schistura larketensis Choudhury _et al.,_ 2017

(Fig. 1 C)

Schistura larketensis Choudhury *et al.,* 2017: 089–100 (Type locality: Krem Khung about 1.5 km from Larket village, East

Jaintia Hills District, Meghalaya, India).

Material examined: GUMF 0261, female, 54.5 mm SL, holotype; GUMF 0264/3, 3exs., 49.6–61.3 mm SL; Krem Khung, Larket village, East Jaintia Hills District, Meghalaya, India.

Diagnosis: Body with pale to weakly-pigmented; thick and short basicaudal bar immediately below lateral line (often appearing broken in some individuals); eyes vestigial or absent; anterior nostrils forming long and pointed triangular tube-like flaps; incomplete lateral line; small and cylindrical axillary pelvic lobe; emarginated caudal-fin.

Distribution: Krem Khung, Larket village, East Jaintia Hills, Meghalaya, India.

***Schistura papulifera* Kottelat *et al.*, 2007**

(Fig. 1 D)

Schistura papulifera Kottelat *et al.,* 2007: 35-44 (Type locality: Krem Synrang Pamiang system, in the Jaintia Hills, Eastern Meghalaya, India.

Diagnosis: Pale white body, vestigial eye which is subcutaneous and eternally appearing as small diffuse blackish spot, not communicating with outside by a canal; lower half of head covered by numerous small skin projections and five pores in supratemporal canal of cephalic lateralis line system; 8½ branched dorsal-fin rays; incomplete lateral line, extending to level of pelvic fin origin and no axillary pelvic bone.

Distribution: Krem Synrang Pamiang system, in the Jaintia Hills, Eastern Meghalaya, India.

***Schistura reticulofasciata* Singh & Bănărescu, 1982**

(Fig. 1 E)

Schistura reticulofaciata Singh & Bănărescu in Singh *et al.*, 1982: 206 (Type Locality: Barapani, near Shillong, Meghalaya, India)

Material examined: ADBU-MF/1001/1–7, 7 exs., 43.6–49.0 mm SL; Ano stream, Damring River, Brahmaputra drainage, West Garo Hills, Meghalaya, India (25º41′27.29"N, 90º23′15.29"E, altitude 455 m asl); Wimarithy K. Marak, 12-ii-2022.

Diagnosis: Body with network of numerous irregular bars, most of which are vertical and connected by one or two longitudinal stripes; lateral line incomplete; processus dentiformis present; black spot on dorsal-fin base; basicaudal bar incomplete; caudal fin emarginated.

Distribution: Barapani, near Shillong, East Khasi Hills and Ano Stream, Damring River, West Garo Hills, (Brahmaputra drainage) Meghalaya, India.

***Schistura syngkai* Choudhury, Mukhim, Dey, Warbah & Sarma, 2019**

(Fig. 1 F)

Schistura syngkai Choudhury *et al.,* 2019: 186 (Type locality: Twahdioh stream of Wahblei River, near Seinduli village, Surma-Meghna drainage, West Khasi Hills District, Meghalaya).

Material examined: ADBU-MF/1003/1–7, 7 exs., 31.5–37.9 mm SL; Ruding stream, Dudhnoi River, Brahmaputra drainage, East Garo Hills, Meghalaya, India; Wimarithy K. Marak, 19-x-2021.

Diagnosis: Body with prominent dark brown or black mid-lateral stripe about eye diameter or wider, overlain on 12-18 vertically-elongated black blotches; lateral line incomplete; dorsal-fin with three oblique bars, dark blotch slightly above the base of the simple rays; basicaudal bar incomplete and black spot above margin of caudal-fin base, caudal-fin slightly emarginated.

Distribution: Twahdioh Stream, Wahblei River, Surma-Meghna drainage, West Khasi Hills District and Ruding stream, Dudhnoi River, Brahmaputra Drainage, East Garo Hills District, Meghalaya, India.

***Schistura* sp. 1**

(Fig. 1 G)

Material examined: ADBU-MF/1004/1–6, 6 exs., 32.9–41.1 mm SL; Sarongkol stream, Didram River, Brahmaputra Drainage, North Garo Hills District, Meghalaya, India (25º53′50.28"N, 90º31′48.48"E, altitude 106 m asl); Wimarithy K. Marak, 19-x-2021.

Diagnosis: Body with 9-10 bars; two rows of black marking on dorsal-fin; lateral line incomplete; basicaudal bar complete and black spot above it, caudal fin truncated.

Distribution: Sarongkol stream, Didram River, Brahmaputra drainage, North Garo Hills District, Meghalaya, India.

Schistura sp. 2

(Fig. 1 H)

Material examined: ADBU-MF/1005/1–5, 5 exs., 21.9–37.0 mm SL; Wah Sohphoi River, Barak-Surma-Meghna Drainage, Eastern-West Khasi Hills District, Meghalaya, India; Ibansiewdor Marngar and Spellindar Warjri, 27-xi-2022.

Diagnosis: Body with 6-7 saddles reaching up to or beyond lateral line, blotches or black patches along the lateral line between the saddles; lateral line incomplete; basicaudal bar incomplete, caudal-fin emarginated.

Distribution: Wah Sohphoi River, Barak-Surma-Meghna drainage, Eastern West Khasi Hills, Meghalaya, India.

Schistura sp. 3

(Fig. 1 I)

Material Examined: ADBU-MF/1002/1–2, 2 exs., 34.9–35.9 mm SL; Chidrang stream, Damring River, Brahmaputra drainage, Meghalaya, India (25º53′57.13"N, 90º37′18.42" E, altitude 90 m asl); Wimarithy K. Marak, 22-iii-2022.

Diagnosis: Body with 9 broad bars, interspace very narrow; incomplete lateral line; basicaudal bar complete; caudal-fin deeply emargnated.

Distribution: Chidrang stream, Damring River, Brahmaputra drainage, Meghalaya, India.

Discussion:

The meristic count of the *Schistura* species with incomplete lateral line in Meghalaya is shown in Table 2. The studies have revealed that there are differences in dorsal-fin rays where it is 3/7½ in *Schistura devdevi* and *S. syngkai*; 3–4/7½–8½ in *S.* sp. 1; 4/8½–9½ in *S.* sp. 3; and 4/8½ in *S. fasciata, S. larketensis, S. papulifera, S. reticulofasciata* and *S.* sp. 2. Anal fin rays shows the same counts in almost all the species except in *S. larketensis* and *S. papulifera* where it shows a range of 3/5–5½ and 3/5–6½ respectively. Pelvic-fin rays of all species are with 7–8 rays except *Schistura devdevi* with 6 rays. Caudal-fin rays also shows similarities and variations among this species group where it is 8+7 branched rays in *Schistura devdevi*; 9+8 in *S. fasciata, S. larketensis* and *S.* sp. 3; 8+9 in *S. papulifera*; 8+8 in *S. reticulofasciata, S. syngkai* and *S.* sp. 2 while it shows in range of 7–8+8 in *S.* sp. 1.

Comparative ostelogy

Comparative study of the bones of 6 species of incomplete lateral lined *Schistura*; 3 already described ones viz., *S. fasciata, S. reticulofasciata* and *S. syngkai* and 3 unknown species viz., *Schistura* sp. 1, *S.* sp. 2 and *S.* sp. 3, revealed the differences in their neurocranium structure, ceratobranch structure, air bladder capsule structure, vertebrae counts, fin insertions and caudal vertebrae complex.

Neurocranium structure: Variations in the neurocranium structure of incomplete lateral lined *Schistura* is observed in the shape of fontanelle, demarcation between two sides of frontals, supraethmoid-ethmoid complex (narrow to broad) and different shape of parietals which are shown in Fig. 2 (A–F).

The shape of the anterior part of the fontanelle shows variation among different species. It is pointed in *Schistura reticulofasciata* and *S.* sp. 2 (Fig. 2 B and F respectively) whereas it is blunt in the rest of the species observed. The base of the fontanelle is observed to be broadest in *Schistura reticulofasciata* (Fig. 2 B) and narrowest in species like *S. fasciata* and *S. syngkai* (Fig. 2 A and D respectively). The supraethmoid-ethmoid complex joins firmly with anterior part of frontals and prevomer. Its size varies from one species to another where it is narrowest in *Schistura fasciata* (Fig. 2 A) and broadest in *S.* sp. 1 (Fig. 2 E). Frontal bone is paired in all cases and articulated anteriorly with the posterior part of supraethmoid-ethmoid complex; posteriorly, it is joined with the fontanelle and a pair of parietal on each side of frontal. Number of gill rackers ranges from 8 in *Schistura fasciata* and *S.* sp. 1, 9 in *S. reticulofasciata* and *S.* sp. 3 to 10 in *S. syngkai* and *S.* sp. 2 (Table 3).

Ceratobranch and air bladder capsule structure: Variation in number of pharyngeal teeth in ceratobranch is observed in all the species. A prominent small posterior process is also observed on it in all cases with slight variation (Fig. 3 A–F, where it is not much visible in some due to image taken from different angle).

Presence of free part of the air bladder structure is observed in *S. syngkai, S.* sp. 1 and *S.* sp. 3 (Fig. 4 C, D and E respectively) while it is absent in *S. fasciata, S. reticulofasciata* and *S.* sp. 2 (Fig. 4 A, B and F respectively).

Vertebrae counts and fin insertions: Variation in vertebrae counts among 6 species of incomplete lateral lined *Schistura* and all the meristic counts are given in Table 2 & 3. Study shows that *Schistura fasciata* and *S.* sp. 2 has the highest number of vertebrae counts with 37 vertebrae where as *S.* sp. 3 has the lowest number with 32 vertebrae. Insertion of dorsal-fin in *Schistura fasciata*, *S. reticulofasciata*, *S. syngkai* and *S.* sp. 1 shows similarities of insertion between 11th and 12th vertebrae while *S.* sp. 3 between 10th and 11th vertebrae and *S.* sp. 2 between 12th and 13th vertebrae. Likewise, anal-fin insertion shows some similarities and variations which ranges from 20th -21st vertebrae in *Schistura* sp. 3 and 23rd-24th vertebrae in *S. fasciata*. Abdominal vertebrae range from 15 vertebrae in *Schistura* sp. 3 to 21 vertebrae in *S. fasciata*. Caudal vertebrae also show the range from 16 vertebrae in *S. fasciata* to 19 vertebrae in *S.* sp. 1.

Caudal vertebrae complex: Variations and similarities in caudal vertebrae complex are observed among the species of incomplete lateral lined *Schistura* from Meghalaya which are given in Fig. 5 (A–F). Number of hypural ranges from 5 in *Schistura syngkai* (Fig. 5 D), *S.* sp. 1 (Fig. 5 E) and *S.* sp. 2 (Fig. 5 F) to 6 in *S. fasciata* (Fig. 5 A), *S. reticulofasciata* (Fig. 5 B) and *S.* sp. 3 (Fig. 5 C). Variation in epural size can be observed in all cases where it is broadest in *Schistura fasciata* (Fig. 5 A) and narrowest in *S.* sp. 3 (Fig. 5 C) and *S. syngkai* (Fig. 5 D). In *Schistura* sp. 2, 1st hypural is not reaching to the base of parhypural of 1st preural centrum (Fig. 5 F).

Conclusion: Comparative study of osteology of *Schistura* with incomplete lateral line from Meghalaya revealed that there are distinct variations and similarities in structure of bones among different species. Similarities in bone structure among the incomplete lateral lined *Schistura* may be an indication of their close relation to one another whereas the differences in bone structures also helps in grouping them as different species. Further comparative osteological studies of *Schistura* and other fishes from Meghalaya needs to be carried out to solve the various ambiguities in the field of fish taxonomy and to construct proper phylogeny.

Figures legend

Figure 1: A. *Schistura devdevi*, ZSI/VF/ERS 2495, 34.2 mm SL; **B.** *Schistura fasciata* ADBU-MF/1000/2, 63.1 mm SL; **C**. *S. larketensis,* GUMF 0264/3, 49.6 mm SL (Photo courtesy H. Choudhury); **D.** *S. papulifera,* MHNG 2680.074, holotype, 45.1 mm SL (Photo courtesy M. Kotellat); **E.** *S. reticulofasciata,* ADBU-MF/1001/1, 45.5 mm SL; **F.** *S. syngkai* ADBU-MF/1003/1, 37.9 mm SL ; **G**. *Schistura.* sp. 1, ADBU-MF/1004/1, 41.1 mm SL; **H**. *Schistura* sp. 2, ADBU-MF/1005/2, 34.5 mm SL.; **I.** *Schistura.* sp. 3, ADBU-MF/1002/1, 35.9 mm SL.

Figure 2: Neurocranium structure showing differences in shape of fontanelle which is indicated by an arrow in the figure. **A**. *Schistura fasciata* ADBU-MF/1000/1, 61.04 mm SL; **B**. *S. reticulofasciata* ADBU-MF/ 1001/3, 46.2 mm SL; **C**. *Schistura* sp. 3, ADBU-MF/1002/2, 34.9 mm SL; **D**. *S. syngkai* ADBU-MF/1003/3, 35.0 mm SL; **E**. *Schistura* sp. 1, ADBU-MF/1004/4, 40.0 mm SL; **F.** *Schistura* sp. 2, ADBU-MF/1005/1, 37.0 mm SL. Scale = 1 mm.

Figure 3: Ceratobranch structure: showing differences in pharyngeal teeth and posterior process. **A**. *Schistura fasciata*; **B**. *S. reticulofasciata*; **C**. *S.* sp. 3; **D**. *S. syngkai*; **E**. *S.* sp. 1; **F.** *S.* sp. 2. Scale = 1 mm.

Figure 4: Air bladder capsule structure showing the presence or absence of free part of air bladder which is indicated by arrow in the figure. **A**. *Schistura fasciata*; **B**. *S. reticulofasciata*; **C**. *S.* sp. 3; **D**. *S. syngkai*; **E**. *S.* sp. 1; **F.** *S.* sp. 2.

Figure 5: Caudal vertebrae complex. **A**. *Schistura fasciata*; **B**. *S. reticulofasciata*; **C**. *S.* sp. 3; **D**. *S. syngkai*; **E**. *S.* sp. 1; **F.** *S.* sp. 2. **npu**– posterior uroneural; **epu**– epural; **hp**– hypural; **ust**– urostyle; **ph**– parhypural; **hpu**– haemal spinal and arch; **pc1**– 1st preural centrum; **pc2**– 2nd preural centrum. Scale = 1 mm.

Table legend

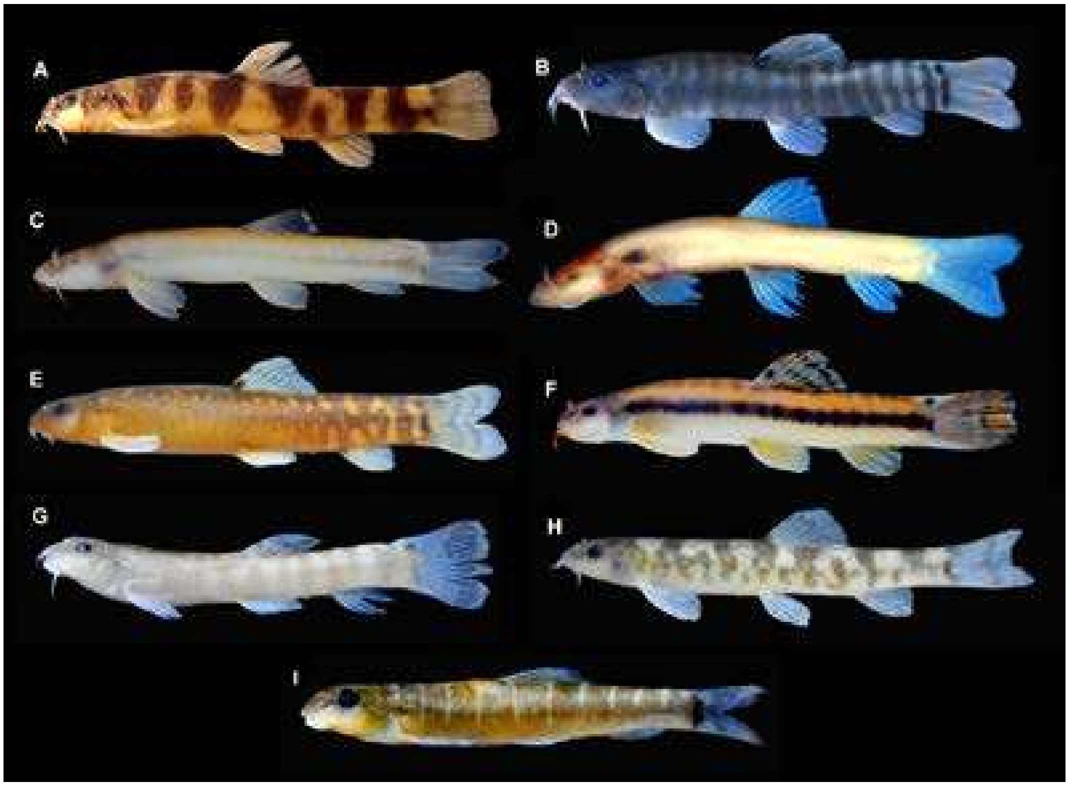
Table 1: Distribution of *Schistura* species with incomplete lateral line in two river systems in Meghalaya, northeastern India and their status.

CR – Critically Endangered, **LC** – Least Concern**, NE** – Not Evaluated, **NT** – Near Threatened, **VU** – Vulnerable, **Brah** – Brahmaputra River System, **Ba-Su-Me** – Barak-Surma-Meghna River System.

Table 2: Meristic data of *Schistura* with incomplete line from Meghalaya.

Table 3: Osteological data of *Schistura* with incomplete lateral line from Meghalaya.

FIGURES



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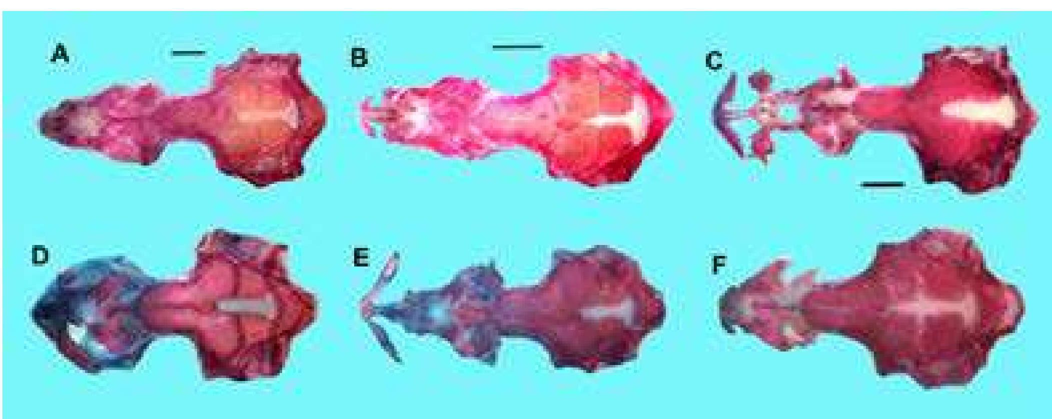

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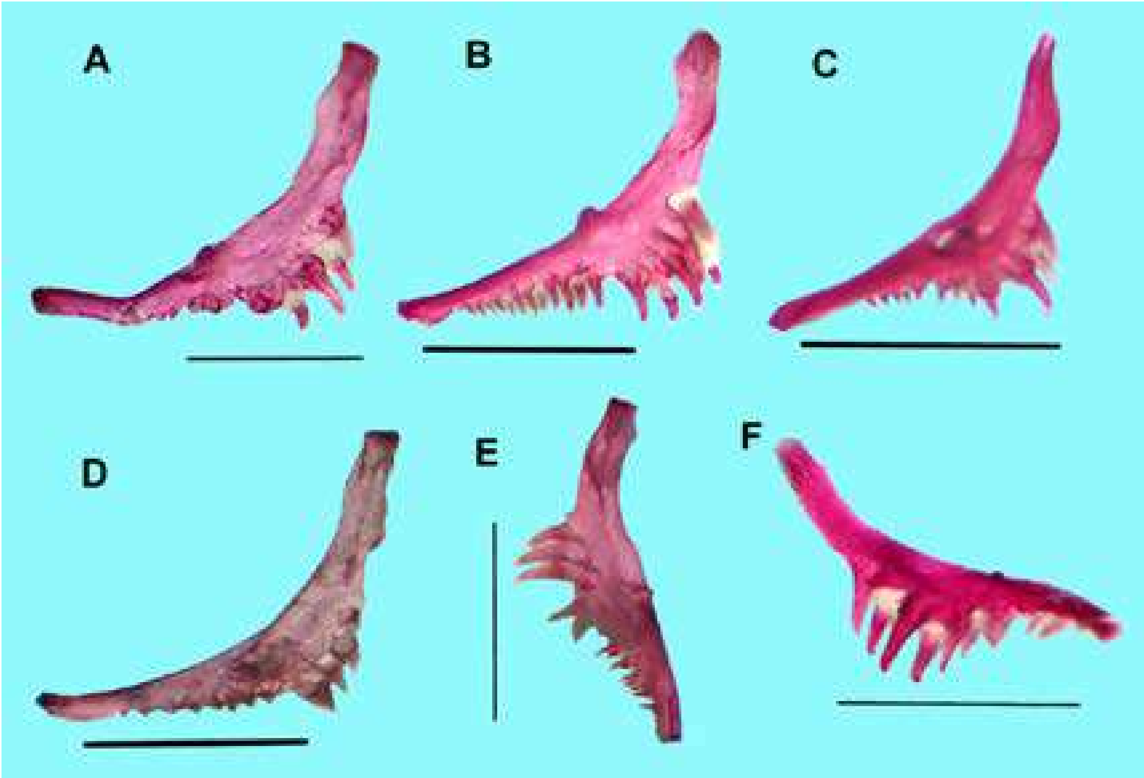

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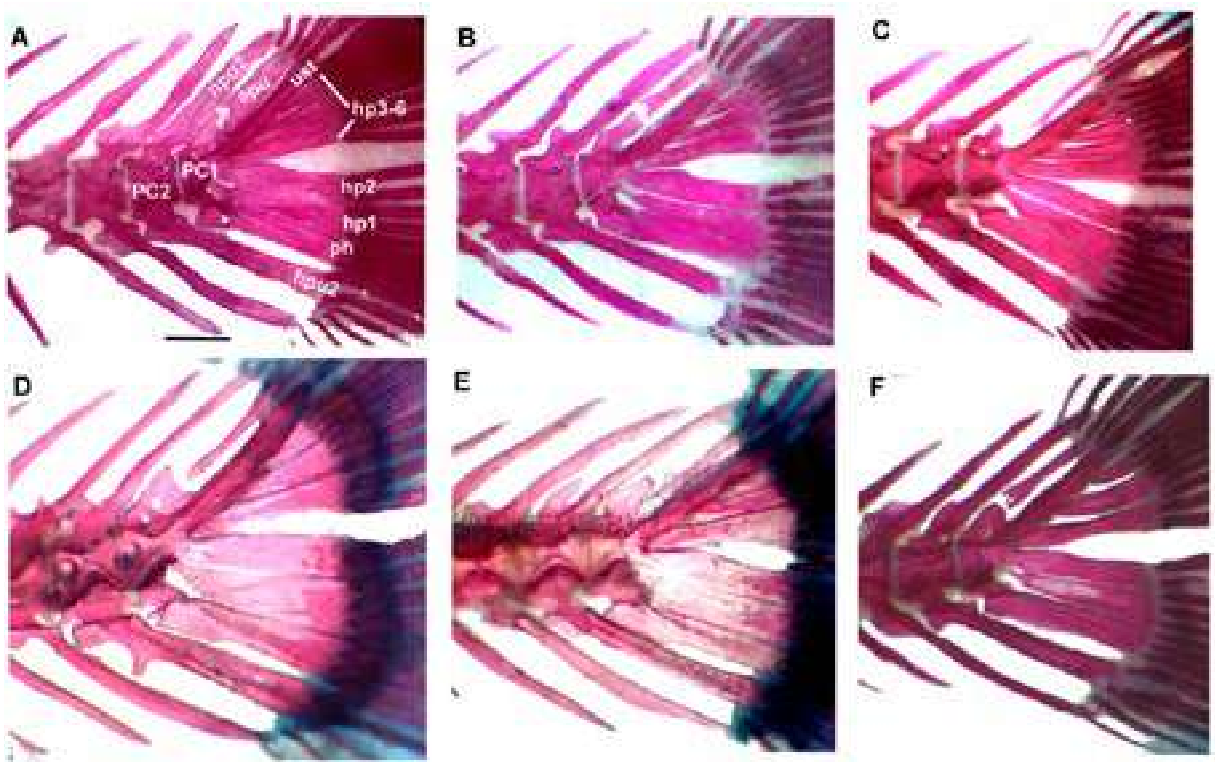

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TABLES

Table 1: Distribution of Schistura species with incomplete lateral line in two river systems in Meghalaya, northeastern India and their status.

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Sl. No.	Species	Brah	Ba-Su-Me	IUCN Status (2010)
1.	*Schistura devdevi* (Hora, 1935)	+	+	NT
2.	*Schistura fasciata* Lokeshwor & Vishwanath, 2011	–	+	NE
3.	*S. larketensis* Chouhdury *et al.*, 2017	+	–	LC
4.	*S. papulifera* Kottelat *et al.*, 2007	+	–	CR
5.	*S. reticulofasciata* (Singh & Bănărescu, 1982)	+	+	VU
6.	*S. syngkai* Choudhury *et al.*, 2019	+	+	NE
7.	*S.* sp. 1.	+	–	NE
8.	*S.* sp. 2.	+	–	NE
9.	*S.* sp. 3	+	–	NE

Table 2: Meristic data of Schistura with incomplete line from Meghalaya.

	S. devdevi ZSI/VF/ERS 2076; ZSI/VF/ ERS 2495	*S. fasciata* MUMF 1101 (holotype); ADBU-MF/1000/1–5	*S. larketensis* GUMF 0261 (holotype); GUMF 0264/3	*S. papulifera* Kottelat *et al.*, 2007	*S. reticulofasciata* ZSI/V/F/ERS 1929; MUMF 11070-11071; ADBU-MF/1002/1–8
Dorsal-fin rays	3/7½	4/8½	4/8½	4/8½	4/8½
Anal-fin rays	3/5½	3/5½	3/5-5½	3/5-6½	3/5½
Pectoral-fin rays	10	10	11-12	12-13	11
Pelvic-fin rays	6	8	7-8	8	8
Branched caudal-fin rays	8+7	9+8	9+8	8+9	8+8

	S. syngkai ADBU-MF/1003/1–7	*S.* sp. 1 ADBU-MF/1001/3,5,7	*S.* sp. 2 ADBU-MF/1005/1–5	*S.* sp. 3 ADBU-MF/1002/1–2	
Dorsal-fin rays	3/7½	3-4/7½–8½	4/8½	4/8½–9½	
Anal-fin rays	3/5½	3/5½	3/5½	3/5½	
Pectoral-fin rays	11	11	11	10	
Pelvic-fin rays	7	8	8	8	
Branched caudal-fin rays	8+8	7–8+8	8+8	9+8	

Table 3: Osteological data of Schistura with incomplete lateral line from Meghalaya.

	S. fasciata ADBU-MF/1000/1	*S. reticulofasciata* ADBU-MF/1002/1–8	*S.* sp. 3 ADBU-MF/1002/2	*S. syngkai* ADBU-MF/1003/3,4	*S.* sp. 1 ADBU-MF/1004/4, 5	*S.* sp. 2 ADBU-MF/1005/1
Total vertebrae	37	35-36	32	34-35	35	37
Dorsal-fin insertion	11-12	10-11, 11-12	10-11	11-12	11-12	12-13
Anal-fin insertion	23-24	21-22, 22-23	20-21	21-22	21-22	22-23
Abdominal vertebrae	21	18-19	15	16-17	16	20
Caudal vertebrae	16	16-17	17	18	19	17
Gill racker	8	9	9	10	8	10

Acknowledgements

We would like to extend our gratitude to Dr. Maurice Kottelat, a Swiss Ichthyologist for sharing research paper and photo; Prof. Dandhadar Sarma and H. Choudhury, Guwahati University for accessing their specimens and sharing specimen photo; and to Fr (Dr) Stephen Mavely, Vice Chancellor, Assam Don Bosco University for his encouragement and giving the opportunity to carry out the research. We also want to extend our thankfulness to Dr. Boni Amin Laskar for valuable comments and suggestions while reviewing this manuscript. We also extend gratefulness to the lab mates Bidangshri, Nilibo, Velentina and Ibansiewdor for supporting mentally and physically in all the laboratory works and Daphisha for contributing her specimen collection, and to all the fishermen for helping them in collection of specimens from various rivers of different locations.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Comparison of the Population of Soil-Inhabiting Nematoda in The Context of Pesticide Application with an Observation on Their Trophic Groups

Debabrata Sen and Samprit Deb Roy

Zoological Survey of India, M-Block
New Alipore, Kolkata- 700053

Abstract

Soil-inhabiting Nematodes are agriculturally important for significant loss of crop production as well as for their beneficial role in soil ecosystem. During a visit to Bali Island of Indian Sundarbans, West Bengal, India, few soil samples were collected from agricultural fields. As reported by the villagers, some fields were applied with pesticides like Furadon (carbofuran 3% g) and Phorate (Phorate 10% g organophosphate) and some were without any pesticide. Both of these pesticides have nematicidal effects besides being contact and systemic insecticide. The collected soil samples were processed by Cobb's Sieving and Decantation Method followed by modified Baermann Funnel Technique to extract the nematodes. The populations of nematodes were counted with the help of a counting dish and a hand tally counting machine under a stereo zoom microscope following standard method. The soils applied with pesticides, collected from cauliflower and tomato fields, showed a lesser population count of 26 and 98 nematodes respectively in 250 gm. of soil for each of the samples, whereas the population count for the soils without pesticides from vegetable and paddy fields were 293 and 625 nematodes respectively in the same quantity of soils. The nematodes were identified up to the generic level and presence of twelve genera was observed which indicates an idea about their trophic groups in the soil micro-habitat of agro-ecosystem being associated with the mangrove ecosystem ('ecotone' of terrestrial and marine ecosystem) of Sundarbans. So this observation can be considered as various trophic levels of nematodes in an 'ecotone'. Soils with the pesticides showed only two trophic groups (omnivorous and predatory-omnivore), whereas soil without pesticides revealed four trophic groups (plant and hyphal feeder, omnivorous, bacterial feeder and predatory) of nematodes. The difference in population in different soils was statistically analyzed to show the relation between the nematode population in the soil applied with pesticides and without pesticides.

Keywords: Soil-inhabiting Nematoda, Sundarbans, Population, Pesticide, Trophic groups

Introduction

A study was initiated on the population of soil-inhabiting nematodes in the Agricultural fields of Bali Number 9 village, P. O. Bali Hathkhola, Bali island of Indian Sundarban, South 24-Parganas districts, West Bengal, India to get an idea about the effects of pesticide usage on the relative population difference of the nematodes in the fields of various agricultural practices such as vegetables and rice cultivation under normal circumstances of weather at any instance. In this study, samples were collected from four different fields *viz*. Cauliflower bed (latitude 22º088000N and longitude 88º754607E), Vegetable bed (latitude 22º087528N and longitude 88º754754E), Tomato field (latitude 22º091680N and longitude 88º761145E) and Paddy field (latitude 22º091715N and longitude 88º761040E). 250 gm of soil samples were collected from each of the fields. Two soil samples were collected from the fields applied with pesticide and two samples were from the fields without any pesticide. The nematodes, extracted from the collected soil samples, first counted for the population comparison and then were identified up to the generic level to observe their

*Author for correspondence : debabrata.zsi@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

trophic group and to have an idea about their feeding habits in the area of study. Their total population was counted separately for each of the sample to observe whether there is any comparative difference of population count in two different types of soils. This population data was statistically analyzed.

As reported by the villagers, cauliflower (*Brassica oleracea*) and tomato (*Solanum lycopersicum*) fields were applied with pesticides like Furadon (carbofuran 3% g) and Phorate (Phorate 10% g organophosphate). Vegetable and paddy (*Oryza sativa*) fields were without any pesticide. Fields those are applied with pesticides (Phorate/Furadon) are known to have nematicidal effects and widely used as contact and systemic insecticides for its efficacy (Webb and Corbett, 1973**,** Oyedunmade *et al.,* 2009, Meher *et al.,* 2010, Chelinho *et al.,* 2011). The soils associated with these crops were chosen to compare the population of nematodes in these two types of agricultural practices in four fields just on the basis of pesticide usage only. Total twelve genera of soil nematodes were recovered of which four genera from cauliflower, two genera from tomato, four genera from vegetable and five genera from paddy field and Some of the same genera have been found in soil samples of different crop fields under study (Table 1). To be more precise, *Aporcelaimellus* was found in the soils associated with cauliflower and tomato, *Laimydorus* was present in those of cauliflower, tomato and paddy. An attempt was made to find out to compare the population of nematodes in two types of agricultural practices.

Soil nematodes are very small in size (0.3 to 10mm), population abundance is very high (generally million/m2) and diverse (>30 taxa/m2) in all kind of soils (Yeates, 1979). They are most abundant in the upper strata of the rhizosphere, they may also be found up to the depth of over 20 feet (Jenkins and Taylor, 1976). Most of the soils contain 90% of the nematodes at top six inches of soil surface (Crofton, 1966). Nematodes are important for their beneficial and harmful role in soil micro-habitat. An average annual yield loss of the world's major crops due to the damage by the soil and phytophagous nematodes has been estimated (Sasser and Freckman, 1987; Dasgupta, 1998; Luc *et al.*, 2005, Perry and Moens, 2006). On the other hand, as nematodes are heterotrophic in soil food webs, they play an important role in the transformation of organic matter into mineral and organic nutrients which are beneficial for the growth of plants resulting in better crop productivity (Ingham *et al.*, 1985; Ferris *et al.*, 1998, 2004) and thus Nematode feeding activity contributes to the stability of soil food web and they play important roles in many ecosystem services and processes (Yeates *et al.,* 2009). The feeding types and feeding groups in plant and soil nematodes was studied (Yeats, 1971) and their trophic groups has been designated as omnivorous, phyto-phagous or plant feeders, fungal feeders, bacterial feeders, predators, predatory-omnivore etc. (Yeates *et al.*, 1993). The feeding types of the genera were also observed in the agro-ecosystem in two types of agricultural practices.

Materials and Methods

For the present study, soil samples were collected from agro-ecosystem closely associated with mangrove ecosystem of Sundarbans. Soil samples of about 250 gm. each were taken from soil of four different agricultural fields as mentioned earlier, from a depth of 2 – 10 centimeters from the surface with the help of a hand-shovel. The geographical co-ordinates were noted with the help of a GPS to get the specific locations. The collected soil samples were processed following standard methods of 'Cobb's sieving and decantation technique' (Cobb, 1918) followed by 'modified Bearmann's funnel technique' (Christie and Perry, 1951) to extract the nematodes present in the samples. The extracted nematodes were then taken for population counting in live condition. After the population count was done and the numbers were noted for further study the nematodes were killed and fixed instantly by Seinhorst's method in hot Formaldehyde-acetic acid solution (FA) solution. These were preserved in the same solution with appropriate labels. The specimens were transferred in cavity blocks containing glycerine-alcohol and were kept in a desiccator for 2 to 3 weeks. After complete dehydration of the specimens, permanent slides were prepared by using anhydrous glycerine as a mountant medium. Paraffin was used to seal the cover glass with the slide containing specimens in anhydrous glycerine. Finally, the nematodes were observed and studied under a Nikon eclipse Ni DIC microscope to identify the genera.

Method counting of nematode population: The live specimens of nematodes for each individual sample were taken for population counting. In this process, the extracted nematodes with 3 – 4 ml of water for a specific sample were taken in a 100 ml measuring cylinder and addition of clean water up to 100 ml was done. Then with the help of a pipette or a glass dropper the sample was made homogenous carefully by bubbling the water repeatedly. 10 ml of this water, containing homogeneously suspended nematodes, was taken in a counting dish by a graduated pipette. Counting of nematodes in the counting dish was done under a stereo-zoom microscope with the help of a 4-digit hand tally counter. The same process of counting was repeated thrice for each of the four samples. The mean of nematode population from three counts of each sample was recorded. The process of calculation for each of the samples was as follows:

Suppose, 10 ml of homogeneous suspension contains x number of nematode.

1ml of homogeneous suspension contains x/10 of nematode.

100 ml of homogeneous suspension contains 100x /10 of nematode.

In this way, the individual mean of nematode population for each of the four samples was calculated. After that the mean of total population was finally calculated and were recorded for statistical analysis.

Observation and Result

Twelve genera of soil-inhabiting nematodes were observed to be associated with the soils of four types of crops. These are *Laimydorus* Siddiqi, 1969, *Mesodorylaimus* Andrassy, 1959, *Thornenema* Andrassy, 1959, *Aporcelaimellus* Heyns, 1965, *Discolaimium* Thorne, 1939, *Mylodiscus* Thorne, 1939, *Dorylaimoides* Thorne and Swanger, 1936 under the order Dorylaimida; *Tylenchus* Bastian, 1865 and *Rotylenchus* Filipjev, 1936 under the order Tylenchida; *Rhabditis* Dujardin, 1845 and *Mesorhabditis* (Osche, 1952) Dougherty, 1953 under the order Rhabditida and *Clarkus* Jairajpuri, 1970 under the order Mononchida. Population count of nematodes extracted from the soils applied with pesticides collected from the cauliflower and tomato fields are 26 and 98 respectively whereas, the population count from the soils without pesticides, collected from the vegetables and paddy fields are 293 and 625 respectively. The number of nematode population in four crop fields in two different types of soils and the trend of population increase in both types of soils have been shown (fig. 1 and 2). From the above data, it is evident that the nematode population in the fields of cauliflower & tomato, applied with pesticides with chemical compound Carbofuran 3% and Phorate 10%, having nematicidal effect, clearly indicates a sharp decline in comparison with the population in the fields of vegetables and paddy, which were devoid of any pesticides. As the values indicate a clear comparison with difference in population number, the relation drawn by the above observation can be established statistically.

The samples were tested on the basis of Chi square analysis to justify and to infer the relationship of the population count against the pesticides affecting the nematodes in the agricultural fields. For the study and the calculations of the Chi square variables, the small sample grid was used as the sample size was small (table 2). The values were obtained from the 2x2 contingency table for a special case of a table with only two rows variables to examine and to draw the inference for the test following the proper method & guidelines. The calculation of the chi square variables was performed readily with Brandt & Snedecor's formula (Bailey, 1995). The chi square value is now being discussed below with the Yates' correction. Though the correction is overcautious in its desire to avoid a type-1 error, the corrected value and the original value are both discussed below.

As calculated from the table, the level of significance to consider under the sample size is 0.05 and the degree of freedom *(df)* is 1, as for the two variable parameters were considered under the observation, for one sample is applied with pesticides and the other is devoid of any pesticides. After calculating the chi square analysis, the outcome is 6.165 with the p value of 0.013, which after Yates' correction standardized to 5.661 as for the chi square analysis and 0.017 for the value of p, demonstrating a significant relation between use of pesticide and decline in population (table 2, Fig. 5).

The nematodes present in both types of the soils, applied and not applied with pesticides found in the agricultural fields of cauliflower, tomato, vegetable, and paddy are categorized under different trophic groups to observe the feeding habits for each of the genus (table 1). The total number of the trophic groups present in the soil without pesticides is four, in which plant and hyphal feeder, omnivorous, bacterial feeder and predatory feeding groups are present in contrast to the number of the trophic groups present in the soil applied with pesticides is only two in which predatory-omnivorous, and omnivorous nematodes were observed. The percentage of various trophic groups was calculated. The trophic groups are comprised of plant and hyphal feeder (17%), omnivorous (33%), predatory-omnivorous (8%), bacterial feeder (17%) and predatory (25%) in the ecosystem under the study (Fig. 3). The percentage of trophic groups present in the soils applied with pesticide (33%) and that of without pesticide (67%) were also observed (Fig. 4).

Discussion

An attempt was made to assess the relation between the variation of nematode population and application of pesticide with the help of Chi square analysis. According to the Chi square 'test of independence', two following hypotheses were drawn:

Null Hypothesis - The outcome of the population variation and the effect of the pesticides having nematicidal effect tested at random at any instance are not particularly related. They are of independent relationships.

Alternative Hypothesis – The decline in the population variation and the effect of the pesticides having nematicidal effect tested at random at any instance are related. They are not of independent relationships.

Now to draw the inference based on the result of Chi square test of independence is to analyse the *p* values (level of significance) to determine whether the null hypothesis is accepted or rejected. As it occurs the *p* values in both the cases of original and after Yates' correction is significantly less than the chi square value generated in the considered level of significance (p <0.05), which is at $df = 1$ and at $p = 0.05$ is 3.841, which in turn infer the values are statistically significant and thus the 'Null Hypothesis' is finally rejected and the 'Alternative Hypothesis' [$X^2(1, N=4) = 6.165$, $p=0.013$] is accepted. This fact establishes that the effect of the pesticides having nematicidal effect clearly played a role on the population reduction of nematodes in the fields. The chi square distribution curve which plots χ^2 value against the *p* for the degree of freedom or $df = 1$, shows the cumulative probability associated with the chi square value (fig. 5). It is worthy to mention for the present study that although the individual number of sample count is 4 as they are collected from four different agricultural fields but in the present case they are grouped under 2 categories (soil with pesticide and soil without pesticide), which is considered the special case of a table with only 2 rows, having 2 individual columns, hence according to Brandt and Snedecor's formula (Bailey, 1995) the degree of freedom (*df*) is less than the number of column, $df = c - 1 = 1$. The present study is fully consistent with the studies done on the effect of carbofuran, phorate, other pesticides and organic materials to reduce the population of soil-inhabiting nematodes associated with different types of agricultural crops (Webb and Corbett, 1973, Oyedunmade *et al.,* 2009, Meher *et al.,* 2010).

The area under the study is ecologically significant because the agro-ecosystem here is associated with the mangrove ecosystem ('ecotone' of terrestrial and marine ecosystem) of Sundarbans. So the present observation can be considered as the population of soil-inhabiting Nematoda and their various trophic levels in an 'ecotone'. It was observed that only the nematode with omnivorous and predatory-omnivorus feeding habits were present in the soil applied with pesticides whereas, a variety of feeding habits like plant and hyphal feeder, omnivorous, bacterial feeder and predator, in the soil without pesticide were noted signifying a more stable soil micro-habitat and indicating that more trophic groups with diverse feeding habits are present in the soil without pesticide. A relevant work on the effect of carbofuran on the reduction of population abundance and trophic groups of soil nematodes was done by Chelinho *et.al.*, 2011 which is in conformity with the present investigation. In that study, effects on total nematode abundance, number of families and abundance of nematode feeding groups as well as potential shifts in both trophic and family structure were assessed in soil nematode communities showing a decline of population without significant change in community structure and trophic groups (Chelinho *et.al.*, 2011).

Table 1: Nematode genera observed in the respective agricultural fields with their trophic groups

Associated Plant/field	Name of the genera	Use of pesticides	Trophic Group
Cauliflower	1. *Aporcelaimellus* Heyns, 1965	Soil applied with Phorate/ Furadon	Predatory-omnivore
	2. *Mesodorylaimus* Andrassy, 1959		Omnivorous
	3. *Dorylaimoides* Thorne & Swanger, 1936		Omnivorous
	4. *Laimydorus* Siddiqii, 1969		Omnivorous
Tomato	1. *Laimydorus* Siddiqii, 1969	Soil applied with Phorate/ Furadon	Omnivorous
	2. *Aporcelaimellus* Heyns, 1965		Predatory-omnivore
Vegetable	1. *Thornenema* Andrassy, 1959	Soil without application of pesticide	Omnivorous
	2. *Discolaimium* Thorne, 1939		Predatory
	3. *Mylodiscus* Thorne, 1939		Predatory
	4.*Clarkus* Jairajpuri, 1970		Predatory
Paddy	1. *Laimydorus* Siddiqii, 1969	Soil without application of pesticide	Omnivorous
	2. *Rotylenchus* Filipjev, 1936		Plant feeding
	3. *Tylenchus* Bastian, 1865		Plant and Hyphal feeder
	4. *Mesorhabditis* Osche, 1952		Bacterial feeder
	5. *Rhabditis* Dujardin, 1845		Bacterial feeder

Table 2: (2x2) grid for chi square (χ^2) analysis for special case with only 2 rows

Use of pesticides	Number of nematodes present in reference soil samples		Total
Pesticide applied	26	98	124
Pesticide not applied	293	625	918
Total	319	723	1042

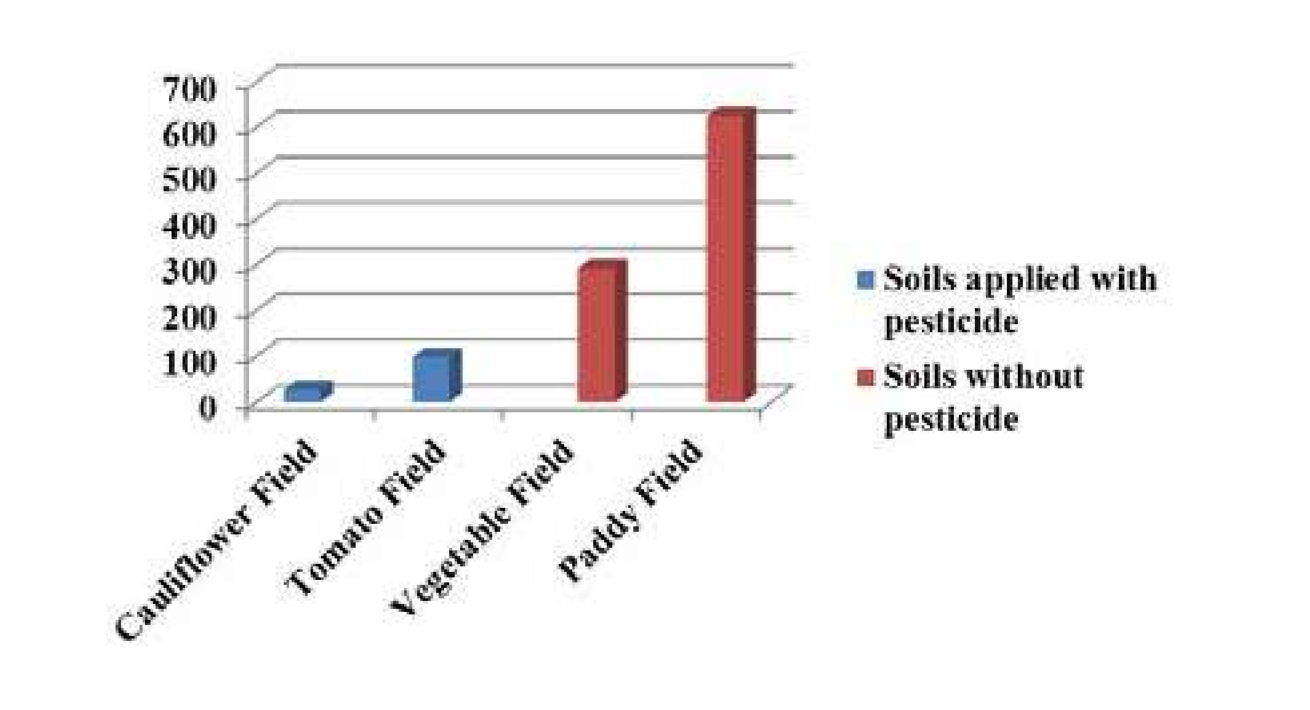

Figure 1: Number of nematode population in four crop fields in two different types of soils

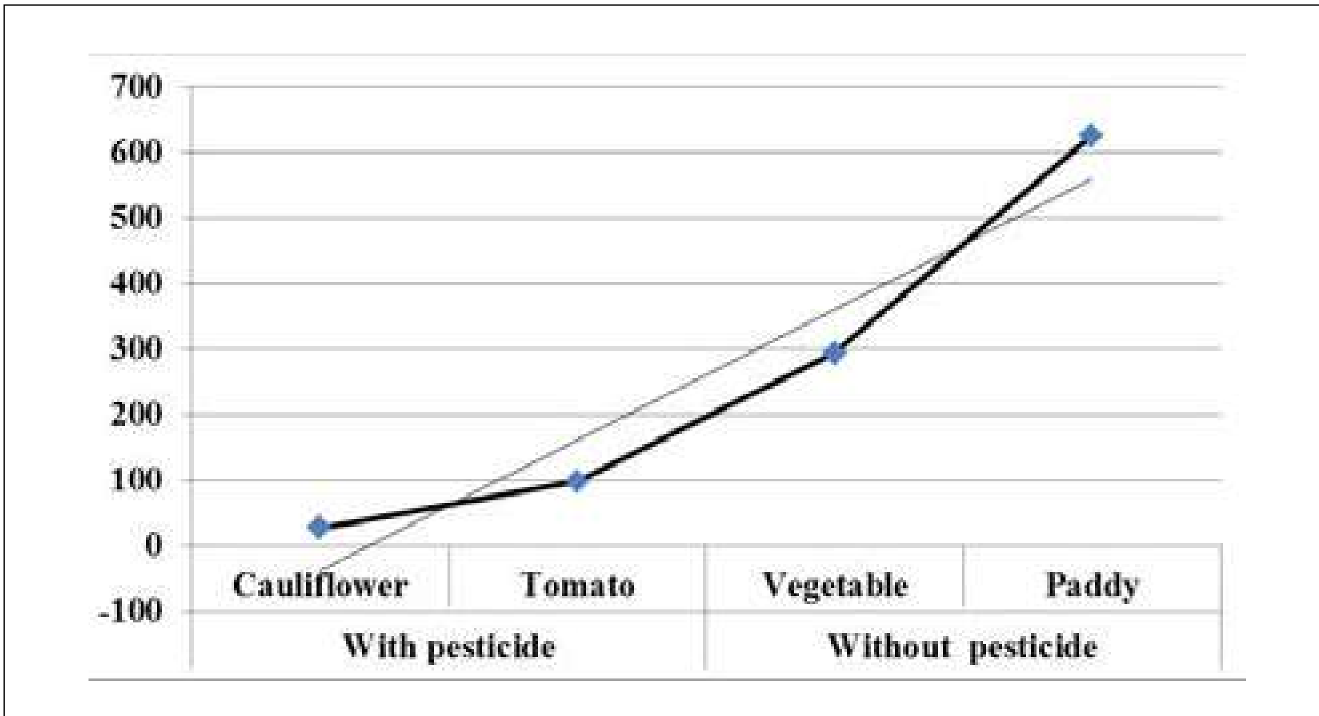

Figure 2: Trend of population increase in the soils applied with pesticide and without pesticide

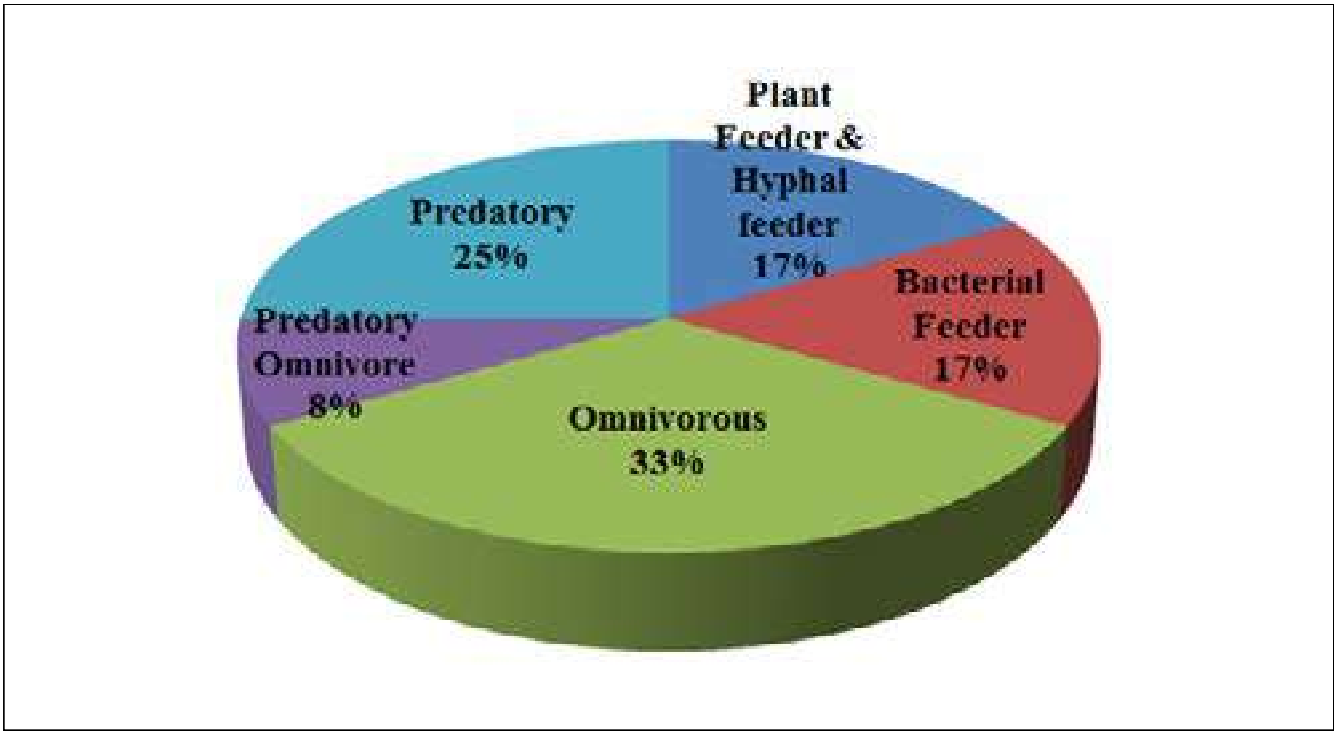

Figure 3: Percentage of different trophic groups

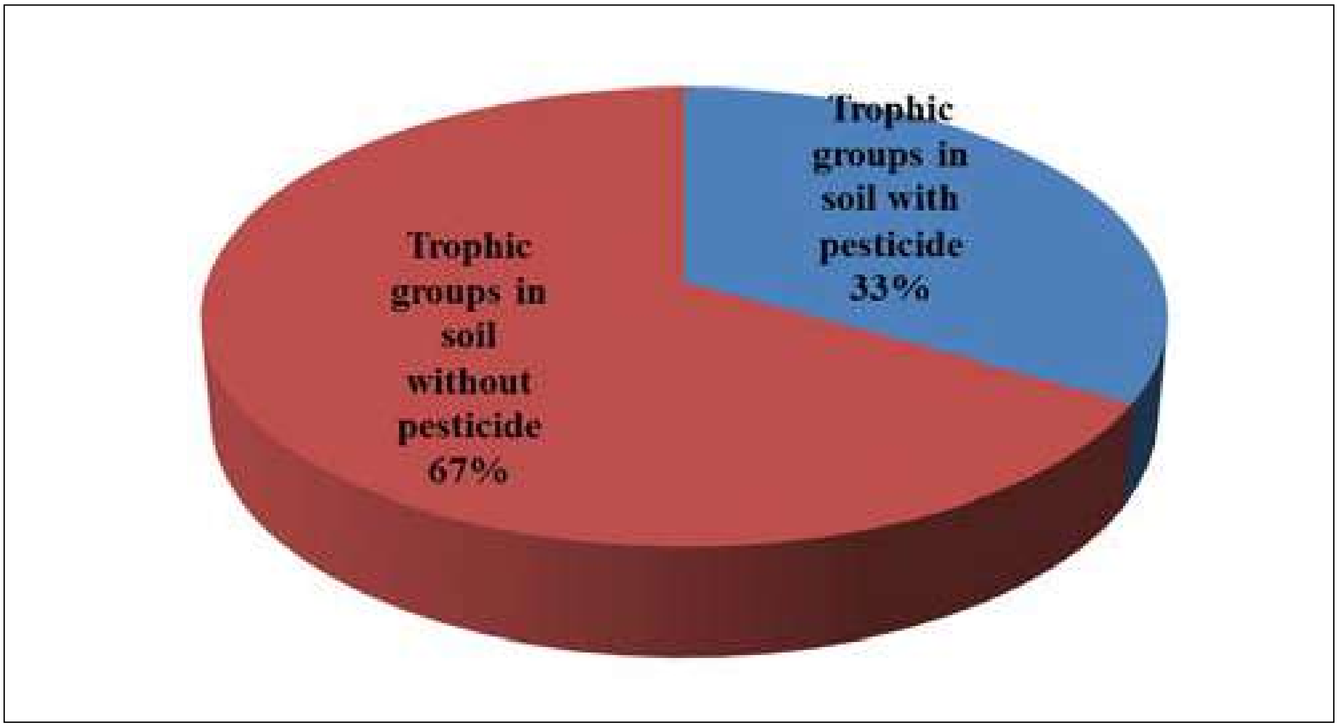

Figure 4: Percentage of trophic groups present in the soils applied with pesticide and without pesticide

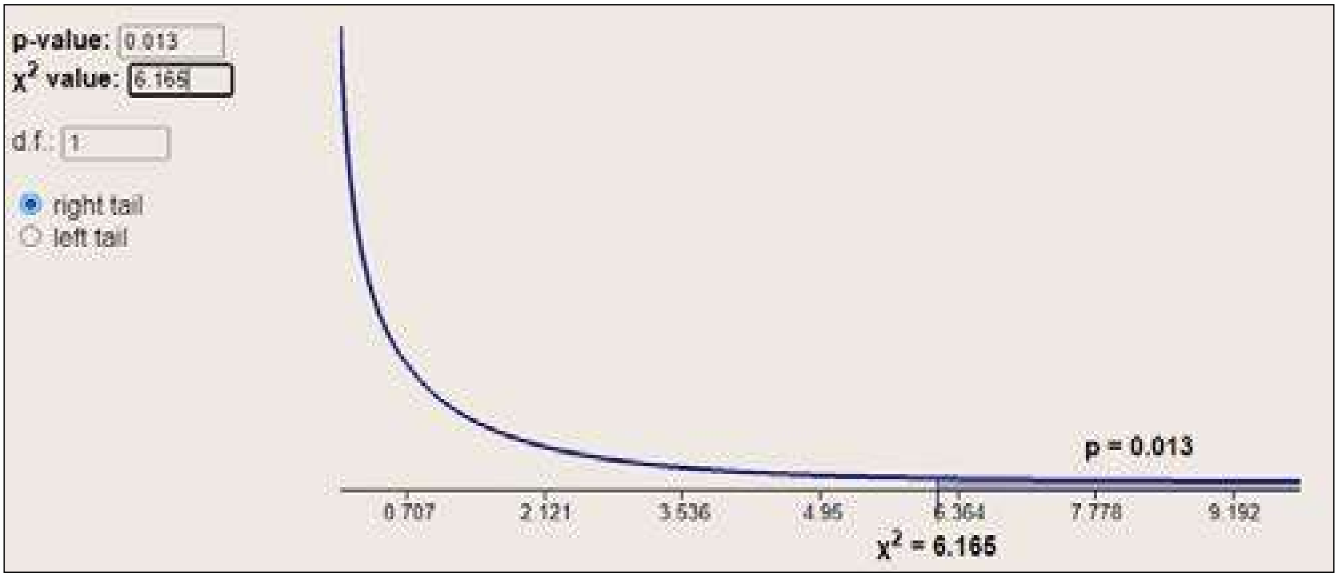

Figure 5: Normal distribution curve of the chi square statistics ($\chi^2 = 6.165$) & *p*-value (0.013)

Acknowledgements

Authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India for to carry out the work, to publish the result and for her constant inspiration during the work.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Do Earthworms Truly Always Assist Farmers or is There Another Fact ?

Pooja Tiwari & Shweta Yadav

Department of Zoology,
Dr. Harisingh Gour Vishwavidyalaya (A Central University),
Sagar 470003, Madhya Pradesh, India

Abstract

Among all the soil creatures, earthworms are regarded as the most crucial. They are found in the areas where the soil contains enough water and temperature. They also exhibit a variety of environmental adaptations to the various environments. Earthworms may live in local microsites, even in unsuitable areas, when the conditions are favorable (such as urban gardens, desert oasis, etc.), especially if well-adapted species have been introduced. Despite the fact that earthworms have many positive effects on the soil ecology, certain of their activities are deemed undesirable. The destructive behaviors of earthworms include removing and burying surface residues that would otherwise protect soil surfaces from erosion, producing fresh casts that promote erosion and surface sealing, increasing soil compaction on the surface, leaving castings on lawns where they are an annoyance, dispersing weed seeds in gardens and agricultural fields, transmitting plant or animal pathogens, and riddling irrigation canals that reduce their ability to function. Although being little understood, there is a surge in exotic earthworm invasions as a result of worldwide commerce in agriculture, waste management, and bioremediation. Exotic earthworm invasions are spreading globally and having a significant impact on plant populations and soil processes. It has been documented that at least 100 different species of earthworms are found outside of their natural habitats. Non-native earthworms can potentially colonize new places despite disturbance and interference. The present study discusses on the impact of invasive earthworms on the agroecosystem and analyzes the importance of earthworms in all soil ecosystems.

Keywords: Exotic earthworms, disturbance, native earthworms, colonization of species, biological invasion, competition.

1.0 Introduction

In many situations, earthworms constitute the most prevalent and significant animals found in soil. Their feeding and burrowing activities have a substantial impact on the physical and chemical properties, nutrient cycling, and plant development in the soil, making them crucial to agroecosystems. Darwin (1881) was the first to demonstrate that earthworms have a substantial influence on soil processes that are crucial to the operation of terrestrial ecosystems. Earthworms are often beneficial to soils, especially in systems that are managed for conservation, according to subsequent research, which focuses mostly on agricultural and pastoral systems (e.g., no tillage). Earthworms are important detritivores, ecosystem designers, and contributors to soil formation (Eisenhauer *et al.*, 2007). Invasive species gradually reduce native populations by outcompeting or devouring native species. Certain elements of earthworm activity are deemed undesirable despite the numerous documented and speculated positive impacts of earthworms on soil structure, nutrient dynamics, and plant development (Edwards and Bohlen, 1996; Lavelle *et al.*, 1998; Parmelee *et al.*, 1998). Earthworm activity has been found to hasten the breakdown of plant litter, boost nutrient transformation and plant nutrient absorption, increase soil aggregation and porosity, and enhance water infiltration and solute movement (Satchell, 1983; Lee, 1985; Hendrix, 1995; Edwards and Bohlen, 1996; Edwards, 1998; Lavelle *et al.*,

*Author for correspondence : kmshweta@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

1999). Although these effects are usually seen as positive in agricultural soils, Hendrix and Bohlen (2002), Bohlen *et al.* (2004a, 2004b), and James and Hendrix (2004) conversed about the negative effects that invasive/exotic earthworms have on soil processes. The profiles of soils, the dynamics of nutrients and organic matter, other soil creatures, and plant communities are all possible targets of exotic earthworms. These detrimental activities include removing and burying surface residues that probably protect soil surfaces from erosion; producing fresh casts that increase erosion and increasing surface soil compaction by surface sealing; depositing castings on the surface of lawns where they are inconvenience in gardens and agricultural fields; transmitting plant or animal pathogens; riddling irrigation ditches, making them less able to carry water increasing soil nitrogen losses through leaching and denitrification; and increasing soil carbon losses through enhanced microbial respiration. Earthworms have a wide range of environmental adaptations and may exist in a number of settings if the soil's water and temperature are favourable for at least a small part of the year. Earthworms can colonize nearby microsites with favorable circumstances, even in inappropriate habitats (such as urban gardens or desert oasis), especially if well-adapted species have been introduced.

There are around 7000 species of earthworms recorded worldwide (Grdisa, 2013; Reynolds and Wetzel, 2012); however, only 3000–3500 of these species are thought to be authentically described (Csuzdi, 2012). Misirlioglu *et al.* (2023) recently published a comprehensive checklist comprising 5,738 species/subspecies, including 5,406 species and 332 unique subspecies, that are distributed globally across 382 genera and 23 families. India is home to a diverse array of earthworm species and subspecies, with a total of 453 identified across 67 genera and 10 families (Lone *et al.*, 2021, 2022; Tiwari *et al.*, 2021; Hasan *et al.*, 2023). Although a few exotic and peregrine species are also documented, the majority of these species are native to the nation (Narayanan *et al.*, 2019; Narayanan, 2020; Anuja *et al.*, 2022). Earthworm have emerged on every continent except for Antarctica, and some groups have spread globally due to human transport. Due to its diverse geographic locations, which include a large latitudinal range (between 8.4°N and 37.6°N) and longitudinal range (between 68.7°E and 97.22°E), edaphic conditions, and climatic elements (ranging from temperate to tropical), India is known for having a high diversity of earthworm species (Zodinpuii *et al.*, 2019; Lalthanzara *et al.*, 2020). The geological past of the ancient supercontinent of the Gondwana Land, from which it split in the late Jurassic and drifted until crashing into the Asian mainland in the Eocene, provides additional support for this fact (Julka *et al.*, 2009). Also, there are deficiencies in the genetic diversity and biogeography of a number of earthworm species that are either exotic or peregrine and have a broad distribution. For example, the Megascolecidae family of exotic earthworms, *Metaphire houlleti* (Perrier, 1872), is extensively distributed in various areas of India, including the north (Jaswinder *et al.*, 2015), north eastern (Thounaojam *et al.*, 2020), central (Prakash, 2017), and southern regions (Narayanan *et al.*, 2016). Comparable exotic earthworm species with widespread populations in India include *Amynthas corticis* (Kinberg, 1867), *A. morrisi* (Beddard, 1892), and *Pontoscolex corethrurus* (Müller, 1857). Consequently, it is crucial to comprehend both the invasion's effects and those on native earthworm populations. The objective of the present investigation is to analyse the effects of invasion on the recipient ecosystem, including above and below-ground species, the interactions between native and exotic earthworms, and native and exotic plants.

2.0 Materials and Methods:

A data set of previously published literature over five decades was gathered for the study using searches on the Wiley Online Library, Science Direct, Google Scholar Database, Biodiversity Heritage library, and ResearchGate, as well as specific requests to the authors. In order to search the database, the keywords "earthworm invasion," "invasive species," "invasive earthworms and plants," "biological invasion," "exotic earthworm and plant herbivory," "peregrine," "introduced earthworms," "belowground invasion," and "invasion biology" were used either alone or in conjunction with others. The following criteria were used to choose 170 articles of published literature for the study from both national and international journals: (1) described that exotic earthworms affect forest ecosystems; (2) documented negative impacts of invading earthworms on soil biodiversity; (3) shown beneficial relationships between exotic earthworms and exotic plants; and (4) demonstrated negative effects of earthworm invasion on plant defense features. Out of 170 papers, 90 showed the effects of earthworm invasion on forest ecosystems, primarily in North American forest ecosystems; 40 focused on the effects of exotic worms on native worms; 25 on soil vertebrates; and the remaining 15 showed the facilitative relationships between exotic worms and exotic species (Figure 1).

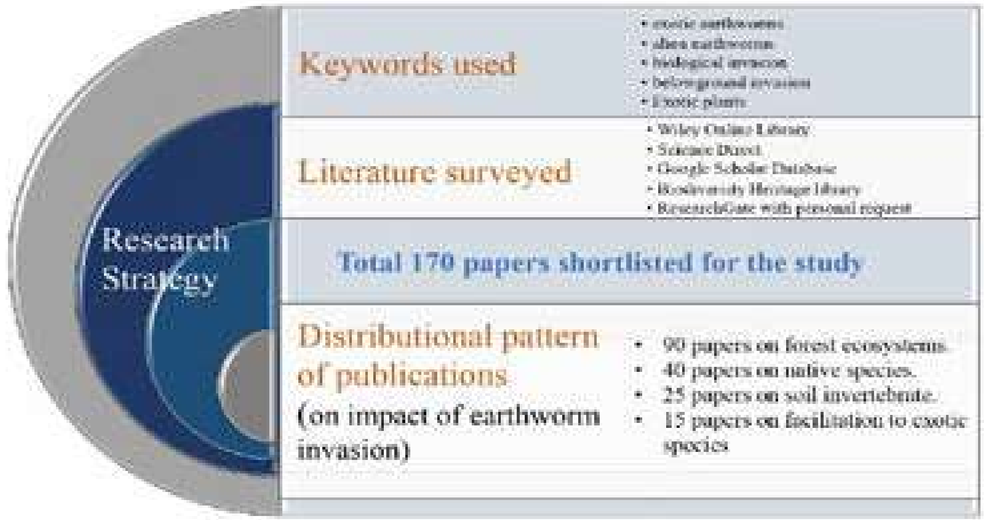

Figure 1. Layout of the methodology used in the study.

3.0 Results and Discussion:

Anthropogenic biotic exchange endangers biodiversity and can impair ecosystem function (Sala *et al.*, 2000). Invasion by exotic earthworms, in particular, has been shown to have dramatic effects in recipient ecosystems. For instance, invasion by earthworms, in previously earthworm-free ecosystems, alters the physico-chemical characteristics of the soil. Soil changes can have far-reaching consequences on soil organisms, which account for a large portion of terrestrial biodiversity. When earthworms invade previously earthworm-free forests, they cause a long cascade of ecological effects, including changes in soil nutrient status, soil bulk density, soil microbial processes, and a reduction in native plant and soil microarthropod species richness as shown in Figure 2 (Frelich *et al.*, 2006; Eisenhauer *et al.*, 2007; Hendrix *et al.*, 2008).

Changes in soil properties caused by earthworms can lead to changes in plant communities *via* ecological cascades (Lavelle *et al.*, 1997; Frelich *et al.*, 2019). Earthworms also have a significant impact on the soil microbial community and the activity of microbial enzymes (Jana *et al.*, 2010; Tao *et al.*, 2009; Zhang *et al.*, 2010).

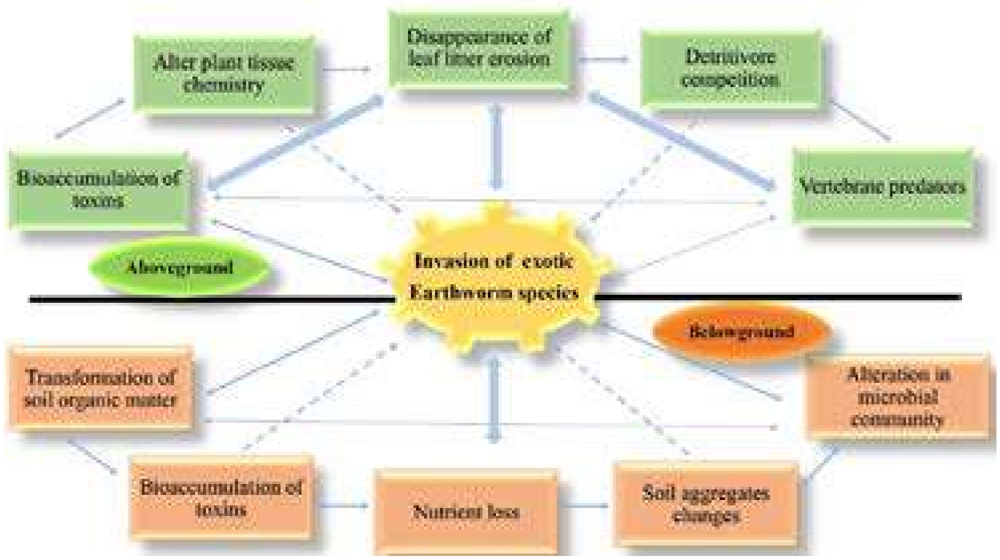

Figure 2. Earthworm invasion's layout and consequences on the soil ecosystem.

3.1 Impact of exotic earthworms on soil invertebrates:

Invasive earthworms are known to reduce soil biodiversity (Ferlian *et al.*, 2018). Earthworms have the ability to interact with other subterranean fauna, both through direct devouring and indirect modification of soil properties *via* chemical or physical means. The findings of Gao *et al.* (2017) indicate that the presence of the invasive earthworm species, *Amynthas agrestis*, may lead to a decline in the abundance of springtail (Collembola) in a microcosm study. That decrease may be attributed to alterations in the habitat and a reduction in the availability of food resources. The literature on the effects of invasive earthworms on soil invertebrate communities includes both positive and negative effects. The increased habitat complexity provides short-term benefits to soil micro-arthropod communities in earthworm-invaded soils (Migge-Kleian *et al.*, 2006). In contrast, the long-term effects of earthworm invasion on soil invertebrates are widely acknowledged to be negative due to significant loss of organic layers (Migge-Kleian *et al.*, 2006). The organic layers of the soil are home to the majority of soil invertebrate communities. Habitat loss may thus force soil invertebrates to disperse deeper into the soil, or their densities may eventually decline (Brown, 1995). The presence of all three ecological groups (epigeic, aneceic and endogeic) of earthworms can significantly reduce the organic material in the soil's organic layer, resulting in a significant depletion of resources for soil invertebrates (Ferlin *et al.*, 2018). Furthermore, endogeic and anecic earthworms are more harmful to other soil invertebrates than epigeic earthworms (Eisenhauer, 2010; Migge-Kleian *et al.*, 2006).

3.2 Impact of Invasion of exotic earthworms and soil vertebrates:

Only two vertebrates—birds and salamanders—have been investigated regarding the consequences of earthworm invasion**.** The disappearance of leaf litter layers caused by invasive earthworms in recipient ecosystem reduces habitat quality for forest floor salamanders and ground-nesting birds in general (Loss and Blair, 2011; Ransom, 2012). However, earthworms may become food for some species. As a result, the interaction of these factors is likely to determine the overall influences.

Salamanders are an important component of food webs in forest ecosystems. By consuming and controlling arthropod populations, they serve as the top predators in the leaf litter food web (Wyman *et al.*, 1998, Walton and Maerz *et al.*, 2006). These are particularly lungless vertebrates and need to allow gaseous exchange across their skin, which have moist membrane, and because of this they are very much sensitive to soil pH (Sugalski *et al.*, 1997). In North American forests it has been shown that biological invasion affects the population of these vertebrates. These particular forests are invaded by invasive shrub, *Berberis thunbergii*; its expansion alters the soil chemistry, e.g., it increases soil pH and composition of the soil and leaf litter layers, and facilitates the invasion of exotic earthworms, which prefer higher pH to survive (Laverack *et al.*, 1961). By reducing leaf litter, earthworms alter the amounts of microhabitats that are accessible, which is crucial for the survival of many terrestrial salamanders in the northeastern United States These invasions may affect salamanders as well as their predators as a result of a decline in soil arthropods and leaf litter, which might cause a trophic cascade that alters the function of eastern deciduous forest ecosystems.

3.3 Impact of exotic earthworms on soil microbiota:

The soil profile, which serves as a home for soil microorganisms, is significantly impacted by earthworm invasion (McLean *et al.*, 2006). During invasion, earthworm activity disrupts the soil layer, which changes the structure and activities of the microbial community in the soil. Microorganisms in soil exhibit a wide range of genetic and functional diversity. In addition, the enzymatic activities of microbes have the ability to break down a wide variety of organic substrates. Organic layers are the habitat for the majority of microbial biomass and activity site. The invasion affects the organic layer thickness, which results into disruptions of microhabitats. As a result of the earthworms' burrowing activities, it is probable that the invasion of earthworms may have an effect on the distribution of soil microorganisms. Mycorrhizal fungi are an important component of the microbial community, which as a whole is responsible for regulating the way plants interact with the soil. Both the stimulating effects of their mucus and the feeding behavior may have an influence on the microbial diversity pattern in the soil (Chapuis-Lardy *et al.*, 2010). As earthworms are fed, microorganisms move through their guts, where some species thrive while others cannot survive due to the microhabitat of the gut. It decreases the ratio of fungus to bacteria (Brown, 1995; Lavelle *et al.*, 1995).

3.4 Impact of exotic earthworms on defense trait of plants:

Plants in natural populations are frequently attacked by a variety of adversaries, such as diseases and herbivores. Despite the fact that many plants have all-purpose defenses against diseases and herbivores. These defensive substances are plant secondary metabolites that have distinct effects on either herbivores or plant diseases, which are plants' natural enemies. There are several kinds of secondary metabolites that can influence both pathogens and herbivores function (Schönbeck and Schlösser, 1976; Barbosa, 1991; Krischik, 1991; Harborne, 1993; Hammerschmidt and Schultz, 1996; Karban and Baldwin, 1997). Certain secondary metabolites altered their chemical structure in order to become effective against infections, whereas others, like flavonoid, may not need these kinds of alterations. With continuous influence on the biochemistry of the soil, non-native earthworms have the ability to change the ways in which plants defend themselves against herbivores and pathogens. A change in the concentration of chemical defense compounds in plants caused by the invasion of earthworms is associated with increased leaf herbivory. The invasive earthworms cause a reduction in the amount of leaf dry matter and an increase in the tree's vulnerability to infection by fungal pathogens (Thakur *et al.*, 2020). Salicinoids and flavonoids are two primary classes of phenolic compounds that have a function as chemical defense in plants. These chemicals have capabilities of being both anti-herbivore and anti-pathogen. The percentage of leaf dry matter reduces by invasive earthworms. A lower palatability indicates a higher leaf dry matter content, which is frequently related to the vulnerability of a tree's leaves to be damaged by leaf-chewing insects.

3.5 Interaction between native and exotic species of earthworms:

Native species are quickly overrun by invasive earthworms, which also severely deplete the variety of native species and, in some cases, lead to extinctions (Kemp *et al.*, 2009). Like some other exotic species, including invasive plant species, non-native earthworms have a friendly and helpful interaction. According to the hypothesis "Invasive meltdown," one invasive species creates an environment that is favourable for other invasive species, which results in an increase in invasion (Simberloff and Von Holle, 1999). The modifications to the soil's qualities were brought about by the invasive plant species *Berberis thunbergii,* a Japanese barberry that has spread to deciduous woods in North America. Sites where the Japanese barberry has invaded have higher pH values, less leaf litter, a thinner organic layer under the soil, and more rapidly nitrifying soil due to the shrub's leaf litter.

Due to its sharp spines, this plant avoids deer herbivory and thrives (Ehrenfeld *et al.*, 1997). By altering soil chemistry through the chemistry of leaf litter, it speeds up its invasion (Ehrenfeld *et al.*, 2001; Li *et al.*, 2008). The invasive earthworms, which prefer basic soil to dwell in, were harmed by the alterations created in the deciduous forest by that invading plant. Consequently, invasive plants encourage the invasion of exotic earthworms.

4.0 Conclusions:

The study found that ecological invasion has expanded into a global problem. A disturbed soil fauna that lacks native earthworms makes it easier for exotic earthworm invasion. Earthworm invasion is highly correlated with anthropogenic activities and infrastructure, such as forest roads, fishing sites, cottages, and timber harvesting. Successful invasion by exotic earthworms causes soil's chemical and physical composition to change. In plant communities, exotic earthworms have a species-specific effect. They have an impact on native ecosystem diversity, soil microbes, soil invertebrates, and soil vertebrates. The invasion has the most harmful impact on the mycorrhizal fungus group of microbes. Earthworm invasion lowers soil faunal diversity and density as well as invertebrate diversity and density. In India's agro-ecosystem, it is important to evaluate the effects of introduced earthworm species.

5.0 Acknowledgement:

Authors are thankful to the Department of Zoology, Dr. Harisingh Gour Vishwavidyalaya (A Central University), Sagar for proving facilities required for the study.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Seasonal variation of the species complex of necrophagous fly communities from a dry deciduous forest landscape

[1]Garima Hore, Oishik Kar*, [1]Atanu Naskar, [1]Jayita Sengupta and [1]Dhriti Banerjee**

[1]Diptera Section, Zoological Survey of India, M-Block, New Alipore, Kolkata 700053
**Presenter's mail id: oishikkar10@gmail.com*

Abstract

A plethora of necrophagous insect species exist on or around a cadaver, and a certain chronological sequence of colonization is expected to occur based on their preference, enabling microbial decomposition and aiding in maintaining ecosystem balance. Necrophagous flies comprise the foremost and often the most significant carrion entomofauna, playing crucial ecological roles in the decomposition process. They are therefore significant from both forensic entomological and ecological standpoints. Calliphorids, sarcophagids, and muscids constitute the predominant families of necrophagous flies to colonize carcasses. In the present study, a total of 24 species of necrophagous flies belonging to six dipteran families from three sites of Sonamukhi Protected Forest, Bankura have been documented seasonally. The dipteran families documented in the present study are Calliphoridae, Sarcophagidae, Muscidae, Phoridae, Stratiomyidae, and Sepsidae. The present research, a comprehensive account of the seasonal variations of necrophagous fly communities from a dry, deciduous forest landscape, the first of its kind conducted from this region displayed a diverse necrophagous species composition, consisting of 24 species under 12 genera from 6 families. Notably, out of the 24 species recorded in the present study, a total of 4 species were recorded for the first time from this state. Taxa richness tends to decline as environmental quality, favourable climatic conditions decline. The current study reveals that, on a seasonal note, pre-monsoon > monsoon > post-monsoon is favourable for necrophagous community growth and development. Thus, the relevance of the present study is not only limited to the medico-legal forensic entomological context but is also focused on assessing the risk status of the study sites in and around the Sonamukhi forest area with the help of ecological indices and biomonitoring of the study area. Consequently, the presence or absence of the indicator species or indicator community reflects the prevailing environmental conditions.

Keywords: Forensic entomology, Decomposition, Species composition, Biomonitoring, Seasonality

Introduction

Necrophagy is the act of devouring dead or decaying animal flesh. Although scavenger vertebrates, like vultures and jackals, constitute an important part of the detrivore community by devouring animal remains, the role played by the necrophagous arthropods is also of immense significance from ecological perspective (Amendt *et.al.*, 2004; Anderson, 1995). A diverse fauna of necrophagous species that comprise a vital part of the decomposition process belongs to arthropod groups such as Diptera, Coleoptera, Hymenoptera, and Arachnida (Amendt *et al.*, 2000; Amendt *et.al.*, 2004; Gruner *et al.*, 2007).

A wide array of necrophagous insect species occurs on or around a cadaver and, relying on their preference for a given stage of decomposition, a certain chronological sequence of colonization is expected to occur (Byrd and Castner, 2010). Necrophagous flies are the foremost and often the predominant consumers of carrion and thereby not only play

**Author for correspondence : atanu.diptera@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

a crucial ecological role in the decomposition process but also represent an important tool in criminal investigations (Catts and Goff, 1992).

Detrivores affect the decomposition of detrital resources in virtually all natural systems, with severe consequences for community structure and ecosystem function (Seastedt and Crossley, 1984; Moore *et al.*, 2004). Detrivores not only accelerate microbial decomposition by shredding, consuming, and transforming organic detritus but also help in nutrient cycling (Edwards *et al.*, 1970; Kitchell *et al.*, 1979; Vossbrinck *et al.*, 1979; Lussenhop, 1992). Thus, the importance of necrophagous flies, an important section of the detrivore community is not only in the ingestion of carrion but also in making the carrion available to microorganisms (Galante and Marcos-Garcia, 2008).

In India, necrophagous flies colonizing corpses are mostly the calliphorids, sarcophagids, and muscids, visiting carcasses at fresh and decay stages whereas flies from families like Fannidae, Stratiomyidae, Phoridae, Sepsidae, Piophiliidae, Neriidae, Anthomyiidae, Ulidiidae have also been reported (Joseph and Parui, 1980; Bharti and Singh, 2003; Majumdar *et al.*, 2007; Sinha, 2009; Bharti, 2012; Chakraborty *et al.*, 2015; Archana *et al.*, 2016; Khullar *et al.*, 2016; Singh *et al.*, 2016, Hore and Banerjee, 2017; Hore, 2021, Kar *et al.*, 2022).

Diptera or true flies are potentially useful bio-indicators for assessing the impact of environmental changes and monitoring forest recuperation. Moreover, Diptera also occupies a wide array of ecological niches and several different trophic levels (Majer, 1987). Analysis of dipteran community composition can be crucial in determining indicator faunae for detecting even subtle changes in the environment (Sousa *et al.*, 2014; Odat *et al.*, 2015).

The necrophagous flies colonizing carrion form a successional sequence of families and species that relies on the size of the carrion, and also on the climatic and edaphic conditions of the region where they are located. Indeed, very few species are widespread worldwide, and each geographical area and ecosystem has its specialist species devouring carrion (Galante and Marcos-Garcia 2008).

The habitat of the protected forest of Sonamukhi, Bankura, West Bengal is characterized by climatic extremities with temperature ranges between 39° to 42° C during summer and 7° to 14° C during winter. Sonamukhi protected forest area signifies unique topographical features for its location as an ecotone. The present study is the first comprehensive study of necrophagous dipteran fauna from the Protected Forest Area of Sonamukhi, Bankura. The main objectives of the study lie mainly in assessing the seasonal variation in the diversity and abundance of necrophagous dipteran species obtained from various meat bait traps located in typical three types of ecosystems, namely, forest vegetation, agricultural fields, and human-inhabited village areas nearby. The importance of the study lies in generating a clear idea about the species richness status of necrophagous dipteran fauna in different ecosystems and its correlation with seasonal patterns and anthropogenic disturbances. This present work carries immense significance from both ecological as well as forensic entomological perspectives.

Materials and Methodology

1) **Study site:** Three study sites, each representing an ecosystem type, were selected for the present study. The first study site was the Sonamukhi protected forest area, Bankura, West Bengal. The agricultural fields and human-inhabited village regions nearby were considered as the two other ecosystem types in the study. Sonamukhi is located at 23°18 N 87°25 E, with an average elevation of 66 m (217 ft).
2) **Duration of the study conducted:** The study was conducted for a duration of three years (2017-2019), during three seasons, namely, pre-monsoon (PRM), monsoon (MON), and post-monsoon (PST). This was done to monitor the seasonal variation in necrophagous species composition in the three ecosystem types.
3) **Collection, identification, and preservation:**
    i) **Placing meat bait for collection of necrophagous species-** Goat meat and liver were used as baits for collecting the necrophagous fly species. A total of twelve (four traps each for three ecosystems) such traps were kept in open areas close to herbage each in the forest, agricultural fields, and human-inhabited village regions of Sonamukhi, Bankura. The same procedure was repeated for each year of study during pre-monsoon, monsoon, and post-monsoon.
    ii) **Collection and preservation of specimens-** A modified version of the Malaise trap was utilized for the collection of adult specimens. Adult flies were collected and sacrificed by placing them in a killing jar containing cotton soaked with benzene as the killing agent. Flies were sorted and kept in insect

envelopes; then kept in a relaxing chamber for about 24 hours; then the specimens were pinned using entomological pins, dried in a drying chamber for 3-4 days, and finally stored in the insect cabinet after labeling.

iii) **Morphological identification of the fly specimens collected**- Senior-White (1940), Nandi (2002), and Oriental Catalog (1977) were utilized for taxonomic and morphological identification of specimens. The morphology of adult flies was photo-documented with the help of LEICA M205A coupled with LEICA DFC 500 camera as shown in the figures below.

4) **Statistical analysis:** All statistical analyses were conducted in Microsoft Office Excel 2019. The biodiversity indices considered for the present study are as follows- Species diversity, Species richness, Relative abundance, Index of dominance, and Shannon's diversity (SH) index (Hubalek, 2000).

Results

A. Taxonomic studies:

The present research, the first of its kind from this region showed a diverse necrophagous species composition, consisting of 24 species under 12 genera from 6 families. Notably, out of the 24 species recorded in the present study, a total of 4 species (Plate 1 A-D) were recorded for the first time from this state to date, marked with double asterisks.

List of Dipteran species

Family	Species
Stratiomyidae	*Hermetia illucens* Linnaeus, 1758
Phoridae	*Megaselia (Megaselia) scalaris* (Loew, 1866)
Sepsidae	*Australosepsis niveipennis* (Becker, 1903)
Sepsidae	*Sepsis indica* (Wiedemann, 1824)
Sepsidae	*Sepsis nitens* (Wiedemann, 1824)
Sepsidae	*Sepsis (Sepsis) cynipsea* (Linnaeus, 1758)
Muscidae	*Musca (Musca) domestica* (Linnaeus, 1758)
Muscidae	*Orthellia viridis* (Wiedemann, 1824)
Muscidae	*Atherigona orientalis* (Schiner, 1868)
Sarcophagidae	*Sarcophaga (Liopygia) ruficornis* (Fabricius, 1794)
Sarcophagidae	*Sarcophaga (Liosarcophaga) dux* (Thomson, 1869)
Sarcophagidae	*Sarcophaga (Liosarcophaga) brevicornis* (Ho, 1934) **
Sarcophagidae	*Sarcophaga (Parasarcophaga) albiceps* (Meigen, 1826)
Sarcophagidae	*Sarcophaga (Parasarcophaga) taenionota* (Wiedemann, 1819)
Sarcophagidae	*Sarcophaga (Iranihindia) martellatoides* (Baranov, 1931)
Calliphoridae	*Hemipyrellia ligurriens* (Wiedemann, 1830)
Calliphoridae	*Hemipyrellia pulchra* (Wiedemann, 1830) **
Calliphoridae	*Lucilia cuprina* (Wiedemann, 1830)
Calliphoridae	*Lucilia porphyrina* (Walker, 1856)
Calliphoridae	*Lucilia sericata* (Meigen, 1826) **
Calliphoridae	*Chrysomya bezziana* (Villeneuve, 1914) **
Calliphoridae	*Chrysomya megacephala* (Fabricius, 1794)
Calliphoridae	*Chrysomya nigripes* (Aubertin, 1932)
Calliphoridae	*Chrysomya rufifacies* (Macquart, 1842)

B. Diversity and abundance studies (Results of Statistical analyses):

The current experiment spanned from 2017 to 2019. The total number of specimens captured was 1,995. In the forest ecosystem, during the pre-monsoon season, a total of 268 specimens of 24 different species were recovered from the malaise traps. In the monsoon season, a total of 196 specimens of 20 different species were recorded from the malaise traps. In the post-monsoon season, a total of 200 specimens of 20 different species were recorded from the malaise traps. In the agricultural field during, the pre-monsoon season, a total of 278 specimens of 21 different species were recovered from the malaise traps. In the monsoon season, a total of 229 specimens of 22 different species were recorded from the malaise traps. In the post-monsoon season, a total of 181 specimens of 21 different species were recorded from the malaise traps. In human habitation, during the pre-monsoon season, a total of 272 specimens of 24 different species were recovered from the malaise traps. In the monsoon season, a total of 208 specimens of 21 different species were recorded from the malaise traps. In the post-monsoon season, a total of 163 specimens of 20 different species were recorded from the malaise traps.

Statistical analyses:

Species composition

Overall, the most frequent were *Sarcophaga (Liosarcophaga) dux* (SLD) (n = 484) & *Sarcophaga (Liosarcophaga) ruficornis* (SLR) (n = 232), and the least occurring species were *Hemipyrellia ligurriens* (HL) & *Lucilia porphyrina* (LP) (n = 8). In the forest ecosystem, the most frequent were SLD (n= 163) & SLR (n = 82) and the least occurring species were *Chrysomya rufifacies* (CR) (n = 2). In agricultural fields, the most frequent were SLD (n = 161) & SLR, and *Megaselia scalaris* (MS) (n = 77) and the least occurring species were HL & *Chrysomya nigripes* (CN) (n = 2). In human habitation, the most frequently occurring species were SLD (n= 160) & SLR, and MS (n = 73).

Diversity

The number of taxa and Shannon index (H) of all species increased near the Agricultural fields (transition of forest ecosystem and human inhabitation zone) and declined towards human habitation. While dominance decreased in the human inhabitation zone. These values are affected by the number of individuals and taxa in the community. Diversity value was highest in the Agricultural fields>forest ecosystem> human inhabitation (2.604 > 2.516 > 2.405) respectively. The number of the most frequently occurring SLD (H) varied as (0.341 > 0.337 > 0.330). A high value of H was recorded in the pre-monsoon > monsoon > post-monsoon (2.6 > 2.5 > 2.4).

Seasonal species richness

Seasonal species richness was highest in the pre-monsoon > monsoon > post-monsoon for all the sites. The only difference is the number of specimens being captured and the site localities prevailing climatic conditions. The highest seasons species richness was of pre-monsoon of Agricultural fields > forest ecosystem > human inhabitation (278 > 272 > 268) respectively.

Relative abundance

The cumulative abundance value for the forest ecosystem seasonally was pre-monsoon = monsoon > post-monsoon (99.88 = 99.88 > 96). The cumulative abundance value for agricultural fields seasonally was pre-monsoon > monsoon > post-monsoon (99.88 > 99.86 > 97.97). The cumulative abundance value for human habitation was post-monsoon > pre-monsoon > monsoon (99.68 > 96.16 > 92.09). (Figure 3). Overall, comparatively agricultural field > forest ecosystem > human habitation (Table 1).

Index of dominance

The cumulative dominance value for the forest ecosystem seasonally was monsoon > post-monsoon > pre-monsoon (0.12 > 0.10 > 0.09). The cumulative dominance value for agricultural fields seasonally was pre-monsoon > post-monsoon > monsoon (0.60 > 0.10 > 0.09). The cumulative dominance value for human habitation was pre-monsoon > post-monsoon > monsoon (0.11 > 0.09 > 0.08) (Figure 3) (Table 2).

SH index

The cumulative SH for the forest ecosystem seasonally was post-monsoon > pre-monsoon > monsoon (2.6 > 2.25 > 0.4). The cumulative dominance value for agricultural fields seasonally was post-monsoon > monsoon > pre-monsoon (2.4 > 2.02 > 1.29). The cumulative dominance value for human habitation was post-monsoon > pre-monsoon > monsoon (2.51 > 2.44 > 2.23) (Figure 3) (Table 3).

Discussion

Taxa richness tends to decline as environmental quality, favourable climatic conditions decline. This seemed to happen seasonally, with the pre-monsoon season being the most favoured for most of the species. Regarding species composition SLD & SLR are clearly, the most frequently occurring in all three sites annually, therefore acting as opportunistic species. Relative abundance gave an idea of species under stress, their resource utilization, and uniformity.

During the study, it was observed that overall SLD best utilized this ecosystem resources and was more evenly distributed than any other flies. SLD had an RA of Agricultural fields>forest ecosystem>human inhabitation (26.10 > 23.74 > 22.38) respectively. Therefore, acting as an opportunistic species. A high abundance of such groups indicates the availability of resources and their utilization over time.

The index of dominance was used to determine the domination by a few species or families indicates stress or conditions which preferentially support particular taxa such as nutrient enrichment and toxic contaminants or in other words it reflects the degree of the unfavourable environment on each species. The current study shows that the season-wise pre-monsoon > monsoon > post-monsoon is favourable for necrophagous community growth and development.

SH index reflects the dispersion of species in this necrophagous community, the more the value of the H, the more dispersion is shown by the species, but this is inversely proportional to the decrease in the number of species or uniformity. The current study shows that the season-wise pre-monsoon > monsoon > post-monsoon is favourable for necrophagous community growth and development.

Biomonitoring is a valuable assessment tool that is receiving increased usage. The presence or absence of the indicator or of an indicator species or indicator community reflects environmental conditions. Taxa richness tends to decline as environmental quality, favourable climatic conditions decline. This seemed to happen seasonally, with the pre-monsoon season being the most favoured for most of the species. During the study, it was observed that overall SLD best utilized this ecosystem resources and were more evenly distributed than any other flies. SLD had an RA of Agricultural fields > forest ecosystem > human inhabitation (26.10 > 23.74 > 22.38) respectively. Therefore, acting as an opportunistic species. A high abundance of such groups indicates the availability of resources and their utilization over time. The current study shows that the season-wise pre-monsoon > monsoon > post-monsoon is favourable for necrophagous community growth and development. The current study shows that the season-wise pre-monsoon > monsoon > post-monsoon is favourable for necrophagous community growth and development.

Tables and Figures

Table 1- The relative abundance is plotted for three seasons of three years graphically; this can be uniform or not uniform. The environment is unfavourable for growth and development. Only the tough species survive, in our case those are SLD and SRL.

	2017	**2018**	**2019**
PRM	Moderately Stressed	Severely Stressed	Moderately Stressed
MON	Severely Stressed	Severely Stressed	Severely Stressed
PST	Stressed	Severely Stressed	Moderately Stressed

Table 2- Index of dominance are plotted for three seasons of three years in graphically, reflects the degree of unfavorable environment on each species. If this value increases, then the community is under stress.

	2017	**2018**	**2019**
PRM	Moderately unfavourable	Severely unfavourable	Moderately unfavourable
MON	Severely unfavourable	Severely unfavourable	Severely unfavourable
PST	Unfavourable	Severely unfavourable	Moderately unfavourable

Table 3- SH index reflects the dispersion of species in this necrophagous community, the more the value of H, the more dispersion is shown by the species, but this is inversely proportional to decrease in the number of species or uniformity.

	2017	2018	2019
PRM	Evenly dispersed	Moderately dispersed	Evenly dispersed
MON	Unevenly dispersed	Evenly dispersed	Evenly dispersed
PST	Evenly dispersed	Evenly dispersed	Evenly dispersed

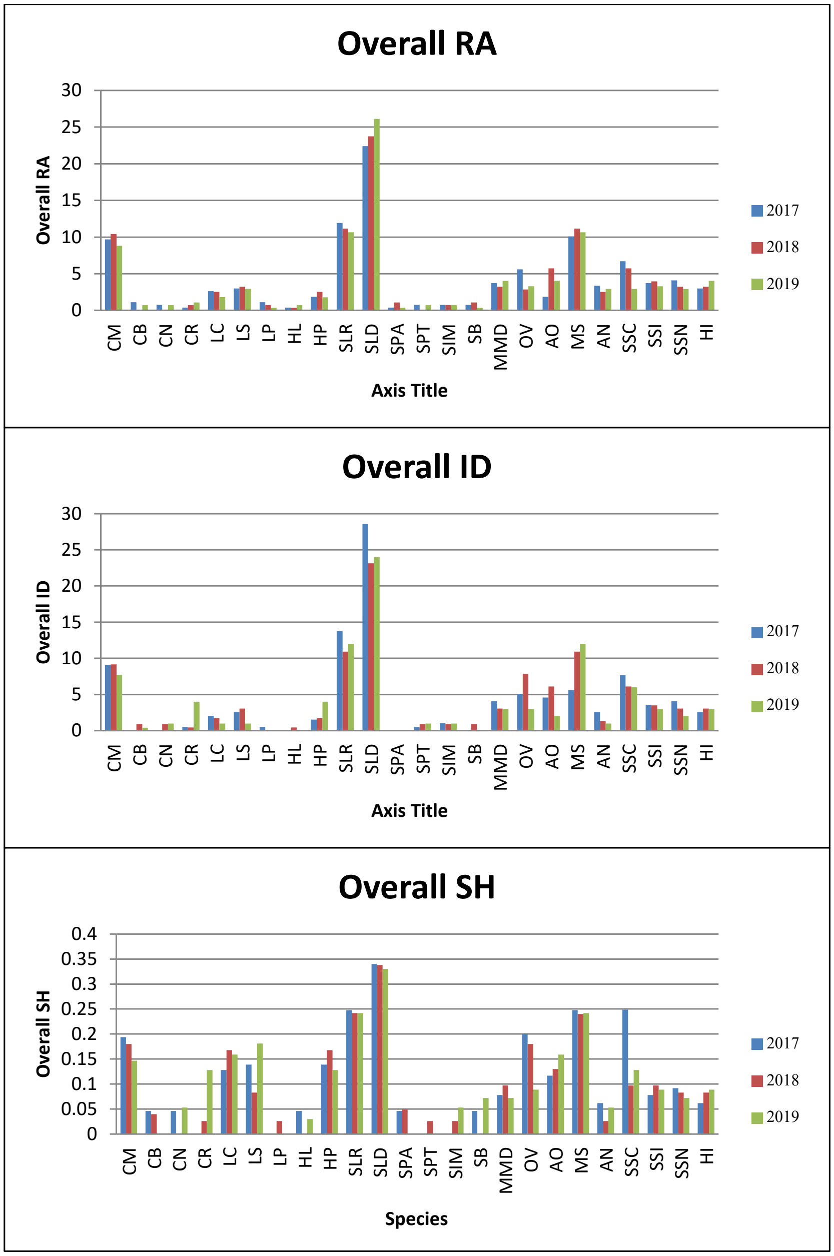

Figure 3: Comparison of the three relative abundance (RA), index of dominance (ID), and SH index (SH) parameters for three years.

Taxonomic plates:

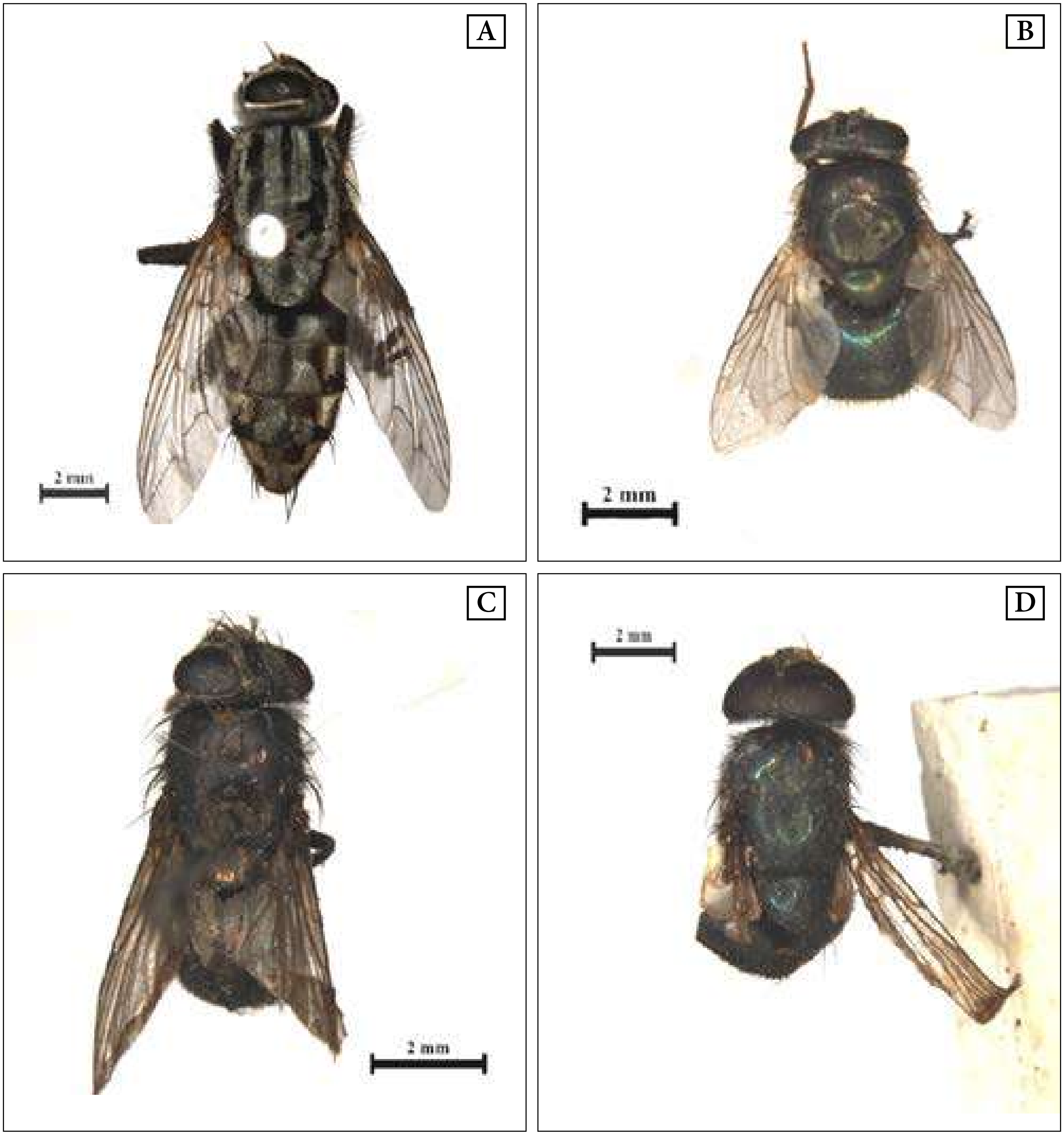

Plate 1 A-D: Habitus of four newly recorded necrophagous flies from Sonamukhi Protected Forest area of West Bengal. A: Dorsal view of *Sarcophaga (Liosarcophaga) brevicornis* (Ho, 1934) (Male); B: Dorsal view of *Hemipyrellia pulchra* (Wiedemann, 1830) (Female); C: Dorsal view of *Lucilia sericata* (Female) (Meigen, 1826); D: Dorsal view of *Chrysomya bezziana* (Villeneuve, 1914) (Male).

Acknowledgements

The authors are grateful to the Director, Zoological Survey of India, Head Quarters, M Block, New Alipore, Kolkata -700053 for her continuous support and enthusiasm. The authors also acknowledge the help of Mr. Panchanan Parui and all the present staff members of the Diptera Section, ZSI. The help of DFO and all the forest staff is also deeply acknowledged for providing us with guidance, accommodation, and necessary facilities. This work was supported by the Zoological Survey of India (ZSI), Ministry of Environment, Forest & Climate Change (MOEFCC) under Grant Number- 282/2021.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

A Study on Ichthyofaunal Diversity of Yerla River, Northern Western Ghat, Maharashtra, India

Angha V. Bhoi-Kamble* and Suresh M. Kumbar
Department of Zoology,
Arts, Commerce and Science College Palus, Dist. Sangli (MS), 416 310
smkumbar@rediffmail.com

Abstract

The freshwater fish fauna of Yerla River, Sangli district was studied between 2021 to 2022. It is aimed at making a comprehensive checklist and to find out real anthropogenic threats to the fish fauna of Yerla River. A total of 58 species belonging to 7 orders, 19 families and 40 genera were recorded. Order Cypriniformes were the most dominant one and represents 33 species followed by Siluriformes (13 species), Anabantiformes (4 species), Cichliformes (3 species), Beloniformes (2 species), Synbranchiformes (2 species) and Gobiiformes (1 species). Among these, 17 species are endemic from the Western Ghats and 4 species endemic from the Krishna River System. As per IUCN's Red list of Threatened Species, 41 species assessed as least concern; 3 species as near threatened; 2 species as vulnerable; 4 species as endangered; 4 species as Data Deficient and the conservation status of one species *Pethia sanjaymoluri* has not yet been assessed. The fish fauna of the river is threatened due to alien species and some anthropogenic activities like releasing of agricultural effluents, domestic organic wastes and non-degradable plastic materials owing to tourism activities. Since, this small study area hosts 17 endemic and 6 threatened species. Therefore, Yerla River will be the most suitable habitat for conservation of endemic and threatened species.

Keywords: *fish diversity, endemics, threats, conservation, Yerla River*

Introduction:

The Western Ghats of India is one of the eight 'hotspots' of biological diversity in the world (Myers *et al.*, 2000), with a high level of endemism, encompasses 320 species belonging to 11 orders, 35 families and 112 genera (Dahanukar and Raghavan, 2013a). Krishna is one of the major perennial River in Western region of Maharashtra. The important tributaries of the river Krishna are Wenna, Urmodi, Tarli, Koyna, Yerla, Warana, Panchaganga, Ghataprabha, Malaprabha, Bhima, Tungabhadra and Musi (Das *et al.*, 2017). In recent years, much interest has developed in the study of phylogeny and taxonomy of the freshwater fishes as a whole (Jayaram, 2009). Much of information has been accumulated in the fields of diversity, density, threats and conservations of freshwater fish fauna of Krishna River system (Arunachalam, 2002; Kharat *et al.*, 2003; Dahanukar *et al.*, 2004; Chandanshive *et al.*, 2007; Sarwade and Khillare, 2010; Jadhav *et al.*, 2011; Kharat *et al.*, 2012; Dahanukar *et al.*, 2012; Kumbar *et al.*, 2021). Earlier studies on the fish fauna of Satara district was carried out by Annandale (1919) reported 18 species in Yenna River at Medha in Satara. Silas (1953) studied the fish fauna of Mahabaleshwar and Wai in Satara district and recorded 14 species, later Kharat *et al.* (2012) has given updated checklist of fish fauna of Krishna River at Wai and Dhom reservoir and reported presence of 51 species. Jadhav *et al.* (2011) reported 58 species of fish in Koyna River. However, Kumbar and Lad (2014) have recorded 13 species of catfish in the Krishna River, Sangli district. Recently, Kumbar *et al.*, 2021 have reported 73 species of fish from the Krishna River in Sangli District. Some reviews have highlighted paucity of data on the fish fauna of the Western Ghats Rivers (Kharat *et al.*, 2003; Dahanukar

*Author for correspondence : anghabhoi@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

et al., 2011; Kharat *et al.*, 2012; Dahanukar *et al.*, 2012). Yerla River is one of the major tributary of Krishna River, there is no report on diversity and density of freshwater fish fauna. Therefore, the present study is undertaken to make comprehensive checklist of fish fauna of Yerla tributary of the Krishna River, Western Maharashtra.

Material and Methods:

Yerla is a tributary of the Krishna River, originated near Manjarwadi village, (17.86° N, 74.27° E) on Solakhnath hill, about of 29 km north of Vaduj village. It is more than 120 km in length (Fig. 1). Yerla River is flowing through Mol, Diskal, Lalgun, Khatav, Vaduj, Nimsod and Chitali villages in the Khatav tahsil. This river joins left side of Krishna River near Bramhanal village. There are two earthen dams near Ner and Yeralwadi near Banpuri village and many small concrete bandh along with the tributary. Yerla river flows around the year and it provides the food and shelter for many aquatic organisms including the fish fauna. Fish species were collected from 12 sampling sites during 2021-2022. Location of each sampling site was documented by using global positioning system (Table 1). The samples were collected by using cast net, gill nets, hand nets, hooks and line. The collected samples were categorized according to the categories defined by Dahanukar *et al.,* 2012 as abundant (76-100 % of total catch), common (51-75 % of total catch), moderate (26-50 % of total catch) and rare (1-25 % of total catch). The collected fishes were preserved in 4% formalin solution. The samples were identified and labeled by using the available literature (Menon, 1987, 1992, Talwar and Jhingran, 1991; Jayaram and Das, 2000; Jayaram and Sanyal, 2003; Jayaram, 1991, 2006, 2010). All identified specimens were deposited at the Department of Zoology, Arts, Commerce and Science College Palus, Sangli District, Maharashtra with accession numbers from ZID 01 to 58. Taxonomic status as per Fricke *et al.*, 2023.

Statistical analysis:

For statistical analysis Shannon diversity index were calculated.

Shannon index (Shannon and Weaver, 1949): A diversity index, taking into account the number of individuals as well as number of taxa, varies from 0 for communities with only a single taxon to high values for communities with $H = -\sum_i \frac{n_i}{n} \ln \frac{n_i}{n}$ many taxa, each with few individuals:

where, *ni* is number of individuals of '*i*' taxon and *n* is total number of individuals.

Result and Discussion:

A total of 58 species of fishes, belonging to 7 orders, 19 families and 40 genera were recorded in the table 2. Order Cypriniformes were the most dominant one and represents 57% followed by Siluriformes 22%, Anabantiformes 7%, Cichliformes 5%, Beloniformes 4%, Synbranchiformes 3%, Gobiiformes 2% (Fig. 2). Among these, 17 species are endemic to the Western Ghats and 4 species endemic to the Krishna River system (Images 1-58). As per IUCN Red list of Threatened Species 41 (76%) species are assessed as least concern, 2 (4%) species *Mystus malabaricus* and *Ompok bimaculatus* as Near Threatened, 2 (4%) species *Wallago attu* and *Gagata itchkeea* as vulnerable, 4 (7%) species *Botia striata, Hypselobarbus curmuca, Puntius fraseri* and *Bangana nukta* as Endangered, 4 (7%) species *Pachypterus khavalchor, Puntius amphibius, Osteobrama peninsularis* and *Hypselobarbus dobsoni* as Data Deficient and the conservation status of one species *Pethia sanjaymoluri* has not yet been assessed. Among 58 fish collected from the Yerla river, 13 species were found common, 5 abundant, 24 moderate and 16 rare (Table 3). High Shannon diversity index showed considerable variation and ranged from 3.00 – 3.41 indicates a strong relationship with overall species richness. The highest fish diversity was recorded from S3 (Wakeshwar) and S9 (Andhali) sampling site i.e., 3.41. The lowest diversity was recorded from S6 (Tupewadi) sampling site (3.00) respectively.

The fish fauna of Yerla River is threatened by anthropogenic activities such as releasing or dumping of agriculture effluents, industrial sewage and domestic organic wastes in some stretch of the river bed at the vicinity of Ner, Turchi and Bramhanal villages. Similarly, over-exploitation of fish using different sizes of gill-nets and unscientific practicing for fish catch could also be a threat to the fish species of the genera like, *Labeo, Cirrhinus, Opsarius, Salmostoma, Hypselobarbus, Mystus, Puntius* etc. We recorded eight introduced species i.e., four transplanted viz., *Cirrhinus mrigala, Labeo rohita, Labeo catla, Labeo calbasu* and four invasive species viz., *Oreochromis mossambicus, Cyprinus carpio, Clarias gariepinus* and *Ctenopharyngodon idella* from various sites of Yerla River. Presence of these transplanted and invasive exotic species is potential threats to most of the indigenous fish species (Kharat *et al.*, 2003; Raghavan *et al.*, 2008; Knight 2010; Kumbar *et al.*, 2021). Studies on Krishna River in Sangli and adjacent areas have recorded several alien species (Jayaram 1995), but Jadhav *et al.*, 2011 could not record any alien species from Koyna River, a tributary of Krishna River. Nevertheless, Yerla River harbours 15 endemic and 4 endangered species. The population of Endangered and Endemic *Botia striata* and *Puntius fraseri* is declining drastically in the study area due to pollution, over fishing for consumption and the competition created by introduced carps such as *Cirrhinus mrigala, Labeo rohita, Labeo catla* (Ghate *et al.*, 2002; Kharat *et al.*, 2003; Dahanukar *et al.*, 2012). Similarly, *Hypselobarbus curmuca* collected moderate to less number and is assessed as Endangered (Dahanukar and Raghavan, 2013b).

In the present study *Opsarius bendelisis, Bangana nukta, Heteropneustes fossilis* and *Gagata itchkeea* (Image 9, 33, 44 and 48) were recorded very less in number. Further, the important Western Ghats and Krishna River endemic species *Pachypterus khavalchor, Osteobrama neilli, Pethia sanjaymoluri, Rohtee ogilbii* have been collected at various sites of the study areas. Possible threats o the fishes of Yerla River are over fishing, recreational activities and pollution of the river. Four species *Pachypterus khavalchor, Puntius amphibius, Osteobrama peninsularis* and *Hypselobarbus dobsoni* assessed as Data Deficient due to lack of substantial information. *Anabas testudineus* (Image 51), a climbing perch of amphibious species was recorded in Bramhanal site (S12). It is widely distributed from India and China across to Cambodia. However, *A. testudineus* is assessed as Least Concern due to its wide distributional range.

Though, the threat of anthropogenic stressors are lesser in its impact compare to other rivers of the district or the tributaries of Krishna River, the presence of eight transplanted, three alien or exotic fish species could be the major threats for indigenous fish species of the Yerla river. However, this fauna was threatened due to directly releasing of industrial and agricultural effluents, domestic organic wastes and non-degradable plastic materials, mostly single use plastics. If the present trend is continued, the adverse conditions might lead to the loss of habitat and fish fauna of Yerla River, which are richly diver at present. Therefore, it is essential to convey awareness in local fishers and people for reducing the deposition of various pollutants and protection of food fishes. The collected data will be helpful for the other researchers in perceiving the aquatic life in Yerla River. It is therefore essential to conserve and protect endemic and threatened species found in the Yerla River.

Table 1: Details of the sampling sites of Yerla River

Site Code	Sampling Sites	GPS Locations
S1	Ner Dam	17°44’50.4”N 74°18’24.9”E
S2	Khatgun	17°42’04.2”N 74°20’47.0”E
S3	Wakeshwar	17°36’09.0”N 74°25’14.1”E
S4	Yeralwadi Dam	17°32’03.5”N 74°29’10.7”E
S5	Chitali	17°25’14.3”N 74°29’45.7”E
S6	Tupewadi	17°20’38.8”N 74°28’28.2”E
S7	Vadiye-Raibag	17°16’50.9”N 74°25’57.3”E
S8	Rampur	17°10’42.4”N 74°25’50.3”E
S9	Andhali	17°08’06.7”N 74°28’55.9”E
S10	Turchi	17°04’08.7”N 74°33’15.7”E
S11	Nandre	16°57’19.3”N 74°32’31.4”E
S12	Bramhanal	16°56’25.8”N 74°30’38.4”E

Table 2: The representative orders, families, genera and species of Yerla River

Order	Families	Genera	Species
Anabantiformes	2	2	4
Beloniformes	2	2	2
Cichliformes	2	3	3
Cypriniformes	5	21	33
Gobiiformes	1	1	1
Siluriformes	6	9	13
Synbranchiformes	1	2	2
Total	**19**	**40**	**58**

Table 3: Checklist of freshwater fishes collected from the Yerla River, Maharashtra, Southern India

Sr. No.	Order	Family	Species	Status	WRE	KRE	IUCN Status
1	Beloniformes	Belonidae (Needle fish)	*Xenentodon cancila* (Hamilton, 1822)	R	-	-	LC
2		Hemiramphidae (Half beaks)	*Hyporhamphus limbatus* (Valenciennes, 1847)	R	-	-	LC
3	Cypriniformes	Botiidae (Pointface loaches)	*Botia striata* (Rao, 1920)	M	+	+	EN
4		Danionidae (Danios)	*Amblypharyngodon mola* (Hamilton,1822)	M	-	-	LC
5			*Devario malabaricus* (Jerdon, 1849)	M	-	-	LC
6			*Salmostoma balookee* (Sykes, 1839)	C	-	-	LC
7			*Salmostoma boopis* (Day, 1874)	A	+	-	LC
8			*Salmostoma novacula* (Valenciennes, 1838)	M	+	-	LC
9			*Opsarius bendelisis* (Hamilton, 1807)	R	-	-	LC
10			*Cirrhinus mrigala* (Hamilton, 1822)	M	-	-	LC
11			*Cirrhinus reba* (Hamilton, 1822)	M	-	-	LC

Sr. No.	Order	Family	Species	Status	WRE	KRE	IUCN Status
13		Cyprinidae (Minnows and Carps)	*Cyprinus carpio* Linnaeus, 1758	M	-	-	-
14			*Garra mullya* (Sykes, 1839)	A	-	-	LC
15			*Gymnostomus ariza* (Hamilton, 1807)	R	-	-	LC
16			*Hypselobarbus curmuca* (Hamilton, 1807)	M	-	-	EN
17			*Hypselobarbus dobsoni* (Day, 1876)	R	-	-	DD
18			*Labeo boggut* (Sykes, 1839)	R	-	-	LC
19			*Labeo calbasu* (Hamilton, 1822)	M	-	-	LC
20			*Labeo catla* (Hamilton, 1822)	A	-	-	LC
21			*Labeo porcellus* (Heckel, 1844)	R	+	-	LC
22			*Labeo rohita* (Hamilton, 1822)	A	-	-	LC
23			*Osteobrama neilli* (Day, 1873)	R	+	+	LC
24			*Osteobrama peninsularis* (Silas, 1952)	M	+	-	DD
25			*Osteobrama vigorsii* (Sykes, 1839)	C	-	-	LC
26			*Pethia sanjaymoluri* Katwate, Jadhav, Kumar, Raghavan & Dahanukar, 2016	M	+	+	NE
27			*Puntius amphibius* (Valenciennes, 1842)	M	+	-	DD
28			*Puntius fraseri* (Hora & Misra, 1938)	R	+	-	EN
29			*Puntius sophore* (Hamilton, 1822)	C	-	-	LC

Sr. No.	Order	Family	Species	Status	WRE	KRE	IUCN Status
30			*Pethia ticto* (Hamilton, 1822)	M	-	-	LC
31			*Rasbora dandia* (Valenciennes, 1844)	M	-	-	LC
32			*Rohtee ogilbii* (Sykes, 1839)	M	+	+	LC
33			*Bangana nukta* (Sykes, 1841)	R	-	-	EN
34			*Systomus sarana* (Hamilton, 1822)	C	-	-	LC
35		Nemacheilidae (Brook loaches)	*Paracanthocobitis mooreh* (Sykes, 1839)	R	-	-	LC
		Xenocyprididae	*Ctenopharyngodon idella* (Valenciennes, 1844)	M	-	-	-
36	Siluriformes	Bagridae (Bagrid catishes)	*Mystus cavasius* (Hamilton, 1822)	M	-	-	LC
37			*Mystus malabaricus* (Jerdon, 1849)	M	+	-	NT
38			*Mystus seengtee* (Skyes, 1839)	M	+	-	LC
39			*Sperata aor* (Hamilton, 1822)	M	-	-	LC
40			*Sperata seenghala* (Sykes, 1839)	M	-	-	LC
41			*Rita gogra* (Sykes, 1839)	R	+	-	LC
42			*Rita kuturnee* (Sykes, 1839)	C	+	-	LC
43		Clariidae (Airbreathing catfishes)	*Clarias gariepinus*	R	+	-	-
44		Heteropneustidae (Stinging catfish)	*Heteropneustes fossilis* (Bloch, 1794)	R	-	-	LC
45		Horabagridae	*Pachypterus khavalchor* (Kulkarni, 1952)	A	+	-	DD

Sr. No.	Order	Family	Species	Status	WRE	KRE	IUCN Status
46		Siluridae (Sheat fishes)	*Ompok bimaculatus* (Bloch, 1794)	C	-	-	NT
47			*Wallago attu* (Bloch & Schneider, 1801)	C	-	-	VU
48		Sisoridae (Sisorid catfishes)	*Gagata itchkeea* (Sykes, 1839)	R	+	-	VU
49	Cichliformes	Ambassidae (Asiatic glassfishes)	*Chanda nama* (Hamilton, 1822)	C	-	-	LC
50			*Parambassis ranga* (Hamilton, 1822)	C	-	-	LC
51		Cichlidae (Cichlids)	*Oreochromis mossambicus* (Peters, 1852)	C	-	-	-
52	Anabantiformes	Anabantidae (Climbing gouramies)	*Anabas testudineus* (Bloch, 1972)	R	-	-	LC
53		Channidae (Snakeheads)	*Channa marulius* (Hamilton, 1822)	M	-	-	LC
54			*Channa punctata* (Bloch, 1793)	M	-	-	LC
55			*Channa striata* (Bloch, 1793)	M	-	-	LC
56	Gobiiformes	Gobiidae (Gobies)	*Glossogobius giuris* (Hamilton, 1822)	C	-	-	LC
57	Synbranchiformes	Mastacembelidae (Spiny eels)	*Mastacembelus armatus* (Lacepède, 1800)	C	-	-	LC
58			*Macrognathus puncalus* (Hamilton, 1822)	C	-	-	LC

Note: A – Abundant, C – Common, M – Moderate, R – Rare, EN – Endangered, NT – Near Threatened, LC – Least Concern, NE – Not Evaluated, DD – Data Deficient, VU – Vulnerable

Table 4: Summary of variation in fish species abundance, Shannon index.

Study sites	Sampling sites											
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
Species	38	30	35	33	30	23	33	28	40	25	30	40
Individual	166	100	129	183	120	91	150	117	175	94	125	179
Shannon Index	3.14	3.25	3.41	3.07	3.29	3.00	3.34	3.16	3.41	3.07	3.21	3.36

Fig. 1 Study area map showing different sampling sites on Yerla river

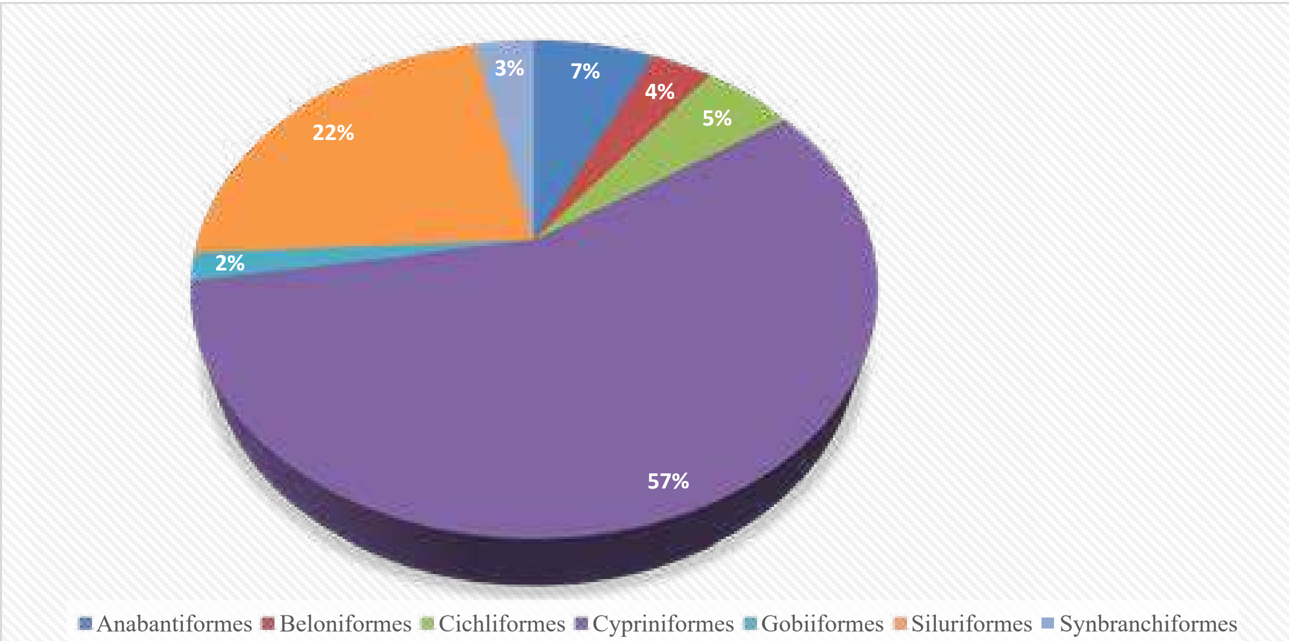

Fig. 2 Percentage composition of orders

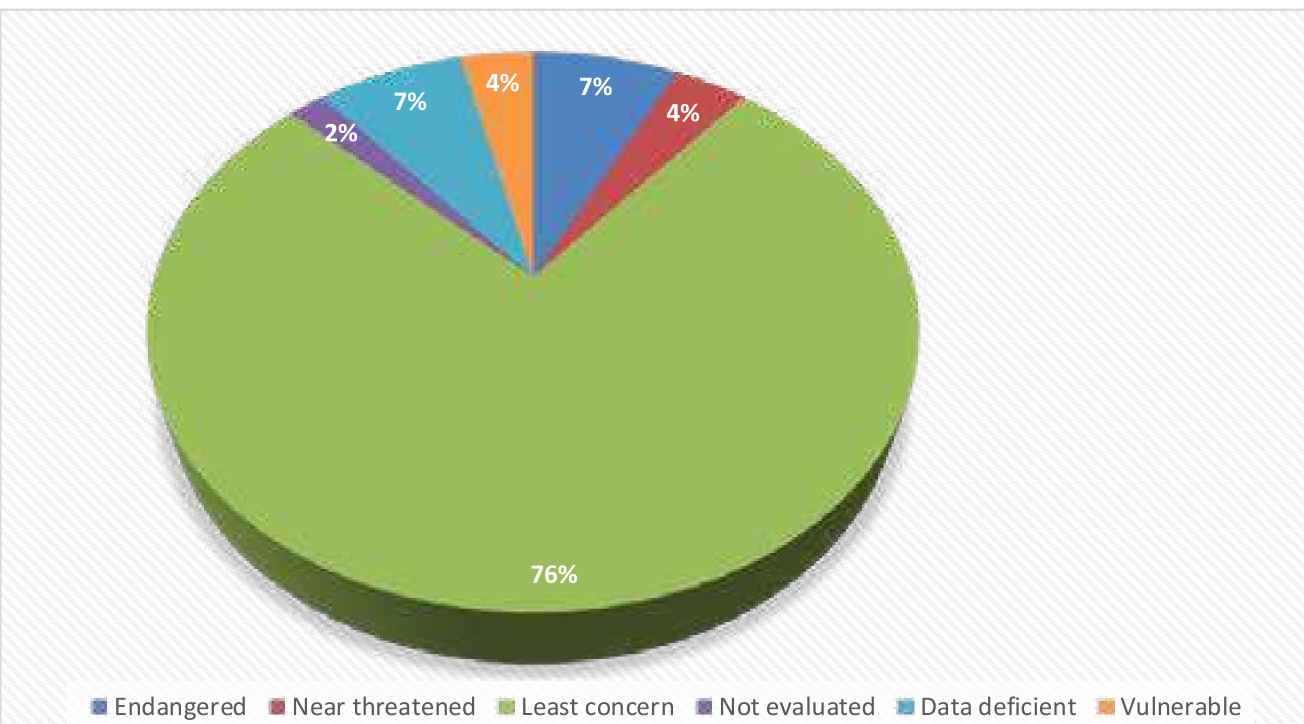

Fig. 3 Percentage composition of conservation status (IUCN) of fish fauna

Image 1. *Xenentodon cancila*

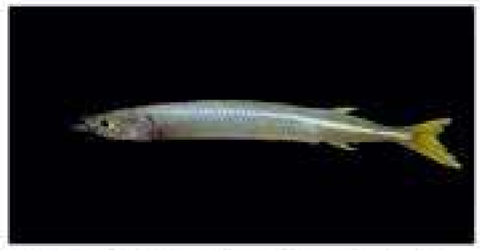

Image 2. *Hyporhamphus limbatus*

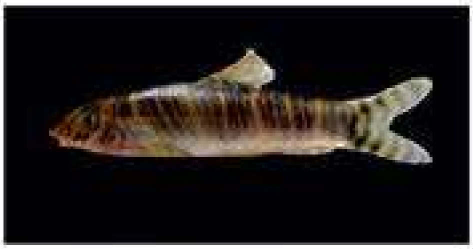

Image 3. *Botia striata*

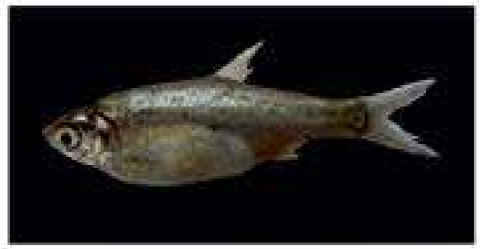

Image 4. *Amblyphryngodon mola*

Image 5. *Devario malabaricus*

Image 6. *Salmostoma balookee*

Image 7. *Salmostoma boopis*

Image 8. *Salmostoma novacula*

Image 9. *Opsarius bendelisis*

Image 10. *Cirrhinus mrigala*

Image 11. *Cirrhinus reba*

Image 12. *Ctenopharyngodon idella*

Image 13. *Cyprinus carpio*

Image 14. *Garra mullya*

Image 15. *Gymnostomus ariza*

Image 16. *Hypselobarbus curmuca*

Image 17. *Hypselobarbus dobsoni*

Image 18. *Labeo boggut*

Image 19. *Labeo calbasu*

Image 20. *Labeo catla*

Image 21. *Labeo porcellus*

Image 22. *Labeo rohita*

Image 23. *Osteobrama neilli*

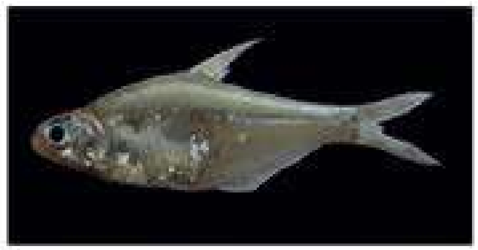

Image 24. *Osteobrama peninsularis*

Image 25. *Osteobrama vigorsii*

Image 26. *Pethia sanjaymoluri*

Image 27. *Puntius amphibius*

Image 28. *Puntius fraseri*

Image 29. *Puntius sophore*

Image 30. *Pethia ticto*


Image 31. *Rasbora dandia*


Image 32. *Rohtee ogilbii*

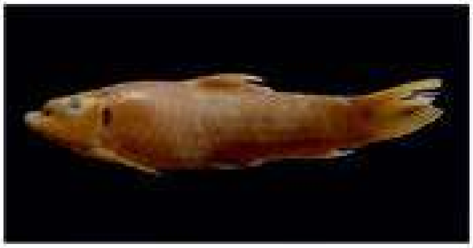
Image 33. *Bangana nukta*


Image 34. *Systomus sarana*


Image 35. *Paracanthocobitis mooreh*


Image 36. *Mystus cavasius*


Image 37. *Mystus malabaricus*


Image 38. *Mystus seengtee*


Image 39. *Sperata aor*


Image 40. *Sperata seenghala*

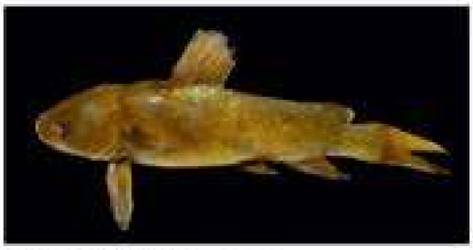

Image 41. *Rita gogra*

Image 42. *Rita kuturnee*

Image 43. *Clarias gariepinus*

Image 44. *Heteropneustes fossilis*

Image 45. *Pachypterus khavalchor*

Image 46. *Ompok bimaculatus*

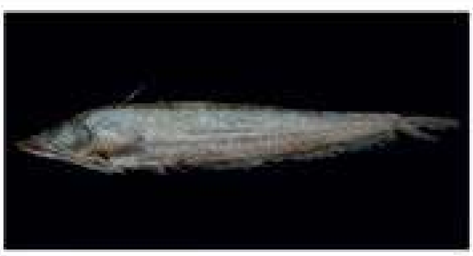

Image 47. *Wallago attu*

Image 48. *Gagata itchkeea*

Image 49. *Chanda nama*

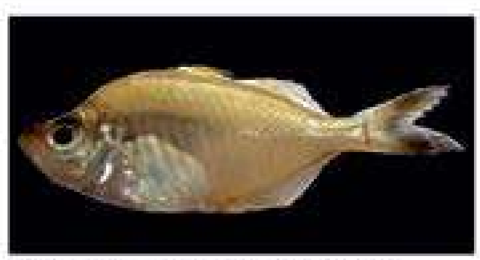

Image 50. *Parambassis ranga*

Image 51. *Anabas testudineus*

Image 52. *Channa marulius*

Image 53. *Channa punctata*

Image 54. *Channa striata*

Image 55. *Oreochromis mossambicus*

Image 56. *Glossogobius giuris*

Image 57. *Mastacembalus armatus*

Image 58. *Macrognathus pancalus*

Acknowledgements:

We are grateful to the Management and Principal, Arts, Commerce and Science College, Palus, District Sangli for providing infrastructural facilities. We also thankful to Dr. Neelesh Dahanukar, Department of Life Sciences, Shiv-Nadar University, Delhi NCR for the identification and encouragement. First author thanks to Department of Zoology, Balwant College, Vita for providing necessary facilities. Also, thanks to Government of Maharashtra for providing financial assistance through MAHAJYOTI fellowship. Thanks to DBT Star College Scheme for partial financial support.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

A Preliminary study of the fish diversity of east Siang and Loihit River of Pasighat and Tezu with the description of a new *Garra* species (Teleostei: Cyprinidae)

Kalpana Thoidingjam[1], Catherine Ngangbam[2] Linthoingambi Irengbam[3] Kh. Rajmani Singh[4]

[1234]Dhanamanjuri University, Thangmeiband, Imphal-795001
[1]abethoi.thoi@gmail.com.
[2] pipingangbam@gmail.com
[3]irengbamlinthoi78@gmail.com
[4]rajmanikh@rediffmail.com

Abstract

The present work is a result of a Preliminary survey on the fish diversity of two major rivers of Arunachal Pradesh *i.e* Siang river and Lohit river at Pasighat and Tezu. A total of 24 species belonging to 5 families of Cyprinidae, Siluridae, Sisoridae, Belonidae and Bagridae were collected. Among them, *Barilius, Garra, Tariqilabeo, Glyptothorax* were commonly found in both the rivers. While in Lohit River of Tezu a greater number of species of the genera *Raiamas, Xenentodon, Pterocryptis, Pseudocheneis, Schizothorax, Batasio, Puntius, Wallago* were collected. A new species of *garra* is also reported belonging to "Smooth snout group", having prominent, regular scales on abdomen, moderately large gular disc, broader than long (length 37.4% HL,55.3 width % HL), anus posteriorly positioned, a black spot at upper angle of gill opening.

Keywords: Fish Diversity, East Siang, Lohit River, Arunachal Pradesh, Brahmaputra, *Garra*.

Introduction

Arunachal Pradesh is located between 26.28°N and 29.30° N latitude and 91.20°E and 97.30°E longitude. The state is a part of Indo-Burma biodiversity hotspot region. It has a highest forest area to geographic area ratio (0.81) with a forest cover of 68.045 km² in the country (Sinha 2019). The state shares its international boundaries with Bhutan in the west, China in the north and Myanmar in the east. The five major rivers namely the Kameng, the Subansiri, the Siang, the Lohit and the Tirap draining the state. Siang River is the largest river among all the rivers of Arunachal Pradesh. It is called the Tsangpo in Tibet, where it has its origin of Brahmaputra River system, originates in Southern Tibet. The Tsangpo which originated in Tibet is called the Siang after it enters India through Upper Siang district in the North eastern state. The Siang joins two other rivers- The Lohit and The Dibang downstream to form the Brahmaputra. Many pioneer researchers had studied the fish diversity of Arunachal Pradesh. Earlier studies reported systematic account of fish resources of Arunachal Pradesh and recorded 131 fish belonging to 10 orders and 27 families (Nath and Dey 2000). The studies on Siang River reveals the presence of different 90 species of fish belonging to 8 order, 24 families and 52 genera (Bilap Kumar Das et. al 2014).

The diversity of topographic and climatic condition has made the state rich with various flora and fauna. Fish is one of the important bio resources which can be used as food, Aquarium fish and in sport industry (Gurumayum et. al 2016). In the present study, we provide a checklist of fish fauna of East Siang and Lohit River. A rigorous collection of fishes from the two rivers will obtain a good number of species diversity as the area lies in a hotspot. During the present study, individual of a hitherto undescribed species of *Garra* were collected from the Lohit river, which is described herein as *Garra tezuensis*, new species.

*Author for correspondence :
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Material and methodology

Study site: The survey was carried out at Pasighat and Tezu with co-ordinates 28°09'69.29" N and 95°3013'.65" E and 27°91'58.66" latitude and 96°17'38.98" longitude of East Siang and Lohit River, Arunachal Pradesh. The study period was during the winter season. Specimens were collected with the help of cast net along with local people. All the essential data such as place of collection, number of fish, body color and body marking were recorded. The collected specimens were preserved in 10 % formalin for further analysis. The descriptions are based on formalin preserved specimens. Measurements were taken point to point with digital calipers to 0.1mm. For identification and classification Nath & Day (2000), Darshan et. al (2018) and Vishwanath (2021) were followed. General count and measurement follows Hubbs and Lagler (1946). Fin rays and numbers of scales were counted under a stereoscopic zoom microscope. Terminology used for the description of the gular disc follows Kottelat (2001). Counts measurements, terminology of oromandibular structures and snout morphology of *Garra* follow Nebeshwar & Vishwanath (2013). Pre anal scales are the ventral mid line row of scales between the anal fin and the anus. Scales count follows Nebeshwar and Vishwanath (2013). The holotype is deposited in the Freshwater fish section, Zoological Survey of India, Kolkata and the paratype specimens are deposited in the Dhanamanjuri University Museum of Fishes, Manipur.

The conservation status of the fish species is based on the IUCN (www.iucnredlist.org.in).

Comparative data for species which could not be examined are derived from the published literature: *G. annandalei* from Bhakta, Meitei et. al (2021); *G. arupi* from Nebeshwar, Vishwanath & Das (2009); *G. chaudhuri, G. jenkinsonianum, G. naganensis* from Hora (1921); *G. compressa* from Kosygin & Vishwanath 1998; *G. jenkinsonianum, G. kempi* from Nebeshwar & Vishwanath (2015); *G. magnidicus*, *G. rupicola* from Nebeshwar & Vishwanath (2013); *G. mini* from (Rahman et. al 2016).

Table 1 shows the list of fish recorded from East Siang and Lohit River along with their economic value and the IUCN 2021 status. In the present study there was also a report of new species of *Garra*, *G. tezuensi*, its characters, morphology and the meristic study were taken

Garra tezuensis, sp.nov

Holotype: ZSI Calcutta, F 9799, 65.2mm SL, India, Arunachal Pradesh, Lohit District, Lohit River at Tezu (Brahmaputra Basin) 27°91'58.66"N 96°17'38.98" E. K Thoidingjam, 18-02- 2023.

Paratype: DMUMF-KT02-10, 58.6-65.2 mm SL; same data as holotype.

Diagnosis: *Garra* can be divided into five species groups based on the snout morphology as suggested by Nebeshwar and Vishwanath (2017): 1) smooth snout species group, 2) transverse lobe species group, 3) rostral flap species group, 4) rostral lobe species group, and 5) proboscis group. *Garra tezuensis* belongs to "smooth snout with poorly developed transverse depression". It is distinguished from the other member of this group in possessing the following characters:

Black spot at upper angle of gill opening present vs absent except *G. jenkinsonianum*; from *G. jenkinsonianum, G. chakpiensis, G. arupi, G. annandalei* in having more posteriorly positioned anus vs anteriorly placed, lesser circumpeduncular scales vs few; from *G. chaudhurii* in having longer snout length vs shorter; from *G. rupecula* and *G. lissorhynchus* in having W shaped black band on caudal fin absent vs. present; from *G. ukhrulensis, G. chakpiensis* and *G. kempi* in having longer disc length vs shorter, wider pulvinus vs narrower and further from *G. magnidiscus, G. rupecula* and *G. mini* in having chest scaled vs naked. A detailed distinguishing characters are discussed.

Description: Morphometric data of the holotype and paratypes are given in Table 2. Body elongated, compressed, more compressed on caudal penduncle region. Dorsal head profile slightly convex rising gently above the snout, dorsal body profile to dorsal fin origin almost straight. Dorsal fin base slightly convex. Profile from the posterior end of the dorsal fin base to caudal fin base straight. Ventral profile from pectoral to pelvic fin origin convex and straight from pelvic fin to anal fin origin. Anal fin base nearly straight, posterodorsally inclined. Profile from posterior end of the anal fin base to caudal fin base straight. Head small (21.55 % SL) interorbital area convex, length greater than width. Snout moderately rounded with incomplete transverse depression interrupted in dorsolaterally in the middle of the head. Sublachrymal groove posteroventrally sloped continuous to the lateral groove of rostral cap.

Two pairs of barbels, rostral anterolaterally located, shorter than eye diameter, maxillary barbels at the corner of the mouth, shorter than rostral barbel. Rostral cap well developed, fimbriated, papillated, rostral cap covering upper jaw. Labrum papillated. Upper lip entirely covered by rostral cap. Lower lip modified into a mental adhesive disc. Disc elliptical, shorter than width and narrower than head width, gular disc large and medially positioned, groove between torus and pulvinus shallow devoid of any transverse lobe.

Dorsal fin rays with iii simple 8½ branched rays, last simple ray longer than head length, distal margin slightly concave, origin at middle of standard length, inserted anterior to vertical through pelvic- fin origin, second branched ray longest, last branched ray not extending to vertical of anal fin origin. Posterior margin emarginated; Pectoral fin with i simple and 12 branched rays reaching beyond mid - way to pelvic fin origin, fifth branched ray longest, shorter than head length. Margin convex when adpressed; Pelvic fin with i simple and 8 branched rays surpassing the anus, second branched ray longest, posterior base closer to anal fin origin than the pectoral fin origin, margin pointed; Anal fin short with ii simple ray and $4^1/_2$ branched ray. Posterior margin straight; Caudal fin forked, tip of lobes pointed with 10+9 rays. Lateral line complete with 32-33 scales; Transverse scales rows between dorsal fin origin to lateral line 3- 3½ and transverse scales rows between lateral line and pelvic fin origin 3; Circumpenduncular scales 12; Predorsal scales 9-10 Scales regularly arranged, Chest and belly scaled; Preanal scales 3, dorsal fin base scales 6; Anal fin base scales 4.

Colour in preservation: In formalin, head and dorsum grey and lateral side light grey. Mouth and abdomen whitish, chest yellowish, black spot at the upper angle of the gill opening. Tubercles on snout creamish white. In live, body dark grey or blackish, ventral whitish and dorsal, pectoral, pelvic, anal and caudal fin slightly orange.

Distribution: *Garra tezuensis* sp. nov. is presently known only from the type locality Lohit River at Tezu, Lohit District (Brahmaputra basin) Arunachal Pradesh.

Etymology: Name after its type locality, Tezu, Lohit District, Arunachal Pradesh, India

Discussion: - Morphology of the snout and the shape and distribution patterns of tubercles on the snout is of taxonomic significance in distinguishing species of *Garra* (Nebeshwar and Vishwanath 2017). The genus had been divided from five species group in which *Garra tezuensis* belongs to smooth snout group. Twenty-eight species of *Garra* currently recognized from the Brahmaputra River drainage in which 3 belongs to smooth snout, 3 from transverse lobe, 2 from rostral flap and the remaining 20 belongs to proboscis group species. In the adjacent river drainage (i,e the Barak - Meghana river, the Kaladan river, the Chindwin – Irrawaddy river drainage and some small coastal rivers between), there are 31 *Garra* species recognized (Zheng Gong et al 2018). Arunachalam et al (2013) described four species of *Garra* from the upper Brahmaputra River drainage of Arunachal Pradesh. Nebeshwar and Vishwanath (2017) indicated the likely synonymy of these four nominal species: G. *nigricauda* to *G. arunachalensis, G. minima to G. quadratirotris and G. kimini* and *G. alticaputus to G. birostris*.

Garra tezuensis belongs to smooth snout group. It differs from its congeners of the group as follows: from *G. annandalei* in having rostral lobe (absent vs present); tubercles on snout (present vs absent); fewer lateral line scale (32-33 vs. 34-38); longer snout length (44.7-52.7 % HL vs. 19.2-25); more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % of distance between pelvic to anal fin origin vs. 30-33.8); lesser circumpenduncular scales (12 vs.16); from *G. arupi* in having transverse lobe absent (vs present); lesser lateral line scale (32-33 vs. 35-36); lesser circumpeduncular scales (12 vs.16); more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % of distance between pelvic to anal fin origin vs. 52.6-60); fewer predorsal scale (9 vs.11-12); longer preanus length (70.2-73.3% SL vs. 62.4-65.6); from *G. chakpiensis* in having larger adhesive disc width (44.0-55.0% HL vs. 36.0-42.0); larger disc length (35.0-38.7% HL vs. 20.0-30.0); longer pulvinus length (21.0-29.0 % HL vs.15.0-18.0); more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % of distance between pelvic to anal fin origin vs 34-40%); lesser lateral line scale (32-33 vs. 38-40); lesser circumpenduncular scales (12 vs 16.); regular predorsal scales (9-10 vs. irregular 11-14, counted along immediately adjacent to the irregular scale row); less pre anal scales (3 vs 6); from *G. chaudhuri* in having black spot on the upper angle of gill opening present (vs absent), transverse scales between dorsal fin origin and pelvic fin origin (6-6½ vs. 8), large eye diameter (22.8-24.3 % HL vs.17.4-21.5), longer snout length (44.7-52.7 % HL vs. 36.8-43), dorsal fin origin at middle of standard length (vs dorsal fin origin slightly nearer to the tip of the snout); from *G. compressa* in having lesser lateral line scales (32-33 vs. 39-40), lesser pre dorsal scales (9 vs. 12-13), wider body at dorsal fin origin (18.5-19.4 vs. 13.7-14.9 %SL); from *G. jenkinsonianum* in having transverse groove absent (present); head length greater than body depth at dorsal fin origin (vs. equal to body depth); lesser circumpenduncular scales (12 vs. 16); fewer predorsal scales (9 vs. 10-11), shorter pre pectoral fin (20.1-22 %SL vs 25.2); longer prepelvic distance (54.8-58.3% SL vs. 50.9); more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % distance between pelvic to anal fin origin vs. 32 %); from *G. kempi* in having lesser predorsal scale (9 vs.14); fewer lateral line scale (32-33 vs. 38-39); longer disc length (35.0-38.7 % HL vs. 20-30); wider pulvinus width (32.7- 36.9 % HL vs. 22-30); longer pulvinus length (21.0-29.0% HL vs.12-18); more posteriorly situated anus (distance from anus to anal fin origin 16.69-22.9 % of distance between pelvic to anal fin origin vs 34-46); from *G. magnidicus* in absence of transverse lobe (vs present); in having lesser lateral line scales (32-33vs 40-42); fewer predorsal scales (9 vs. 12-15); larger interorbital space (54.0-61.0 % HL vs. 41-45); more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % of distance between pelvic to anal fin origin vs 38-52); from *G. mini* in presence of scales on chest (vs absent); fewer predorsal scales (9 vs 14-16); fewer circumpenduncular scales (12 vs. 16); larger interorbital distance (12.7-14.5 % SL vs. 9-10.3); from *G. naganensis* in having longer pre pelvic distance (54.8-58.4 % SL vs. 51.8-53.7), more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % of distance between pelvic to anal fin origin (vs. 44.0-45.0), lesser lateral line scales (32-33 vs. 48), predorsal scales (9-10 vs. 13-14), fewer circumpenduncular scales (12 vs. 19). from *G. rupicola* in absence of W shaped caudal fin (vs present), fewer lateral line scales (32-33 vs. 35-36), scales on the pre dorsal, chest and abdomen present (vs absent), snout length (44.7-52.6 % HL vs. 36.8-43); from *G. ukhrulensis* in having greater disc length (35.0-38.7 % HL vs 24-27.); pulvinus width (32.9-36.7 % HL vs. 26.0-30.0); longer pre anus distance (70.2-73.3 % SL vs. 66.8-69.5); more posteriorly situated anus (distance from anus to anal fin origin 16.7-22.9 % vs 39-46); longer caudal peduncle length (17.6-22.2% SL vs. 13.2-16.8); predorsal scales regularly arranged (irregularly arranged); lesser circumpenduncular scales (12 vs. 16) and lesser pre anal scales (3 vs 6); from *G. lissorhynchus* in absence of W shaped caudal fin (vs. present); in absence of rostral flap (vs. present); lesser lateral line scales (32-33 vs 34-35); presence of scales on chest and abdomen (vs. absent); presence of fimbria on the rostral cap (vs. absent).

The study reveals the presence of twenty-four (24) species belonging to 3 orders, 5 family and 17 genera. Cypriniformes dominated by 16 species followed by 7 siluriformes and 1 beloniformes. The genus *Garra* retains the highest diversity followed by *Barilius* and *Puntius*. Cypriniformes (*B. barila*, *O. bendelesis*, *G. kalpangi* and *G. kempi)* were recorded abundantly from the Lohit River.

Comparative Materials: *Garra annandalei* (Hora) Holotype: ZSI Calcutta, F 6082/2-1; 60.17 mm SL; Kokha nallah, Koshi river, District: Barabakshetra. India. Date of collection: 30.01.1946.

Garra chaudhurii: ZSI F 8146-8148, 3 (holotype and 2 paratypes), 49.5-53.0 mm SL; India: West Bengal: Darjeeling district.

Garra jenkinsonianum: ZSI F 5736/1, holotype, 55.5 mm SL; India: West Bengal: Sita Nullah, Paresnath hills. Collectors-Jenkins and Annandalei.

Garra kempi (Hora) Holotype: ZSI Calcutta, F 7716/1; 87.0 mm SL; Location: Siyom River, below Damda, the Abor hills, Arunachal Pradesh, India. Date of collection: 25.07.2000. collector - Dr. S. W. Kemp.

Garra lissorhynchus (McClelland) Holotype: ZSI Calcutta, FF 8098/1; 73.05 mm SL; (Location: Museum Collection, Assam, India). Collected by: L. Kosygin.

Garra magnidiscus: ZSI/V/APFS/P-622, 83.8 mm SL; India: Arunachal Pradesh: Upper Siang district: a fast-flowing tributary to Siang River, about 3 km from Bomdo village on main road to Tuting, 28°44.04' N 94°51.97' E, 429 m asl; L. Tamang, 26 Oct 2011.

Garra naganensis: (Hora) ZSI Calcutta, F 9970/1; 89.93 mm SL; (Location: Senapathi Stream, Naga Hills, Assam, India). Collected by: L. Kosygin.

Garra chakpiensis: Holotype. MUMF 4308, 83.0mm SL; India: Manipur: Chandel district: Chakpi River at Tangpol (Chindwin River basin), 24 11 50 N 93 54 49 E; B. D Sangningam, 30-31, December 2010.

Garra Ukhrulensis: Holotype. MUMF 4311, 119.0mm SL; India: Manipur: Ukhrul district: Challou River at Khamson (Chindwin River basin), 25 12 18 N 94 30 56 E; L. Kosygin, 17 march 1998.

Garra lissorhynchus: Holotype. MUMF 4163-4166, 4, 67.1-86.2 mm SL; India: Manipur: Tamenglong district: Iyei River at Noney.

Garra jenkinsonianum: ZSI F 5736/1, Holotype, 55.5mm SL; India: West Bengal: Sitanullah, Pareshnath Hills.

Sl No	Order	Family	Species	Economic value	Status (iucnredlist.org)
1	Cypriniformes	Cyprinidae	*Barilius barila*	F; O	LC
2	Cypriniformes	Cyprinidae	*Barilius vagra*	F; O	LC
3	Cypriniformes	Cyprinidae	*Opsarius barna*	F; O	LC
4	Cypriniformes	Cyprinidae	*Opsarius bendelesis*	F; O	LC
5	Cypriniformes	Cyprinidae	*Garra kalpangi*	F	NE
6	Cypriniformes	Cyprinidae	*Garra kempi*	F	LC
7	Cypriniformes	Cyprinidae	*Garra arunachalensis*	F	LC
8	Cypriniformes	Cyprinidae	*Garra sp.nov*	F	NE
9	Cypriniformes	Cyprinidae	*Raiamas bola*	F; O	LC
10	Cypriniformes	Cyprinidae	*Pethia ticto*	F; O	LC
11	Cypriniformes	Cyprinidae	*Puntius chola*	F; O	LC
12	Cypriniformes	Cyprinidae	*Neolissochilus dukai*	F; S	DD
13	Cypriniformes	Cyprinidae	*Tor tor*	S	LC
14	Cypriniformes	Cyprinidae	*Tariqilabeo latius*	F	LC
15	Cypriniformes	Cyprinidae	*Schizothorax progastus*	F; S	LC
16	Cypriniformes	Cyprinidae	*Chagunius chagunio*	F	LC
17	Siluriformes	Bagridae	*Batasio fasciolatus*	O	LC
18	Siluriformes	Siluridae	*Pterocyptis gangelica*	F; O	DD
19	Siluriformes	Siluridae	*Wallago attu*	F	VU
20	Siluriformes	Sisoridae	*Pseudecheneis sirenica*	O	VU
21	Siluriformes	Sisoridae	*Glyptothorax dikrongensis*	O	LC
22	Siluriformes	Sisoridae	*Glyptothorax indicus*	O	LC
23	Siluriformes	Bagridae	*Mystus prabini*	O	NEv
24	Beloniformes	Belonidae	*Xenetodon cancila*	F; O	LC

Table 1 showing the IUCN data

DD- Data Deficient, LC-Least concern, NE- Not evaluated, VU- Vulnerable, F-Food, O-Ornamental, S-Sport

	Holotype	Range			SD
		Min	Max	Mean	
STANDARD LENGTH mm	65.2	58.6	61.8		
In % STANDARD LENGTH					
Body depth at dorsal fin origin	19.6	19.6	21.7	20.7	1.1
Head length	21.6	21.5	25.2	23.4	1.9
Head depth at eye	10.3	8.8	14.9	11.9	3.1
Head width	16.8	16.8	18.7	17.8	0.9
Snout length	11.4	10.5	13.2	11.9	1.4
Eye diameter	5.2	5.2	5.8	5.5	0.3
Body width at anal fin origin	11.0	10.8	11.9	11.4	0.6
Body width at dorsal fin origin	18.6	18.6	19.4	19.0	0.4
Caudal pendunce length	22.2	17.7	22.2	20.0	2.3
Caudal pendunce depth	13.0	13.0	13.9	13.5	0.5
Dorsal fin base length	13.2	13.2	15.7	14.5	1.3
Dorsal fin length	22.3	21.6	25.8	23.7	2.1
Pectoral fin length	20.8	20.1	22.8	21.5	1.4
Pelvic fin length	18.1	17.1	19.6	18.4	1.3
Anal fin base length	7.2	7.2	7.8	7.5	0.3
Anal fin length	18.5	16.6	19.4	18.0	1.4
Pre dorsal length	44.8	44.8	50.4	47.6	2.8
Pre pectoral length	23.6	20.0	23.6	21.8	1.8
Pre pelvic length	56.1	54.8	58.4	56.6	1.8
Pre anal length	77.7	75.2	77.9	76.6	1.4
Pre anus length	72.8	70.2	73.3	71.8	1.6
Pelvic anal distance	17.5	16.3	23.1	19.7	3.4
Gular disc width	11.9	10.7	11.9	11.3	0.6
Gular disc length	8.2	8.0	8.8	8.4	0.4
Pulvinus width	7.9	7.5	8.3	7.9	0.4
Pulvinus length	6.8	5.3	6.3	5.8	0.5
Anus Anal fin distance	3.8	3.6	3.8	3.7	0.1
Inter orbital width (IOW)	13.2	12.7	14.5	13.6	0.9

	Holotype	Range			SD
		Min	Max	Mean	
In % of pelvic anal distance					
Distance from anus to anal fin	22.1	16.7	22.9	19.8	3.1
In % Head length					
Head depth at nape	47.6	37.5	47.6	42.6	5.1
Head depth at eye	64.4	53.3	66.0	59.7	6.4
Head width	77.4	73.7	79.3	76.5	2.8
Snout length	52.7	44.7	52.7	48.7	4.0
Eye diameter	23.8	22.8	24.3	23.6	0.8
Gular disc width	55.0	44.0	55.0	49.5	5.5
Gular disc length	37.0	35.0	38.7	36.9	1.9
Pulvinus width	36.9	32.8	36.9	34.9	2.1
Pulvinus length	29.0	21.0	29.0	25.0	4.0
Inter orbital distance	61.1	54.0	61.1	57.6	3.6

Table 2. Morphometric data of *Garra tezuensis* (n=10); range, mean and SD including holotype

Figure Legends:

Figure 1- River system of Arunachal Pradesh showing the main five rivers; Siang Brahmaputra, Subansari, Tawang, Lohit and Dibang.

Figure 2- Lohit River, Tezu, Arunachal Pradesh, habitat of, *Garra* sp.nov

Figure 3- *Garra tezuenesis;* a-f ZSI Calcutta, F 9799, holotype, 65.21mm SL; India: Arunachal Pradesh: Lohit District: Tezu: Lohit River; (a), dorsal view (b), lateral view (c), ventral view (d) dorsal view of head (e), ventral view of oromandibular structure (f), side view of the snout showing the black spot on the gill.

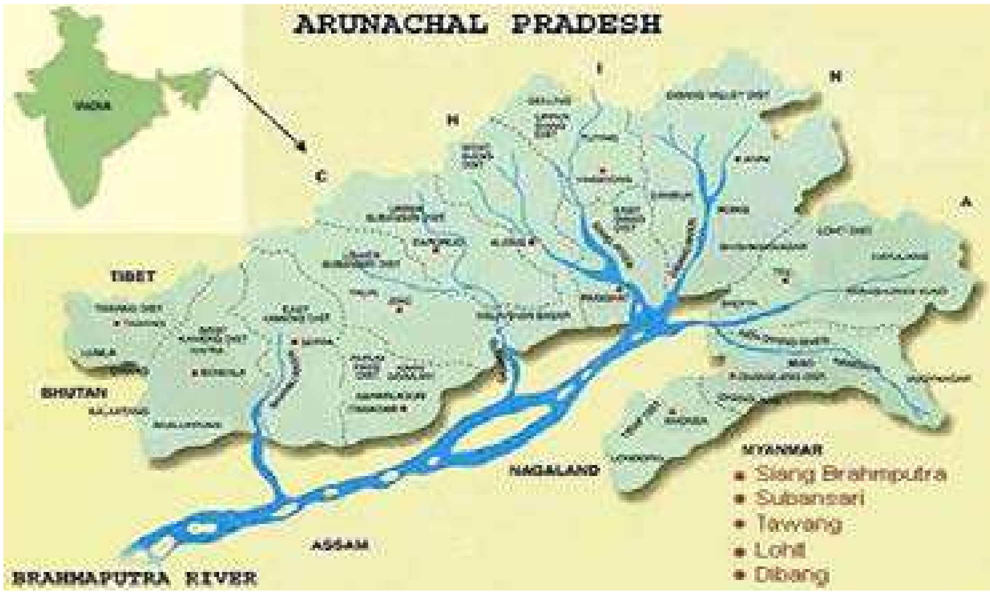

Figure 1

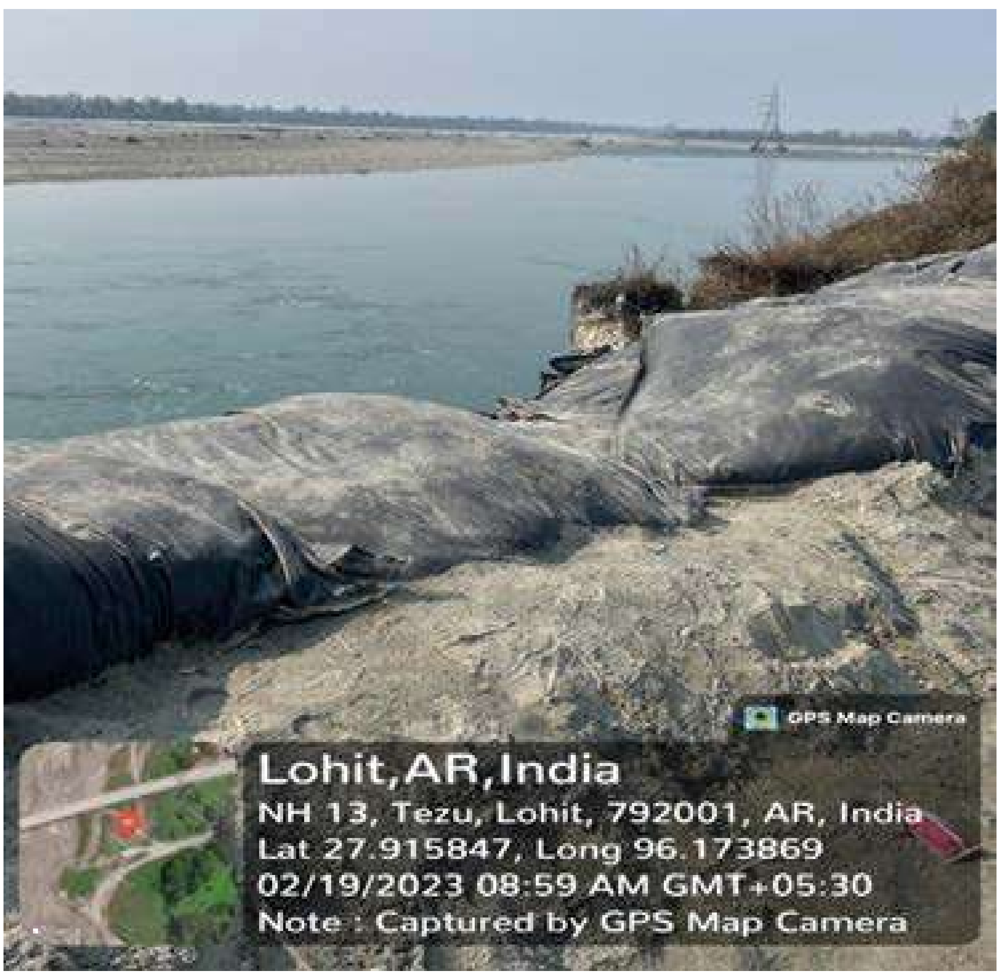

Figure 2

Figure 3

Acknowledgments:

We are grateful to Dhanamanjuri University for providing laboratory facility and giving permission to undertake the study. We are thankful to the Head Department of Zoology Manipur University for giving access to the Museum of Fishes. We express our deep gratitude to Dr Laishram Kosygin Officer In Charge Fresh water Fish Section Zoological Survey of India, Kolkata for giving access to type specimens. We are also thankful to Dr Y. Rameshwori Fishery section Department of Zoology, Manipur University for her encouragement and cooperation. We are also indebted and thankful to Dr Nebeshwar, Dr Darshan for the suggestions, constructive ideas and literature. Dr Nebeshwar was kind enough to share the details of types of *G. jenkinsonianum*, *G. arupi* and *G. annandalei*. We are also grateful to the fishermen of East Siang and Lohit River and the local people for their necessary help and co-operation during this study.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Biodiversity Profile of Phytotelmata of the Southern Western Ghats, and use of the Tree Crab *Kani maranjandu* (species name) Kumar, Raj & Ng, 2017, as an Indicator of Ecosystem Health

Soumya, K. R.* and Biju Kumar, A.

Department of Aquatic Biology and Fisheries, University of Kerala,
Thiruvananthapuram - 695581

Abstract

Kani maranjandu Kumar, Raj & Ng, 2017 (Gecarcinucidae) is India's first tree-climbing crab reported from the Agasthyamalai Biosphere Reserve (ABR), Southern Western Ghats. This unique arboreal species uses phytotelmata or water-filled tree holes as their habitat. The species has been reported from the phytotelmata of trees of evergreen and adjacent semi-evergreen forest covers across the ABR. Phytotelmata being an aquatic microcosm, serves as a discrete ecosystem. It harbours a diverse range of taxa, dominated by insect larvae, crustaceans and amphibians interacting with each other within this small ecosystem. The highly selective habitat requirements of *Kani maranjandu* eventually highlights their importance as indicator species, which can showcase the health and productivity of the forest ecosystem. The multifaceted role of *Kani maranjandu* as a key constituent of phytotelmic container habitat has been evaluated. The eligibility criteria for a bio-indicator have been assessed for this crab species and found fit as a biological indicator towards manifesting the productivity of the forest ecosystem. *Kani maranjandu*, as indicator species, can judge the quality of the container habitat and forest ecosystem, and changes happening over time. Any unusual environmental stress or impact influence subsequent changes in the biotic responses of the animal to look into ecosystem stability. Estimating the ecological stressors and devising the indicator species towards monitoring plans and management measures promotes successful conservation and appropriate management of the ecosystem's biodiversity. The study further suggests conserving larger trees in degraded forests through eco-restoration efforts, besides considering this ubiquitous species as an indicator of ecosystem health.

Keywords: *Kani maranjandu*, Phytotelmata, Agasthyamalai Biosphere Reserve, Bioindicator, Ecosystem management

Introduction

Phytotelmata (Greek, phyton = plant; telma = pond) are plant-held water bodies that occur worldwide, especially in larger tree holes. These were first formally described by Varga (1928) and are more common in the tropics than in temperate zones (Thienemann, 1954). These are lentic habitats, unique for their small size, discreteness and ephemerality (Mogi, 2004) and are known to accommodate aquatic invertebrates (Kitching, 2000; Williams, 2006), most dominated by insect larvae at high densities (Frank and Lounibos, 1983), crustaceans (Jocque *et al.*, 2013) and amphibians (Yanoviak, 1999). These micro-ecosystems are least studied in India, and the majority of the studies are limited to the survey of insect/mosquito larvae (Rao *et al.*, 1970; Nagpal and Sharma, 1985; Subramanian and Sivaramakrishnan, 2007; Majumder *et al.*, 2011; Selvan *et al.*, 2016; Nishadh and Das, 2012; 2014). The astonishing diversity of insect communities belonging to the container habitats was summarized by Greeney, 2001. The literature reveals 70 families of insects belonging to 11 orders predominantly represented by Diptera, Coleoptera and Odonata from phytotelmata.

Kani maranjandu Kumar, Raj & Ng, 2017 (Gecarcinucidae) is India's first tree-climbing crab described recently from the Agasthyamalai Biosphere Reserve (ABR), southern

*Author for correspondence : soumyamrayyar314@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Western Ghats, which inhabit phytotelmata (Kumar *et al.*, 2017). True freshwater crabs from the Old World exhibiting phytotelmy includes *Globonautes macropus* (Rathbun, 1898) (Potamonautidae) from Liberia, West Africa (Cumberlidge and Sachs, 1991); *Malagasya goodmani* Cumberlidge, Boyko & Harvey, 2002 (Potamonautidae) from Tasmania, Madagascar (Cumberlidge *et al.*, 2002); *Malagasya antongilensis* (Rathbun, 1905) (Potamonautidae) from rainforest canopy of Masoala Peninsula, Madagascar (Cumberlige *et al.*, 2005); *Potamonautes raybouldi* (Cumberlidge & Vannini, 2004) (Potamonautidae) from Tanzania East Africa (Cumberlidge and Vannini, 2004); *Ceylonthelphusa scansor* Ng, 1995 (Gecarcinucidae) from Sinharaja forest in Sri Lanka (Ng, 1995); *Archipelothelphusa* sp. (Gecarcinucidae) from Philippines (Ng, 1991a); *Arachnothelphusa* sp. (Gecarcinucidae) from Borneo (Ng, 1991b); and *Arachnothelphusa merarapensis* Grinang, Min & Ng, 2015 (Gecarcinucidae) from northern Sarawak, Borneo (Grinang *et al.*, 2015). The recent discovery of a phytotelmic bromeliad crab *Epilobocera* cf. *gilmanii* (Smith, 1870) (Pseudothelphusidae) (Wehrtmann *et al.*, 2016) from Cuba has contributed to phytotelmy in the New World crabs.

Invertebrates generally act as excellent environmental and ecological indicators due to their sensitivity and ability to produce rapid numerical responses (Samways *et al.*, 2010). Though they are considered outgroups in conservation and monitoring strategies, invertebrates have become principal components in conservation plans and management strategies due to the considerable proportion of species diversity (Mc Geoch *et al.*, 2011). Brachyuran crabs possess several advantages over other counterparts as bioindicators. Crabs quickly confront pollution (Wong *et al.*, 2006) and immediately respond to anthropogenic factors (Bartolini *et al.*, 2009; Barboza *et al.*, 2021) with alterations in feeding behaviour (Wolcott and O'connor, 1992) and reproductive patterns (Beltrame *et al.*, 2011). Massou *et al.* (2018) suggested using the mangrove crab diversity of the Cameroon coast to characterize the functioning of the mangrove ecosystem following the identification of indicator species and rare species.

In the present study, we recommend designating *Kani maranjandu* (the *Kani* crab) as an indicator of the forest ecosystem of the Agasthyamalai Biosphere Reserve for addressing management and restoration programs in the region. The multifaceted role of *Kani maranjandu* as a key constituent of phytotelmic container habitat has been evaluated. The eligibility criteria for a bio-indicator have been assessed for the *Kani* crab and found fit as a biological indicator towards manifesting the productivity of the forest ecosystem. Since the species is associated with phytotelmata of large trees of evergreen and semi-evergreen forest patches, conservation measures on the species bring about the conservation of large trees and their habitats in the forest ecosystem.

Materials and Methods

Site

The Agasthyamalai Biosphere Reserve (ABR) (8°8 to 9°10' North and 76°52' to 77°34 East) is located in the southernmost part of the Western Ghats and covers an area of 3500 km^2, of which 1828 km^2 lies in Kerala and 1672 km^2 in Tamil Nadu. Established in 2001, ABR has been marked as protected, considering its substantial conservation potential. The reserve extends across the borders of the Kollam and Thiruvananthapuram districts of Kerala, and Tirunelveli, Veli and Kanyakumari districts of Tamil Nadu at the south of the Western Ghats. It comprises Neyyar, Peppara and Shendurney wildlife sanctuaries along with their neighbouring areas of Achencoil, Thenmala, Konni, Punalur, Thiruvananthapuram forest divisions and the Agasthyavanam Biological Park range in Kerala. ABR hosts diverse types of forests ranging from tropical wet evergreen forests, South Western Ghats moist deciduous forests, South Western Ghats montane forests, shola forests and grass lands.

The study site was divided into equidistant square-shaped grids of 5 × 5 km (25 km^2). The centroid of these grids was taken along with their respective coordinates to spot the location. A total of 14 forest ranges and three wildlife sanctuaries were investigated for two years, from September 2020 to September 2022, to monitor the biodiversity of phytotelmata and the association of the tree crab *Kani maranjandu* with it.

Tree hole survey

Trees were randomly selected and examined for water-filled tree holes at each location. The present study surveyed all the ground level, midstory and canopy tree holes. The tree holes were inspected for the presence of *Kani* crabs. The geographic coordinates and corresponding elevation levels were recorded for each tree hole location. The height of the hole (m) from the ground was recorded by measuring the distance from the lowest point of entrance of the hole to the ground using a measuring tape. The hole depth was estimated by inserting a metallic rod into the bottom of the hole and measuring the watermark after its removal (Bayliss, 2022). Tree size was determined by estimating DBH (diameter at breast height, cm). Additionally, the external diameter of the hole (entrance diameter, cm) was also recorded. The volume and surface area of each tree hole was calculated using the standard formulae from their linear dimensions and shape. Water parameters such as pH, temperature and conductivity were measured using corresponding meters, and dissolved oxygen (DO) was determined using a Lutron DO-5510 device. The vernacular names of host tree species were noted for later identification.

The habitat preferences of tree crab were inferred from the respective recordings of the phytotelmic parameters.

Biodiversity survey

The water-filled tree holes were agitated to stir up the hole substrate and censused by removing the contents to a plastic container. A suction tube (2 cm diameter) was used to drain large holes, and a turkey baster to drain small holes (Yanoviak, 1999). The samples contained leaf litters and detritus, which were collected by hand (2-45 cm depth). The tree holes were repeatedly flushed with filtered (35 µm sieve) stream water and suctioned to dislodge any remaining invertebrates and detritus (Blakely *et al.*, 2012). The inner walls of the empty tree holes were also inspected with a flashlight in search of any elusive organisms (Yanoviak & Fincke, 2005).

If tree holes contained *Kani* crab, GPS location and corresponding elevation level were recorded. The freshly caught individuals were photographed to record their natural colour and characteristics, and returned to their corresponding tree holes. The collected specimens of each taxa were examined macroscopically and microscopically, and photographed. Insects were identified at the family level (Subramanian and Sivaramakrishnan, 2007; Mekong River Commission, 2006). Copepods, mosquito larvae and anurans were identified with appropriate keys and with the assistance of experts.

Results and Discussion

Biodiversity in Phytotelmata

The aquatic species composition of phytotelmata of the ABR is presented in Figure 1. The insects, especially larvae and pupae (36%), were the most dominant among the metazoan communities of phytotelmata. Diptera (24%) were the foremost group among the insect taxa, while Scirtidae (4%) and Goeridae (4%) were also collected in larval stages. The most commonly encountered groups among dipteran communities were the larvae and pupae of mosquitoes (Culicidae, 12%). The predominance of insect communities, especially dipteran larvae in the present study endorsed with several other studies worldwide on metazoan communities of phytotelmic microhabitats (Blakely *et al.*, 2012, Wittman, 2000, Greeny, 2001, Majumder *et al.*, 2011, Nishadh and Das, 2014). The reason for an enormously high insect diversity lies consistent with the stagnant pools of phytotelmata that serve as appropriate sites for larval development and propagation of these facultative groups.

Among crustaceans, copepods (15%) were obtained in larval and adult stages. Ostracods (8%) were rarely identified up to the family level. Jocque *et al.* (2013) compiled information on aquatic Crustacea in phytotelmata (bromeliads, pitcher plants and tree holes) with world records of over 100 species of freshwater crustaceans to correspond with the views of insect-dominant phytotelmic microcosm. The record provides 68 species of copepods, 16 species of decapods, 14 species of ostracods and 10 species of Anomopoda, illustrating the unexceptional presence of crustaceans in these habitats. Cladocerans constitute 4% of the inhabitants of phytotelmata.

The Formicidae (4%) comprising ants and Scolopendridae (4%) comprising centipedes form accidental species in the tree holes.

Vertebrate communities of phytotelmata comprises of Anurans (8%) including tadpoles and frogs, as water filled tree holes form their significant breeding spots. (Fenolio, *et al.*, 2007; Rowley *et al.*, 2014; Lehtinen *et al.*, 2004).

Gastropods (8%) are very rare inhabitants of tree holes. A species of slug and a snail shell have been recorded from tree holes. The presence of snail shells in water-filled tree holes accounts for a rare occurrence. *Kani* crab might have carried snail shells either as food or to neutralize the acidity of phytotelmic water. This incident finds similar to Bayliss (2002), who reported the unique behaviour of the East Usambara tree hole crab, *Potamonautes raybouldii* (Cumberlidge & Vannini, 2004), which carried snail shells and deposited them inside the tree holes. The release of calcium ions (Ca^{2+}) into the water is probably said to reduce the acidity of hole water and provides dissolved calcium for developing the exoskeleton of crabs following ecdysis.

About 12% of the phytotelmic community in the present study comprises gecarcinucid crabs. The occurrence of crabs in phytotelmic habitat is unusual since decapod crustaceans differ from phytotelmatic micro-crustacean communities in size, trophic level and dispersal. Not all tree climbing crabs are phytotelmic; many species climb trees for feeding, protection from predators and concealment (Cumberlidge *et al.*, 2005). Therefore, only 10 out of almost 1300 species of freshwater crabs, including the unidentified species (Pseudothelphusidae) from Trinidad (Anonymous, 1983), are known to be phytotelmic. However, detailed surveys over a broad range of concealed phytotelmic habitats, strikingly the canopy layers of unexplored forests, promote discoveries of rare endemic species to this group.

Distribution of *Kani maranjandu*

Among the 598 phytotelmata (Figure 2a) surveyed from the ABR, *K. maranjandu* was located in about 46 tree holes. The observed population constituted males, females, juveniles and also young ones during the breeding season. Tree holes with crabs were identified from the debris pushed out of the tree holes (Figure 2b), and the debris piled towards the corner of the entrance of the tree holes. Also, bubbles from the water in the tree holes at times served as an indication for locating the crab in the tree holes. Crabs occupying upper canopy tree holes were located from the debris found on the ground pushed out earlier by these crabs. Although some tree holes lacked crabs, some holes exhibited indications of pushed-out debris, specifying the presence of crab ever before in the hole. The tree hole crab from West Africa, *Globonautes macropus* (Rathbun, 1898) also showcases similar indications of *Kani* crab in tree hollows, such as excavated mud piles and crab footprints in the mud (Cumberlidge and Sachs, 1991). The crabs were captured and photographed (Figures 2c and 2d) in the natural habitat and returned to the tree holes.

It has been observed that the *Kani* crab occupied phytotelmata of trees of evergreen and semi-evergreen forest covers. The presence of crabs was not reported from moist deciduous, dry deciduous, shola forests and mangrove forest areas. The crabs preferred moist and cold climates (23°C - 26°C) with high rainfall and minimum wind disturbances. A high proportion of the crabs were located in the evergreen forests of the Agasthyamalai Biosphere Reserve forests, while a few were recorded from semi-evergreen forest types. The crabs were collected from tree holes of all locations, from the ground level (0 m), middle layer (1 to 2 m) and up to upper canopy layers (5 m).

The physical characteristics of water and parameters of phytotelmata occupied by *Kani maranjandu* are provided in Table 1. The temperature of the water inside tree holes ranged between 22ºC to 27.1ºC. The hole water was less in concentrations of dissolved oxygen (DO) (0.9-3.6 mg/l) with variable levels of dissolved ion concentrations (conductivity, 115-1355 μS). Seasonal variations greatly altered the pH values. The acidic pH (6.7-6.9) was associated with high mineral content, resulting from the decay of plant detritus and other organic debris that accumulated in the tree holes. The neutral pH (7) and alkaline pH were the results of refilling rain water and removal of leaf litter and detritus from tree holes by the crab. These actions might probably result in a reduction of leaf decay and serve to bring about a greater reduction in pH level (7.3-7.8). The colour of the water ranged from clear to yellow to dark brown, depending on the organic content of the phytotelmata. The volume of water inside phytotelmata occupied by *Kani* crab ranged from a few millilitres (190 ml) to several litres (37 l), which is influenced by the depth and surface area of the tree holes. Crabs were obtained from tree holes of depth ranging from 5 cm to 90 cm. The surface area of the tree holes varied between 4 cm^2 to 85 cm^2. The ecological requirements of the East African freshwater crab *Potamonautes raybouldi* (Cumberlidge and Vannini, 2004) from Tanzania virtually lie in connection with the niche requirement of the *Kani* crab. The species inhabit tree holes with slightly acidic (pH 6.1-6.6) and oxygen-depleted water with high mineral content (Bayliss, 2002).

The crabs were distributed in phytotelmata of almost all tree species of evergreen and semi-evergreen forests. However, crabs were predominantly collected from *Alstonia scholaris* (5), followed by *Calophyllum apetalum* (4) and *Diospyros paniculata* (4). Though phytotelmic tree crabs occupy wide range of tree species, crabs prefer specific tree species that supplement them with appropriate niche and ample resources for the survival of the animal. Analogous to the present instance, is the tree species preference of *Potamonautes raybouldi*, where the specimen is exceptionally located from *Myrianthus holstii*, followed by *Diospyros kabuyeana* (Bayliss, 2002). Evidence for tree climbing species [*Globonautes macropus* (Rathbun, 1898)] colonizing dead or live tree cavities has been stated in the literature by Cumberlidge and Sachs (1991). However, *Kani* has not been located from tree holes of dead trees.

With respect to the elevation level (m asl – meters above the sea level), the crabs were documented from all altitude levels between 160 m asl to 1100 m asl of the Agasthyamalai Biosphere Reserve (Figure 3). However, dense distribution was observed between 300-650 m asl. The highest elevation recorded is 1090 m asl. Similar distribution patterns are evident in the distribution patterns of *Potamonautes raybouldi* (see Cumberlidge and Vannini, 2004), where the species displays a relatively extensive distribution range at altitudes between 150-895 m asl.

Evaluation of *Kani maranjandu* as a bioindicator

Many studies suggest the application of macro-invertebrates as indicator species, specifically brachyuran crabs, which effectively indicate alterations in the ecosystem's biotic and abiotic factors. Literature on brachyuran crabs as bioindicators are mostly oriented towards the marine (Lezcano *et al.*, 2015; Giraldes *et al.*, 2021) and estuarine ecosystems (Simonetti *et al.*, 2012; Beltrame *et al.*, 2011). Since there are no studies on arboreal and phytotelmic crabs as bio-indicators, the current study highlights the significance of *Kani maranjandu* as a perfect bio-indicator model of the health of forest ecosystem of the ABR, southern Western Ghats. The heterogeneous role of *Kani maranjandu* within the phytotelmic container habitats of the forest ecosystem has been demonstrated in Figure 4.

The *Kani* crabs are an ideal bio-indicator species, as they are actively engaged in the arboreal habitat. The species forms consumers of higher trophic level. They are also omnivore species and supplement the leaves of the trees with another diet. The mud piling habit and removal of organic debris imparts clear water within the phytotelmata, promoting oxygenation of hole water and supporting rich biodiversity within the microhabitat. Removing debris out of the hole provides nutrient enrichment of the substratum thus promoting proper nutrient cycling within the environment. The animal interactions within the habitat keep the environment healthy and beneficial for all communities residing within the system. Additionally, the mineral-rich phytotelmic habitat is further enriched by crab pellets, which promote the coprophagous food chain in the microhabitat.

The organism to be used as a bioindicator must accomplish certain criteria to suit the conditions of indicator values. The indicator is supposed to have high sensitivity to environmental stressors with early exposure and rapid response to specific stressors. The selected organism should have a short life span with ease in sampling and monitoring values. To add to this, the pre-existing knowledge regarding the species and low-cost operations in the field is highly appreciated for a bio-indicator species (Harwell *et al.*, 2019).

Whether the *K. maranjandu* is an ideal bioindicator of the health and bio-diversity of the phytotelmic habitats of the forest ecosystem is evaluated (Table 2). The criteria such as high sensitivity to environmental stressors with an early and specific response to the stressor for *Kani* crab requires additional research. The short life span with convenient sampling (Harwell *et al.*, 2017) and monitoring values for population studies add to the quality of *Kani* crab as a good bioindicator. All these qualities, together with the taxonomically and biologically stable characteristics of the *Kani* crab, are widely recognized as a bio-indicator species.

Conclusions

Kani maranjandu is an effective management tool for assessing climate change, monitoring pollution, and tracking environmental conditions and the biodiversity of other communities within their respective ecosystem. Any notable alterations in the population size, distribution, reproductive patterns and behavioural responses of the *Kani* crab signal unusual changes in the abiotic factors prevalent in the region, which evokes urgent investigation to interpret the overall health and quality of the ecosystem. Addressing the issue at the earliest will generate data on the whole Agasthayamalai Biosphere Reserve, which gives a complete picture of the forest and the ongoing threats in the ecosystem. Removing the novel cause aids in successfully conserving the ecosystem's biodiversity.

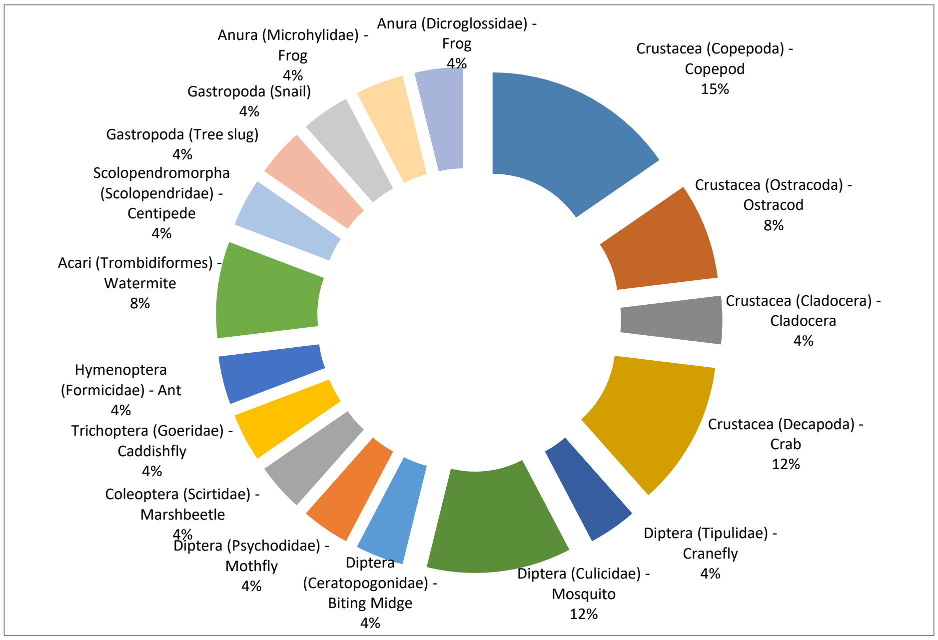

Figure 1. The species composition of phytotelmata of the Agasthyamalai Biosphere Reserve, Kerala.

Figure 2. *Kani maranjandu* and its habitat: (a) Phytotelmata; (b) Pushed out mud from phytotelmata; (c, d) *Kani maranjandu* in the arboreal habitat.

Table 1. The physical characteristics of water and parameters of phytotelmata occupied by *Kani maranjandu*.

Limit	DBH (m)	Height of hole above ground (m)	Surface Area (sq. cm)	Depth of the hole (cm)	Volume of water (L)	Temperature (°C)	DO (mg/l)	pH	Conductivity (µS)	Colour of water
Lower	0.15	0	4	5	0.19	22	0.9	6.7	115	Clear
Upper	2.23	5	85	90	37	27.1	3.6	7.8	1355	Dark brown

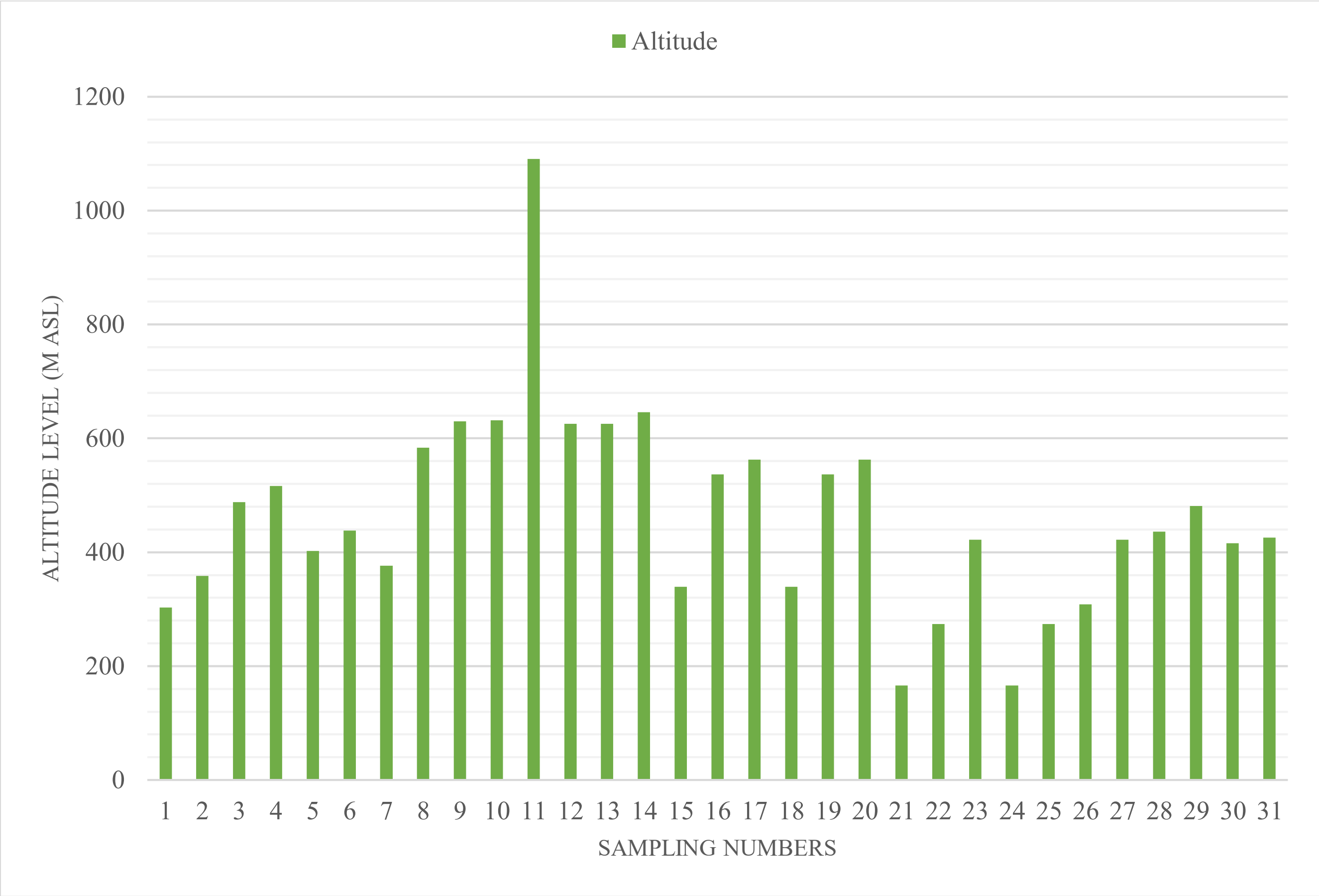

Figure 3. Elevation levels of trees occupied by *Kani* crab from Agasthyamalai Biosphere Reserve, Kerala, India. M ASL - Meters above sea level.

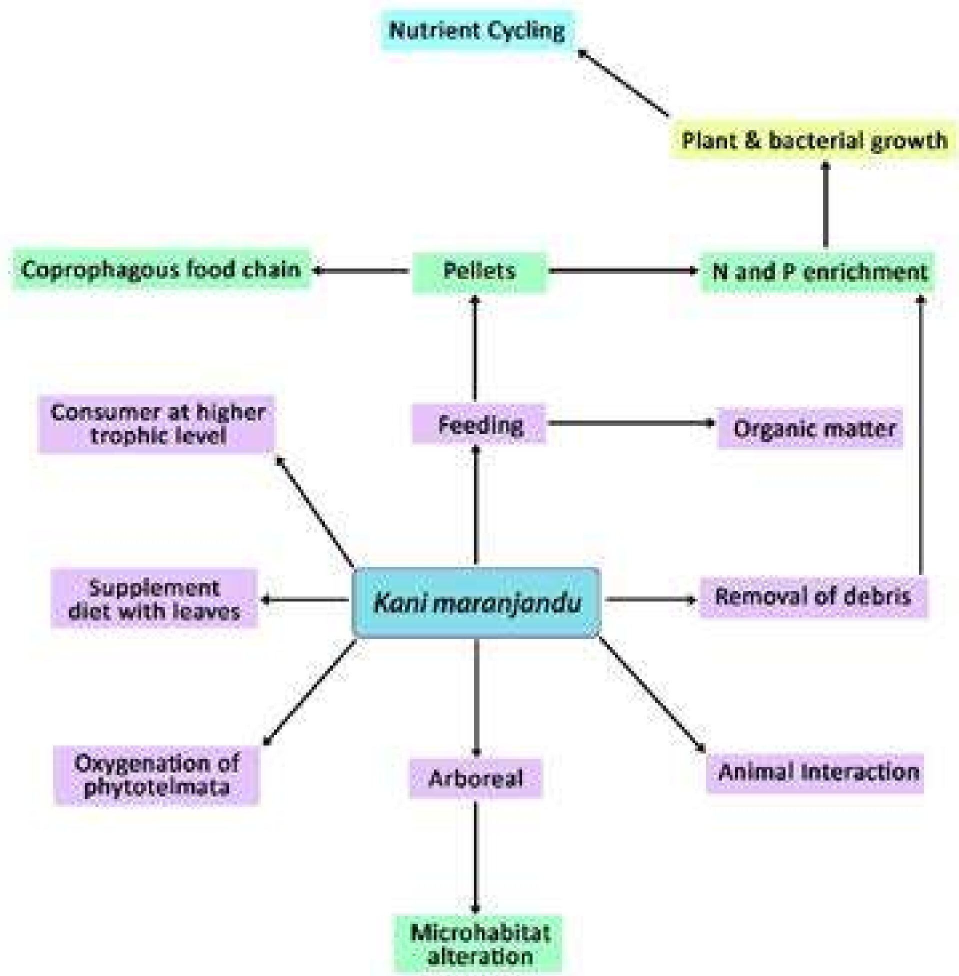

Figure 4. The heterogenous role of *Kani maranjandu* within the phytotelmic containers habitats of forest ecosystem (modified from Arya *et al.*, 2014).

Table 2. Evaluation of *Kani* crab as a bio-indicator species of forest ecosystem of ABR (modified from Holt and Miller, 2011).

Criteria	Sub-criteria	Review	Remarks
Good Indicator ability	Provide measurable response (sensitive to the disturbances or stress but does not experience mortality)	Yes	Needs additional research
	Response reflects the whole population / Community / Ecosystem response	Yes	Clear
Abundant and Common	Adequate local population density	Yes	Clear, but not uniform at all places
	Common, including distribution within area of question	Yes	Clear

Criteria	Sub-criteria	Review	Remarks
Well studied	Ecology and life history well understood	Yes	Clear
	Taxonomically well documented and stable	Yes	Clear
	Easy and cheap to survey	Yes	Depend on forest types
Economically/ Commercially	Species already being harvested for other purposes	No	Not common. Tribes occasionally catch for preparing oil to cure ear ache.
	Public interest in or awareness of species	No	Interest can be developed. Awareness is less.

Acknowledgement

The authors thank the Department of Forest and Wildlife, Kerala, for the sanction (KFDHQ-6568/2019-CWW/WL10 dated 19.08.2020) for fieldwork. The first author thank the financial support of Department of Science and Technology (DST) INSPIRE fellowship for the PhD program. We acknowledge the support of the tribesmen Rajan Kani and Manoj Kani in field assistance. We thank Prof. Dr. La orsri Sanoamuang, Khon Kaen University, Thailand; Dr. Sandeep Das, University of Calicut; Dr. Alex Eapen, ICMR-National Institute of Malaria Research, Chennai for the help in taxa identification.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Investigating the pollen transport network between moths (Lepidoptera) and the economically important plants in central and eastern Himalaya

Rajesh Lenka[1,3,4], Dipayan Mitra[1,2,5], Pallab Chatterjee[1,3,6], Avishek Talukdar[1,3,8,*], Navneet Singh[1,7]

[1]*Zoological survey of India, New Alipore, M-Block, Kolkata-700053, West Bengal, India*
[2]*Department of Botany, University of North Bengal, Raja Rammohunpur- 734014, West Bengal, India*
[3]*Department of Zoology, University of Calcutta, Kolkata- 700019, West Bengal, India*
[4]*E-mail: untamedwild85@gmail.com, ORCID: http://orcid.org/0000-0002-0164-5754*
[5]*E-mail: dip.the.nocturnal@gmail.com, ORCID: http://orcid.org/0000-0002-7216-3920*
[6]*E-mail: cpallab6@gmail.com, ORCID: http://orcid.org/0000-0001-7756-032X*
[7] *E-mail: nsgill007@gmail.com, ORCID: http://orcid.org/0000-0002-6657-7983*
[8]*E-mail: askdar94@gmail.com, ORCID: http://orcid.org/0000-0002-4808-2901*

Abstract

The current study was planned to understand the pattern of pollen transportation in commercially significant plants of the central and eastern Himalayas via non-papilionoid Lepidoptera. For data collection, 14 locations of Arunachal Pradesh, Sikkim, and North Bengal were surveyed between September 2018 to August 2019. Our investigation revealed that 37 species in seven moth families contribute significantly in pollen transportation of eleven economically significant plant species belonging to nine angiosperm families. The analysis is based on a bipartite model between the identified moths and plant taxa to measure pollen carrying capacity, selectivity, connectance, Shannon's diversity, linkage diversity, and link per species. We examined generalist and specialist moth species. The outcome of the current research work offers a basic and fundamental understanding of the ecological role of moths in pollen transportation of economically significant plants in the central and eastern Himalaya, and will thus open up a new doorway in pollination ecology of moths.

Keywords: Angiosperms, Bipartite network, Moth-plant interaction, Non-papilionoid Lepidoptera, Pollen transportation, Potential pollinators

Introduction

Pollen transportation plays a crucial role in the process of pollination, which is vital for the survival of majority of the floral components. This process is essential for the fertilization of the ovules, which leads to the development of seeds and the continuation of the floral generation. Pollen transportation can occur through various means, including wind, water, and animals (Faegri and Van Der Pijl 2014). However, transportation via animal is the most common form and involves the transfer of pollen from flower to flower by animals such as insects, birds, and bats. Pollen is a vital food source for these animals, and as they feed on the nectar within the flower, they inadvertently collect and transport pollen grains on their bodies (Macgregor and Scott-Brown 2020). The transportation of pollen is essential for pollination to occur because it enables the pollen to reach the female reproductive organs of the flower, where it can fertilize the ovules. Without the help of animals, many plant species would not be able to reproduce, and their populations would decline (Macgregor *et al.* 2019). Furthermore, the

*Author for correspondence : askdar94@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

genetic diversity of plant populations would be reduced, which could make them more susceptible to diseases and environmental changes (Atwater 2013). In conclusion, pollen transportation is critical for pollination and the survival of many plant species (Brittain *et al.* 2013; Rader *et al.* 2016) Animal pollination, in particular, is an essential ecological process that benefits both plants and animals, and its importance should not be overlooked (Walton *et al.* 2020; Macgregor and Scott-Brown 2020; Singh *et al.* 2022)"

Vertebrate and invertebrate animal pollinators are contributing towards the pollination of approximate 87.5% angiosperm plants and 25-30% pollination services are provided by non-bee insects (Rader *et al.* 2016). Insects are major pollen transporters especially the nocturnal lepidopterans which are extremely species rich and constitute major portion of nocturnal flower pollinating insects (Faegri and Van Der Pijl 2014; Macgregor *et al.* 2017, 2019; Macgregor and Scott-Brown 2020; Singh *et al.* 2022) 2019; But, moths are less studied for their role as pollen transporters but these nocturnal pollinators plays a vital role as pollen transporters of wild flowers in agricultural landscape (Walton *et al.* 2020, 2021)". In agricultural landscape, macro moths provide an unique and complex pollen transport links which makes them a vital player in overall plant–pollinator network (Walton *et al.* 2020) However, in Indian scenario, no paper could be reviewed with information on pollen transportation of, particularly, economically important plants of Himalayan ecosystem, a home to various agricultural/horticultural plants like, Apple (*Malus domestica*; Rosaceae), Kiwi (*Actinidia deliciosa*; Actinidiaceae), Orange (*Citrus sinensis*; Rutaceae), Plum (*Prunus domestica*; Rosaceae), Walnut (*Juglans rigia*; Betulaceae), Grapes (*Vitis vinifera*; Vitaceae), Pomegranate (*Punica granatum*; Punicaceae), Potato (*Solanum tuberosum*; Solanaceae), Brinjal (*Solanum melongena*; Solanaceae), Tomato (*Solanum lycopersicum*; Solanaceae), Cabbage (*Brassica oleracea*; Brassicaceae), Cucurbits (Cucurbitaceae), oilseeds like soybean (*Glycine max*; Fabaceae), Mustard (*Brassica juncea, Brassica campestris*; Brassicaceae), spices like Large Cardamom (*Elettaria cardamomum*; Zingiberaceae), Ginger (*Zingiber officinale*; Zingiberaceae), Turmeric (*Curcuma longa*; Zingiberaceae) (Xu *et al.* 2009; Basannagari and Kala 2013).

Though, Singh *et al.* (2022) published an important study establishing 140 settling moth species as pollen transporter moth species responsible for transporting pollen of 21 plant families. In another study by Chakraborty *et al.* (2021), the seasonal dynamics of plant-pollinator networks based upon pollen transportation in agricultural landscapes have been analysed and the importance of moths as connector species in transporting pollen has been highlighted.

The present study aims (1) to find out the role of moths in pollen transportation of economically important plants of central and eastern Himalaya, and (2) to find out moth species which may be potential pollinator of various economically important plant species prevailing in Himalayan ecosystem of North-East India.

Material and Methods

Collection surveys and Study Area

Survey cum collection tours were conducted from September 2018 to August 2019 in 14 sites of Arunachal Pradesh, Sikkim and North Bengal (Figure 1). The details of the study sites are given in Table 1.

Collection of Moths and isolation of proboscis

Moth specimens were collected using vertical sheet light trap with mercury vapor lamp (160 W) and killed using individual killing jars fumigated with Ethyl acetate to eliminate any chances of pollen contamination. After that proboscides were isolated from each moth using sterilized forceps for slide preparation and the moths were kept in separate envelop with proboscis code number. Finally, moths were relaxed, stretched and preserved for identification according standard techniques of Lepidopterology (Holloway 2001).

Light microscopy of collected pollen from proboscides of moths

Individual proboscides of moth sample was taken on a glass slide and incubated with few drops of phenol-glycerin solution (1:1) for 1–2 minutes for relaxation. After that, one or two drops of basic Fuchsine dye was added with it and the slides were mounted with cover slips and sealed with nail varnish. Photographs have been taken with Nikon 50i compound light microscope fitted with DP–25 digital camera under 40× magnification (Atwater 2013).

Identification of moths and pollen

Moths were identified using available literatures and compared with the samples housed as the samples with the national collection in Zoological Survey of India. For pollen identification, various websites and available literatures were (Agashe and Caulton 2009; Bhattacharya *et al.* 2014;

Halbritter *et al.* 2018; Global Pollen Project 2022; PalDat 2022).

Statistical Analysis

Bipartite network was constructed for showing the interaction between the identified moth species and angiosperms using 'bipartite' package in Rstudio software (R core development team 2021); Dormann *et al.* 2021). In the metadata used for constructing the bipartite network (Figure 2 and 3), the moths are taken along the columns and the angiosperms are taken along the row. Number of pollen grains per proboscis was considered for analyzing network-level indices and the species-level indices of the bipartite network. For showing the characteristics of the bipartite network, various species network-level indices viz. Nestedness, Selectivity (H'_2), Shannon's diversity index, connectance, links per species, linkage density, interaction evenness, interaction strength asymmetry, are calculated. PDI score or species-level paired difference index: value ranges from 0 to 1; 0 shows complete generalism and 1 indicate the total specialism in both trophic level of a bipartite network. It is used to find out the generalist and the specialist in both trophic level of a bipartite network.

Abbreviation used

PTMS- Pollen Transporter Moth Species (A moth species which carries pollen grains)

PPMS- Potential Pollinator Moth Species (A moth species which carries at least five or more than five pollen grains of a particular plant taxa)

Results and Discussion

A total of 37 species in seven families of moths are identified as the pollen transporter of 11 economically important angiosperm species in eight families. Of the 37 PTMS, maximum species came from Geometridae (12 species; 32.43% of total PTMS), followed by Erebidae (10 species; 27.30%), Sphingidae (nine species; 24.32%), and Crambidae (three species; 8.11%). Whereas, three families i.e., Drepanidae, Nolidae and Noctuidae, each are represented by single PTMS. Among 37 PTMS, 35 (94.59% of all PTMS) are identified as PPMS. The highest number of PPMS came from Geometridae (12 species; 34.28% of all PPMS), followed by Erebidae (10 species; 28.57%), Sphingidae (eight species; 22.85%), Crambidae (two species; 5.71%) and the least PPMS are found from Drepanidae, Nolidae and Noctuidae (one species each). The highest numbers of pollen grains are found to be carried by *Cechetra minor* (Sphingidae) i.e. 246 pollen grains of *Alnus* sp. (Betulaceae), followed by *Sarcinodes aequilineata* (Geometridae) with 200 pollen grains of *Malus*. The least number of pollen grains are found to be carried by *Eudocima falonia* (Erebidae) with only one pollen grain of *Butea* sp. (Fabaceae) and *Simplicia brevicosta* (Erebidae) with only two pollen grains of *Rhododendron* sp. Among these, pollen of *Malus* sp. (Rosaceae) are found to be carried by maximum number of moth species (14 species), followed by Rhododendron sp. (Ericaceae) (six species), Betula sp. (Betulaceae) (five species), Olea sp. (Oleaceae) (two species), Salix sp. (Salicaceae) (one species), Brassica sp. (Brassicaceae) (one species). (one species).

The bipartite network has shown high value of selectivity i.e. $H'_2 = 0.94$ as compared to other networks constructed in moth-plant bipartite network related studies (Macgregor *et al.* 2019; Walton *et al.* 2021; Singh *et al.* 2022). Furthermore, the network also shows high value of nestedness, connectance, linkage density and Shannon's diversity (Table 2), and thus, showing the importance of this network in terms of maintaining the ecosystem function and pollination service provided by moths. Moth-plant bipartite network and module web shows that pollens of *Malus* sp. (Rosaceae), *Rhododendron* sp. (Ericaceae) and *Zea mays* (Poaceae) has the highest interactions with different moth species (Figure 3). The high selectivity value of our bipartite network ($H'_2 = 0.94$) indicates that more specialized species are interacting against generalized species (Rodríguez-Gironés and Santamaria 2006; Blüthgen *et al.* 2006).

Only three moth species e.g. *Rhagastis olivacea* (Sphingidae), *Achaea* sp. (Erebidae) and *Acosmeryx naga* (Sphingidae) show lesser value of PDI score, which means they are not specialist species (those species which have unique interaction in a bipartite network) rather than they are found to be generalists species (having more number of common interactions in a bipartite network).

Our study revealed high potentiality of moths in trans portation of pollen grains as well as their potentiality in pollination of economically important angiosperms. Our results are based on the pollen attached exclusively on the proboscides and thus provide robust inferences for the reasons, 1) pollens on proboscides are less contaminated, and 2) proboscis is the main interacting organ of moth which interacts with flower. Though it is a preliminary study but different network-level indices indicate that this interaction network has high diversity of species and high interaction between specialized and generalized species, particularly in Indian Himalaya, which is a sensitive and mega diverse zone. Our study is providing the baseline information regarding pollen transportation by moths and their importance in pollination. We believe that in the conservation related policies and long-term monitoring of the ecosystem health, moths must be part of management strategies. Decline in moth population could be a potential threat to survivability of economically important angiosperms of this region.

Tables and Figures

Table 1. Details of the sampling localities

Sl. No.	Locality Name	District	State	Latitude (in °)	Longitude (in °)	Elevation (in m)
1	Sitong	West Bengal	Darjeeling	26.9378	88.3714	712.4
2	Eche gaon	West Bengal	Kalimpong	27.1336	88.5744	1773.9
3	Jhendi	West Bengal	Kalimpong	27.0189	88.6472	1742.2
4	Lataguri	West Bengal	Jalpaiguri	26.7475	88.7653	104.8
5	Rishop	West Bengal	Kalimpong	27.1086	88.6486	215.7
6	Jayanti	West Bengal	Alipurduar	26.7039	88.6094	712.6
7	Panthyang	Sikkim	Gangtok	27.3639	88.5686	2022
8	Dikchu	Sikkim	Gangtok	27.3990	88.5233	794
9	Bermiak	Sikkim	Gyalshing	27.2532	88.2332	1453
10	Ravangla	Sikkim	Namchi	27.2857	88.3541	2013
11	Tenga Valley	Arunachal Pradesh	West Kameng	27.2128	92.4642	1339
12	Salari	Arunachal Pradesh	West Kameng	27.3075	92.4096	1285
13	Shergaon	Arunachal Pradesh	West Kameng	27.1342	92.2739	2044
14	Eaglenest WLS	Arunachal Pradesh	West Kameng	27.1575	92.4608	2330

Table 2. Network-level indices of the moth-plant bipartite network

Network-level indices	**Value**
connectance	0.101299
links per species	0.847826
nestedness	17.73053
interaction strength asymmetry	0.608633
linkage density	2.766793
Shannon diversity	2.837667
interaction evenness	0.476659
H'_2	0.948107

Figure 1. Different sampling localities for the study (ArcGIS V.10.5)

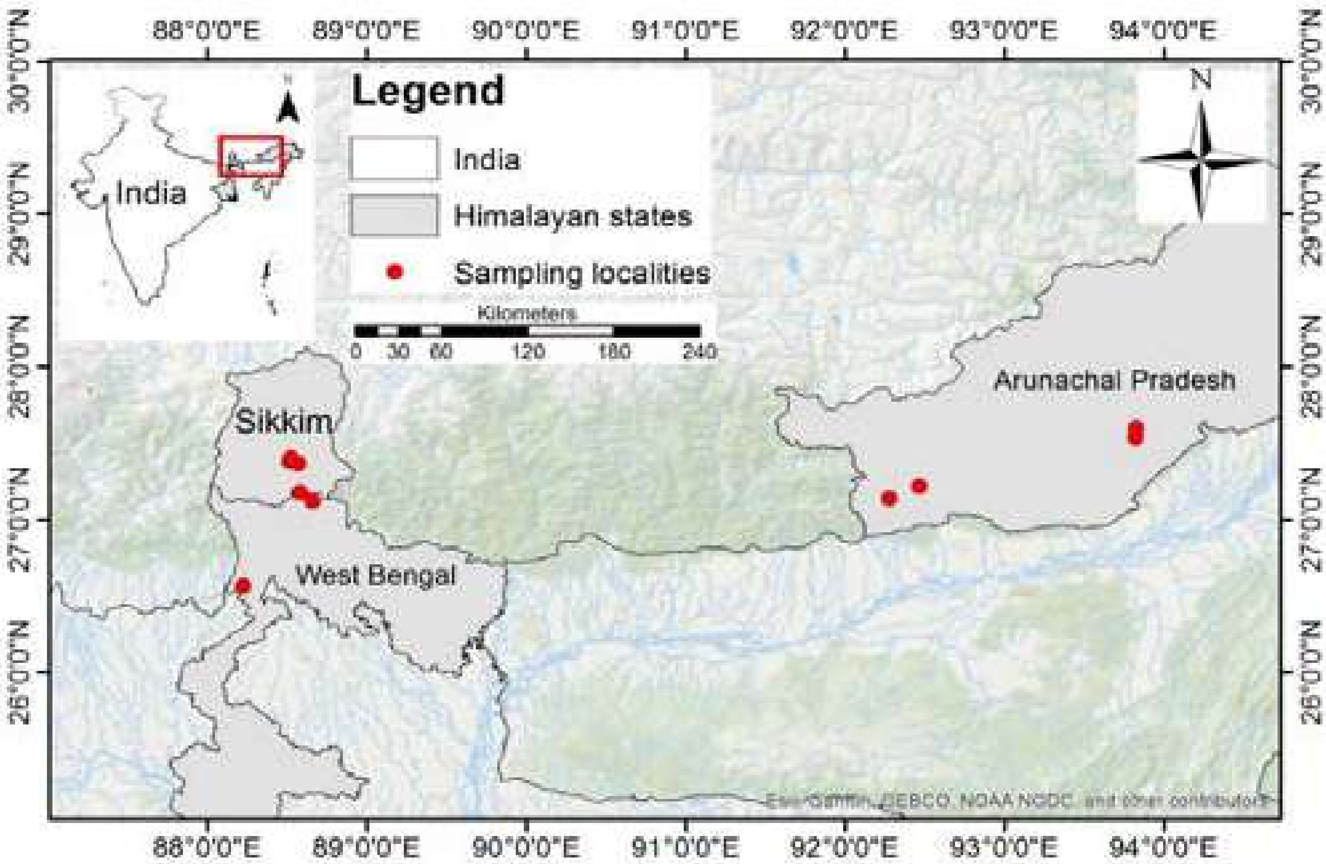


Figure 2. Bipartite network of crop plant species and moth species collected during this study

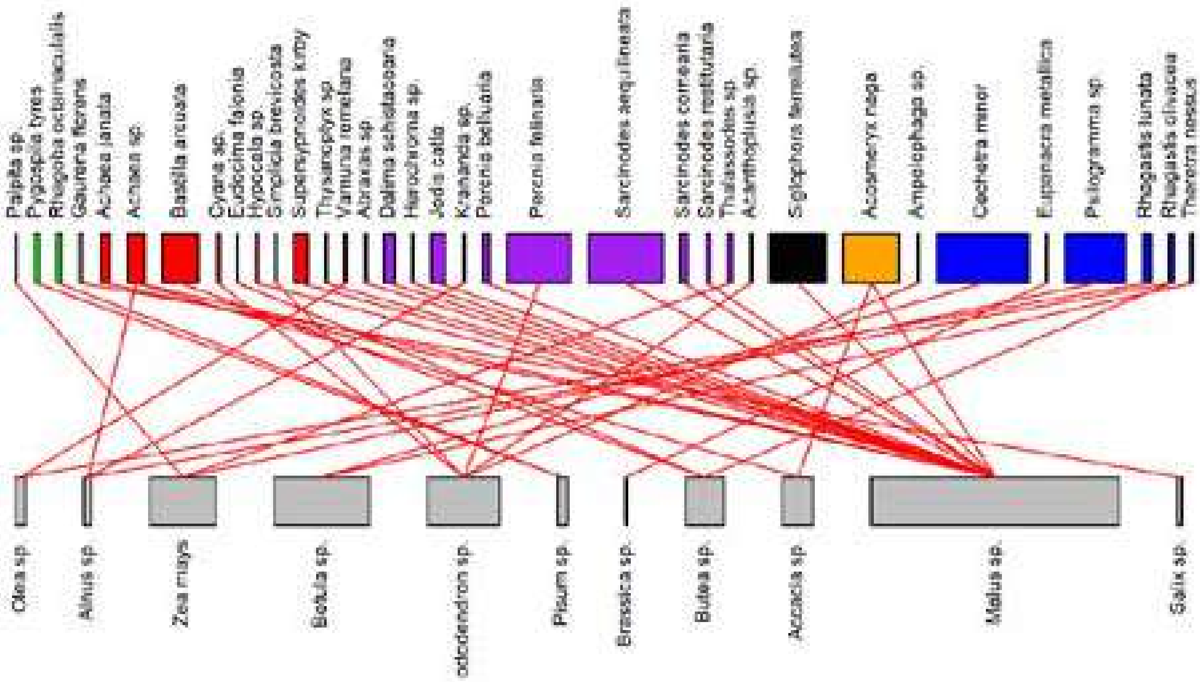
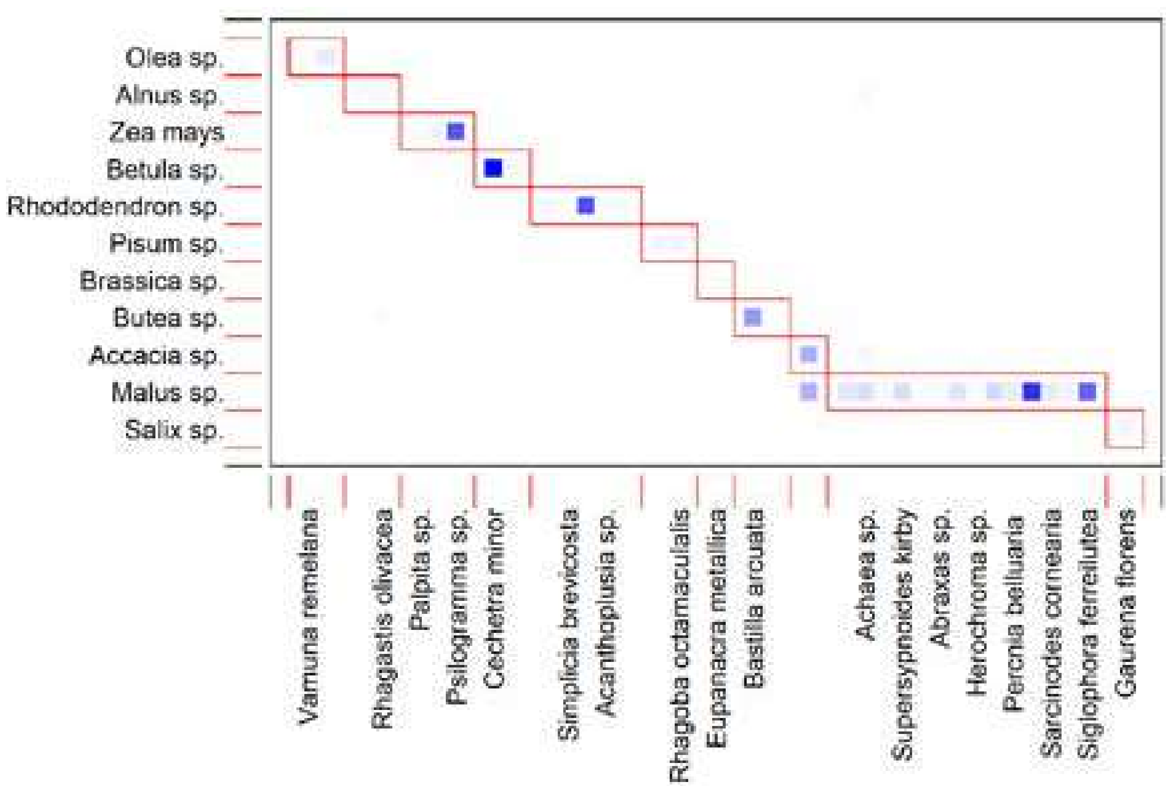


Figure 3. Module web showing only the moth species that taking part actively in their respective plant taxa in the bipartite network constructed during the study



Acknowledgement

We thank Director Dr. Dhriti Banerjee and former Dr. Kailash Chandra of ZSI for providing the necessary permission and facilities for successfully carrying out this project. We also thank the PCCF of Arunachal Pradesh, Sikkim and West Bengal for giving the necessary permissions to conduct the surveys in various locations. We also cannot refrain ourselves from thanking National Mission on Himalayan Studies and GB Pant National Institute on Himalayan Environment and Sustainable development for funding this work.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Pesticide differentially affects natural predators causing pest build up: a case study in brinjal.

Manobrata Das and Parthiba Basu*

Department of Zoology and Centre for Agroecology and Pollination Studies, University of Calcutta, 35, Ballygunge Circular Road, Kolkata-700019, India

Abstract

Pesticide application aimed at pest regulation in agricultural field can have unintended differential and negative impacts on non-target species.Therefore, its continuous and uncontrolled usage can disturb the balance of agricultural ecosystem. The objective of the present study was to assessrelative impacts ofpesticideson pest and predator populations in an agricultural ecosystem. We chose brinjal farm as our focal system as it is an economically important crop that has high pest vulnerability and therefore requires heavy pesticide usage. Whitefly is a major pest of brinjal.Spiders are important natural predators that is known to control pests by active predation. We explored the impacts of pesticide on whitefly and spider populations in brinjal farming system. Thirty farms were selected in the coastal agro-climatic zone in southern West Bengal. Whitefly abundance increased significantly with increasing usage intensity of pesticides used by farmers. Spider abundance decreased as pesticide intensity increased. Decreasing spider density resulted in increased whitefly population. These results show how non-target impact of pesticide impedes natural pest regulation.

Keywords: Pesticide, Pest, Natural predator, Whitefly, Spider, Non target impact

Introduction:

Chemical pesticides are important part of modern agriculture, and they have significantly aided in controlling pests that increased crop yields(Cooper and Dobson 2007). However, careless pesticide application can have unintended and negative consequences for non-target speciessuch as pollinators and natural predators(Theiling and Croft 1988;Vanbergen *et al.* 2013)that provide valuable ecosystem servicesin agricultural systems. Unrestrained use of pesticides can therefore disrupt the balance of agricultural ecosystems. Natural predators are important component of agroecosystemsthat can keep the pest populations at check. Increased pesticide intensity can lower predator population and their pest controlling capacity (Sánchez-Bayo 2021) which in turn may lead to an increase in pest population demanding more pesticide input. Pesticide application therefore triggers a vicious cycle which ultimately leads to both yield loss as well as loss of farm profit due to increase in production cost (Bommarco*et al.* 2011). Despite the risks, the use of pesticides continues to increase globally (Sharma *et al.* 2019). Thus, it is crucial to investigate the understudied relationship between pesticide intensity, pests and predator populations in agricultural ecosystems.

Brinjal is among the most significant three vegetables in many South Asian countries, including India, Bangladesh, Nepal, and Sri Lanka(Alam*et al.* 2003).Whitefly (*Bemiciatabaci*Gennadius) is an important sucking pest that causes significant damage to brinjal plants (Mandal*et al.* 2010.).Whitefly belongs to the Hemiptera order. They harm brinjal plants in both direct and indirect ways.Both nymphs and adults suck sap from the lower leaf surfaces using their piercing and sucking mouthparts.Furthermore, they disrupt

*Author for correspondence : bparthib@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

transport in conducting vessels and appear to introduce a toxin that reduces photosynthesis (Sharma and Chander 1998). Yellow spots appear on the leaves when several insects suck the sap from the same leaf, which causes crinkling, curling, bronzing, and drying. In severe conditions, when most leaves on the plant are affected, photosynthesis is reduced, and yield drops significantly. They are also potential virus vectors; more over honeydew secreted by them attracts black sooty mould another photosynthesis inhibitor further contributing to yield loss. Spiders (order Araneae)are one of the major groups of generalist natural predators and they have been reported to be an important pest regulator (Nyffeler and Benz1987).A healthy spider population is a vital component ofany ecologically efficient, sustainable, low-input agricultural system (Ekschmitt*et al.* 1997). We explored the impacts of pesticideson whitefly and spider abundance in brinjal agricultural systems.

Materials and methods:

Study area:

The study was conducted in the southern part of West Bengal, India. Thirty brinjal farms from three administrative districts (Kultali, Swarupnagar, and Nandigram II) in the "coastal saline agroecological Zone" with a similar agro-climatic regime were chosen for the study. The overall climate in this region is tropical humid, with rainfall ranging from 1600 to 1800 mm and air temperatures can range from22.7°C to 37°C. (Adhikari*et al.* 2010). The study areastretched across 130 kilometres from East (22°0'5.95"N, 87°49'50.30"E) to West (22°51'41.69"N, 88°53'43.73"E). The farms were chosen to be located at least 2 kilometres apart from one another. The same variety of brinjal (*Tarini* variety) was grown on all farms. The farms were selected to represent a pesticide use gradient based on a Pesticide Intensity Index (PII).

Pesticide Intensity Index:

Pesticide intensity index(PII) of an individual farm was estimated from the quantity of chemical pesticides consumed, frequency of use and toxicity levels of the used pesticides. Pesticide input amount is the total amount of chemical pesticides divided by the area of that particular farm (ml/meter2). Pesticide input frequency is the total no of applications of chemical pesticides (no of spray/month). All the pesticides were categorized into four toxicity ranks according to their toxicity levels rank 1= slightly toxic, rank 2= moderately toxic, rank 3= highly toxic, and rank 4= extremely toxic (Sawant*et al.* 2022). Pesticide toxicity rank of individual farm was calculated by the following formula.

Toxicity rank= $\sum_{i=1}^{n} pfi * pti$ (where pf_i is the pesticide use frequency of the i_{th}pesticide and $pt_i$is the toxicity rank for the same. n is the number of pesticides used).

Pesticide amount, frequency, and toxicity were normalized, averaged, and added following Flohre *et al.* 2011.

$$PI = \frac{\sum_{i-1}^{n} (p_i - p_{\min})(\, p_{\max} - p_{\min})}{n} \times 100$$

where PII is the Pesticide use Intensity Index, p_i is the observed value (Total amount of pesticide applications or frequency of pesticide applications or toxicity rank of the farm), p_{min} is the minimum observed value in all farms, p_{max} is the maximum observed value in all farms, n is the number of individual indicators (here n=3), and i is the identifier for the three indicators.

Field sampling:

Fieldwork was performed in the pre-monsoon season of 2019 (from March to June 2019). All thirty fields were sampled once in a similar crop stage. All the sampling was done on days with sunny clear weather (no rain).

Spider sampling:

Four random quadrats of 0.5 meter × 0.5 meter were sampled in each field. Vacuum-sampling was done for 2 minutes in each quadrat at 0800, 1000, 1200 and 1400 hrs. In a quadrat, entire plants were sampled (Green 1999). A vacuum machine (model: STIHL SH 86 C-E) powered by a two-stroke petrol engine was used for sampling. A net sleeve was placed inside the muzzle to sample spiders. Spiders were vacuum sampled, then put into ethyl acetate-killing jars before being transferred to marked vials of 70% ethyl alcohol for taxonomic identification. All the spider samples were identified up to the family level (Sebastian *et al.* 2009) and then up to morphospecies.

Whitefly sampling:

We estimated whitefly population of each field following a presence-absence sampling procedure. This technique requires visual observation of the whitefly adults on the leaves (Palumbo *et al.* 1994).We counted the number of leaves that had one or more whitefly adults, that is, whether they were present or not (absent).Four random quadrats were chosen for the observation and fifty random leaves from each quadrat were observed (50 leaves x 4 quadrat=200 leaves). Whitefly population was estimated as a ratio of whitefly affected leaves (number of leaves present with whitefly/200) and all observed leaves.

Statistical analysis:

All the analyses were performed in R statistical software (version 4.2.1) for Windows (Team, R.C., 2015). Normality and heteroscedasticityof data were checked using normal Q–Q plots and standardized residuals versus fitted value plots (Crawley 2007). Our data did not fit in a normal distribution. To explore the relationshipbetween pesticide intensity (PII), whitefly and spider we fitted our data in generalized linear models (GLMs) using 'glm' and 'glm.nb' functions. To assess the effect of pesticide intensity on the whitefly populationwe assumed binomial error distribution with a 'logit' link.The relationship of spider abundance with pesticide intensity was assessed with another GLM where we assumed a negative binomial error distribution with a 'log' link function. We summed the abundance of spiders of all four quadrats in each field and used them in the analysis. The relationship of whitefly with spider abundance was also explored with a GLM where we assumed a Gamma error distribution with an 'inverse' link. All models were selected based on their lowest Akaike's information criterion (AIC) value (Burnham and Anderson 2002). For the analysis, we used 'readxl','MASS' and 'ggplot2' packages in R.

Results and discussion:

We found a gradient of pesticide intensity across our thirty field sites with the PII value ranging from 0 (no chemical pesticide input) to 92.98 (highest level of chemical pesticide input) (Figure 1). We collected a total of 328 spider specimens from the fields belonging to seven families. Oxyopidae is the most dominant family (66.8%) in our brinjal fields followed by Salticidae (20.4%), Araneidae (6.4%), Theridiidae (3.05%), Tetragnathidae (1.83%), Thomisidae (0.91%) and Lycosidae (0.61%)(Figure 2).

We found whiteflypopulation is increasing with pesticide intensity (GLM binomial $p < 0.05$, df =29, R^2 = 0.48) (Figure 3). This means increased use of pesticides does not guarantee whitefly control. This phenomenon can be caused by pesticide resistance development in whitefly. Whitefly resistance to pesticides is reported in various locationsinIndia (Naveen *et al.* 2017). Spider abundance was negatively affected by pesticide intensity in brinjal farms (GLM negative binomial $p < 0.001$, df =29, R^2 = 00.36) (Figure 4). Our finding corroborates previous studies that have shown pesticides have a negative influence on spiders and other natural predators in agricultural fields (Nash *et al.* 2008). When we looked at how whitefly responds to spider abundance, we found whitefly is negatively related to spider abundance in our farms (GLM Gamma $p < 0.01$, df =29, R^2 = 0.35)(figure5). Farms that have lower pesticide intensity have more spiders and that leads to decreased whitefly density due to predation. On the contrary, farms that use more pesticides experience a rise in the whitefly populationsince there aren't enough spiders to control them, and whiteflies have developed resistance to the pesticides.

The repeated application of compounds containing the same active ingredients, as well as the use of excessive pesticide doses during a cropping season, has resulted in the development of resistance in whitefly to organophosphates, pyrethroids, and carbamate (Kranthi *et al.* 2002) in crops like cotton. Our study reveals possible pesticide resistance of whitefly in brinjal farms and requires further study. Moreover, in high pesticide intensity farms we found a decline in spider abundance. This indicates that spiders are vulnerable to pesticide application.Negative effects on nontarget natural predators, in combination with pesticide resistance in whitefly, could explain the observed higher pest level, and lower spider abundances in high pesticide intensity fields. Some studies have found that natural enemies are commonly more sensitive to pesticides and develop pesticide resistance slower than their prey (Hill and Foster 2000, Xu*et al.* 2001).Generalist natural predators have been shown to be effective at pest control in managed ecosystems (Murdoch *et al.* 1985, Symondson*et al.* 2002).The decrease in spider abundance observed in the current study coupled with a possible pesticide resistancemay have boosted whitefly populations in pesticide-intensive farms. The actual role and effectiveness of spiders in controlling whitefly population is not well documented but our findings clearly suggest that the role of spiders as biological control agents in brinjal deserves more attention.

Figures:

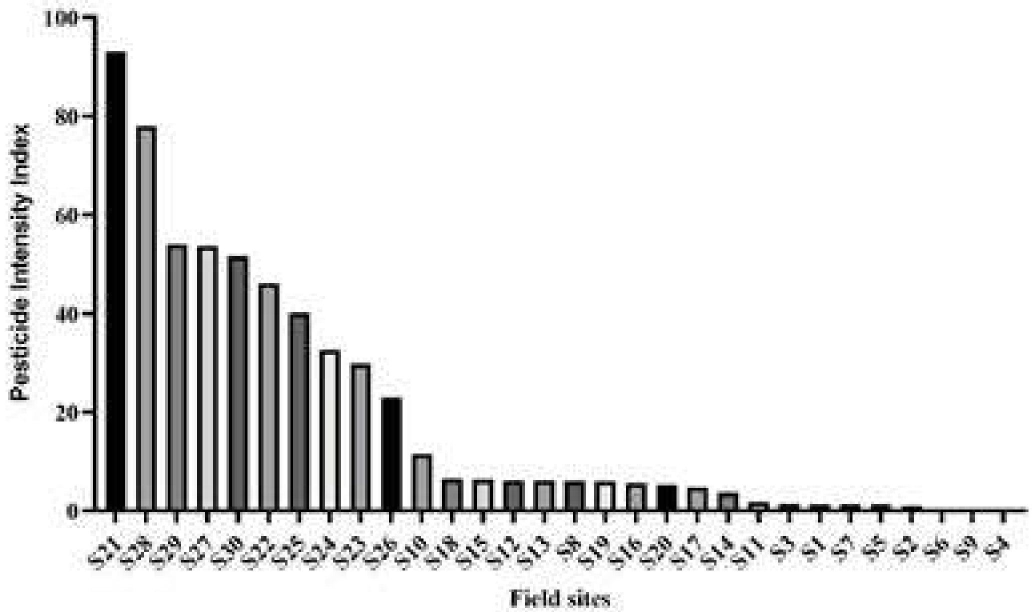

Figure 1: Pesticide intensity index values of our field sites arranged in descending order. S1-S30 are field sites.

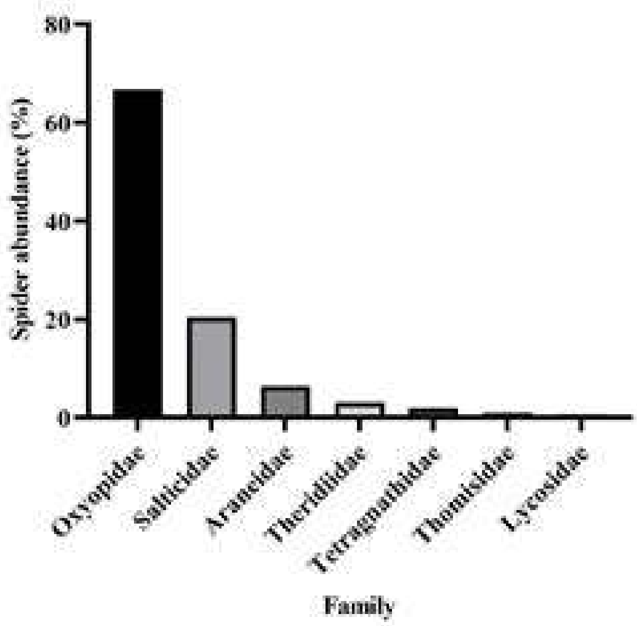

figure 2: Relative abundance of spider families in brinjal farms.In x axis observed spider families and in y axis realtive abundance of spiders(percentage)

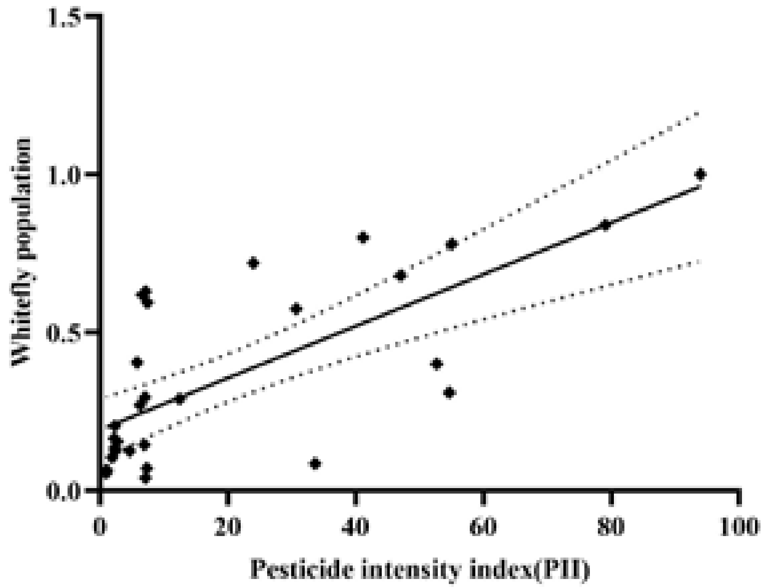

Figure 3 : Relationship of whitefly with pesticide intensification. in x axis pesticide intensification index values and in y axis whitefly population(infected leaves ratio) .p <0.05, df =29,method =GLM, R^2 = 0.48

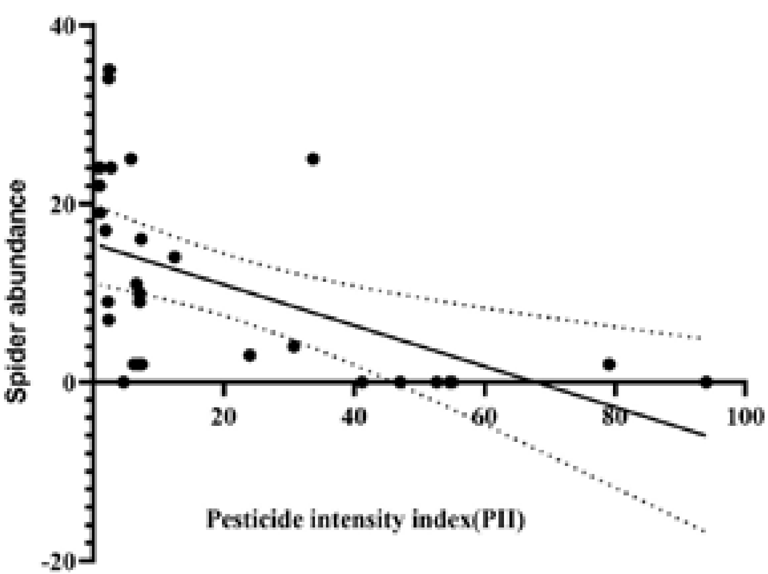

Figure 4: Relatioship of spider abundance with pesticide intensification. in x axis pesticide intensification index values and in y axis spider abundance (total no spider) .p <0.001, df =29, method=GLM, R^2 = 0.36.

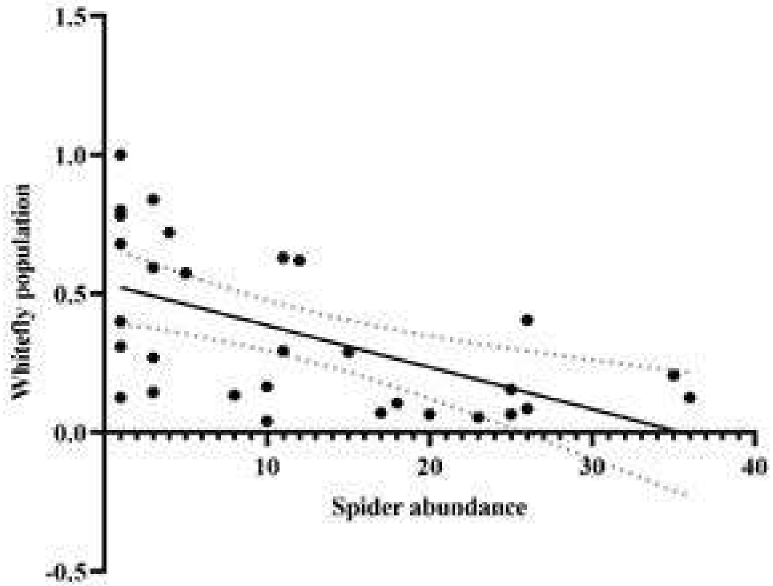

Figure 5: Relationship of whitefly with spider abundance. In x axis spider abundance (total no spider) and in y axis whitefly population (affected leaves ratio). $p < 0.01$, df =29, method=GLM,$R^2 = 0.35$.

Table 1: List of pesticides used in the study sites. Pesticide application and quantity range is in the table.

Pesticide chemical composition	Toxicity	Frequency (application per month)	Quantity (ml/10 litre)
Monocrotophos (36%)	Extremely toxic	1 to 4	10 to 20
Acephate (20%SP)	Highly toxic	10 to 15	10 to 20
Acephate (50%)+Imidacloprid (1.8%SG)	Highly toxic	3	20
Acetamiprid (20%SP)	Highly toxic	3	20
Chloropyriphos (50%) +Cypermethrin (5%)	Highly toxic	1 to 2	10 to 15
Cypermethrin (10%)	Highly toxic	1 to 4	6 to26
Cypermethrin (25%)	Highly toxic	15	10
Cypermethrin (3%)+ Quinalphos (20%)	Highly toxic	4 to 15	16 to 20
Deltamethrin (1%) + Triazophos (35%)	Highly toxic	2	15
Enamectin Benxoate (5%)	Highly toxic	4	15
Enamectin Benzoate (1.9%)	Highly toxic	7 to 15	20
Imidacloprid (70%)	Highly toxic	1	2
Lambda-Cyhalothrin (5%)	Highly toxic	15	20

Pesticide chemical composition	Toxicity	Frequency (application per month)	Quantity (ml/10 litre)
Profenofos (40%) + Cypermethrin (4%)	Highly toxic	1 to 3	10 to 15
Propargite (57% EC)	Highly toxic	1	10
Pyriproxyfen (5%)+ Fenpropathrin (15%)	Highly toxic	4 to 15	10 to 20
Quinalphos (25%)	Highly toxic	15	20
Biological plant insecticide	Moderately toxic	1	5
Diafenthiuron (50%)	Moderately toxic	1	6
Flonicamid (50%)	Moderately toxic	2	5
Pyriproxyfen (10%)	Moderately toxic	10	13
Spinosad (45%)	Moderately toxic	4	6 to 10
Thiamethoxam (25 %)	Moderately toxic	1	5
Thiamethoxam (30 %)	Moderately toxic	15	20
Spinetoram (11.7%)	Slightly toxic	1 to 4	7 to 12
Chlorantraniliprole (18.5%)	Slightly toxic	1	5
Neem based insecticide	Slightly toxic	10	20
Neem based Azadirachtin (1%)	Slightly toxic	2	10
Organic protectant	Slightly toxic	1	10
Plant Extract	Slightly toxic	3	20
Biological Insecticide	Slightly toxic	1	10

Acknowledgments:

This work was supported by a fellowship to the first author from University Grants Commission (UGC), Govt. of India. We gratefully acknowledge University of Calcutta, India, for providing infrastructural support. We also acknowledge the farmers in the study area for their unconditional support during the fieldwork.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

New Distributional Record of *Spilomutilla eltola* (Cameron, 1898) (Hymenoptera: Mutillidae) From India

Joshua B. Terine[1,2]*, Girish P. Kumar[1,3]

[1]*Zoological Survey of India, Western Ghat Regional Centre, Kozhikode 673006, Kerala, India*
[2]*terinejb@gmail.com; https://orcid.org/0000–0002–6981–7401*
[3]*kpgiris@gmail.com; https://orcid.org/0000–0003–2121–0165*

Abstract

The Sri Lankan mutillid species, *Spilomutilla eltola* (Cameron, 1898) (Hymenoptera: Mutillidae) is newly reported from India. Differential characters, figures, distribution map and comparisons of the newly recorded species with description of materials from Sri Lanka is provided.

Keywords: Velvet ant, Sri Lanka, India, Tamil Nadu.

Introduction

The genus Genus *Spilomutilla* Ashmead, 1903 (Hymenoptera: Mutillidae) is widely spread in the Oriental Region (9 species) and one species penetrates to the palearctic (1 species from Iran). All known Oriental species are distributed in India, Sri Lanka and Pakistan (Pagliano *et al.* 2020, Lelej, 2005). According to the current classification (Brothers & Lelej 2017), the genus *Spilomutilla* belongs to the subfamily Myrmillinae Bischoff, 1920. In this paper *S. eltola* is newly reported from India.

Materials and methods

This study is based on a single specimen collected during the extensive survey conducted by the Agasthyamalai Biosphere reserve project. Attempts to collect more specimens were unsuccessful.

The specimen was studied using a Labomed CZM6 microscope. Photographs were taken with a Leica DFC 450 camera and images were stacked using Leica V3.80. The images were post-processed to improve contrast and brightness using Adobe® Photoshop® CS6 software. Distribution map of *S. eltola* was constructed using GIS (version 3. 14) software. The specimen is deposited in the 'National Zoological Collections' at the Western Ghat Regional Centre, Zoological Survey of India, Kozhikode (ZSIK).

The terminology mostly follows the Hymenoptera Anatomy Ontology (2013). We had used the abbreviations T1, T2, T3, etc. to denote the first, second, third, etc., Metasomal terga, S1, S2, S3 etc., to denote the first, second, third, etc., Metasomal sterna, and F1, F2, F3, etc., to denote the first, second, third, etc., flagellomeres. New distribution record is asterisked (*).

Results

Subfamily MYRMILLINAE Bischoff, 1920

Genus *Spilomutilla* Ashmead, 1903

Type species: *Mutilla perfecta* Sichel & Radoszkowski, 1869; *Cameronilla* Lelej in Lelej & Krombein, 2001; syn. Brothers *et al.*, 2019.

***Spilomutilla eltola* (Cameron, 1898)**

Syntypes: *Spilomutilla eltola* female, Sri Lanka: Eastern Province, Trincomalee District, Trincomalee (OUMNH) in

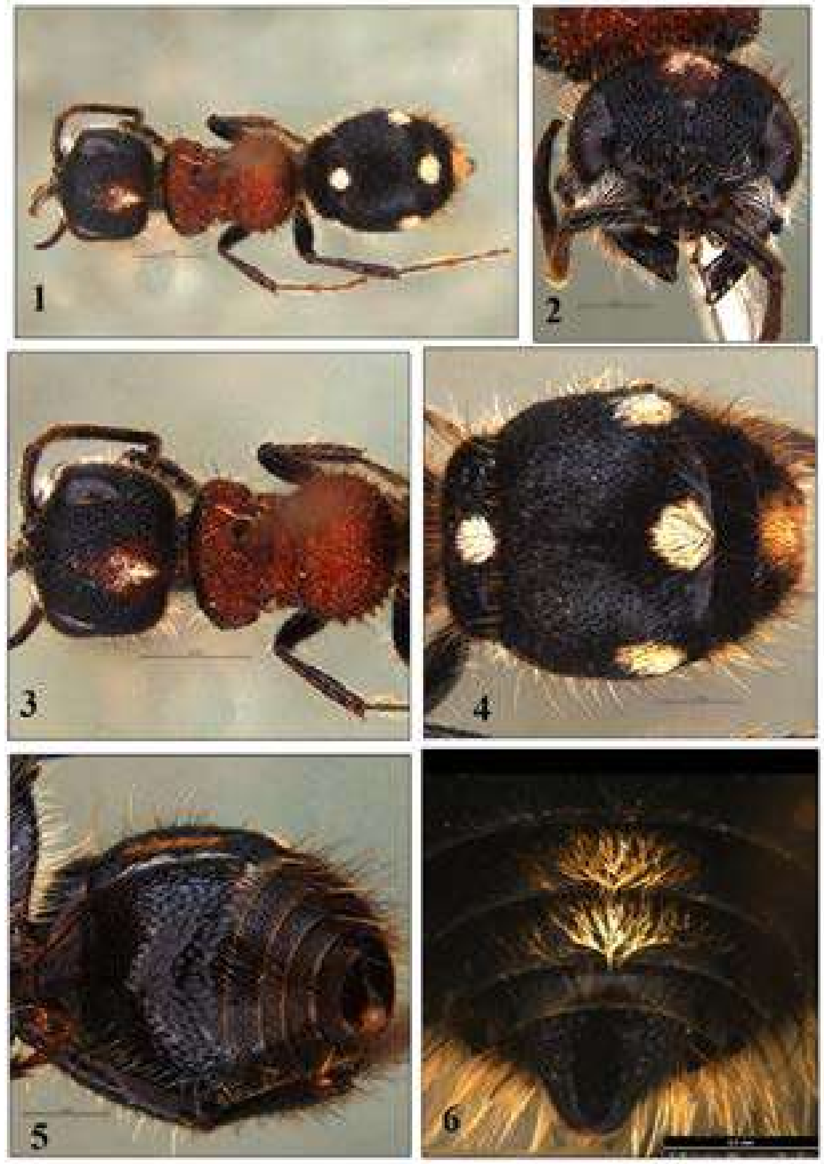
*Author for correspondence : terinejb@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Cameron, 1898: 3–5; André E. female, male, 1907: 3: 251–258.

Diagnosis. Head black, vertex ferruginous and with pale spot. Towards the rim of head and lower side of eyes with pale setae. T4 and T5 with medial pale yellowish round spot.

Description. MALE. Body length 11.06 mm. *Coloration and setation*. Head, metasoma, legs and antennae black. Mesosoma dorsally ferruginous, laterally darker. Head with black setae, towards the rim of head and lower side of eyes with pale setae. Mesosoma and metasoma with sparse pale setae. Head black, vertex ferruginous and with pale spot. Mandible black with sparse pale setae at lower rim. Antennae black, scape with pale setae and shorter ones of same colorant on flagellomeres. T1 with apical medial pale round spot. T2 with one apical pale spot and two similar spots at lateral apical ends. T4 and T5 with medial pale yellowish round spot. S1–S7 black and apical pale setal fringe. Legs with pale setae.

Structure and sculpture. Head. Head punctate, slightly flattened in dorsal view, elongated behind eyes, slightly wider than mesosoma. longitudinal eye diameter 0.59 × minimal distance between eyes, eyes not emarginated. Mandible punctate-alveolate, widened apically. Clypeus medially deeply emarginated. Ratios of pedicel length and F1–3 0.182: 0.431: 0.348: 0.324.



Mesosoma. Maximal mesosoma width 0.9 × head width behind eye. Mesosoma dorsally reticulate, with distinct suture traces, laterally deeply indented at the region of meso–metanotal suture. No traces of scutellar scale. Mesopleuron and metapleuron micro punctate.

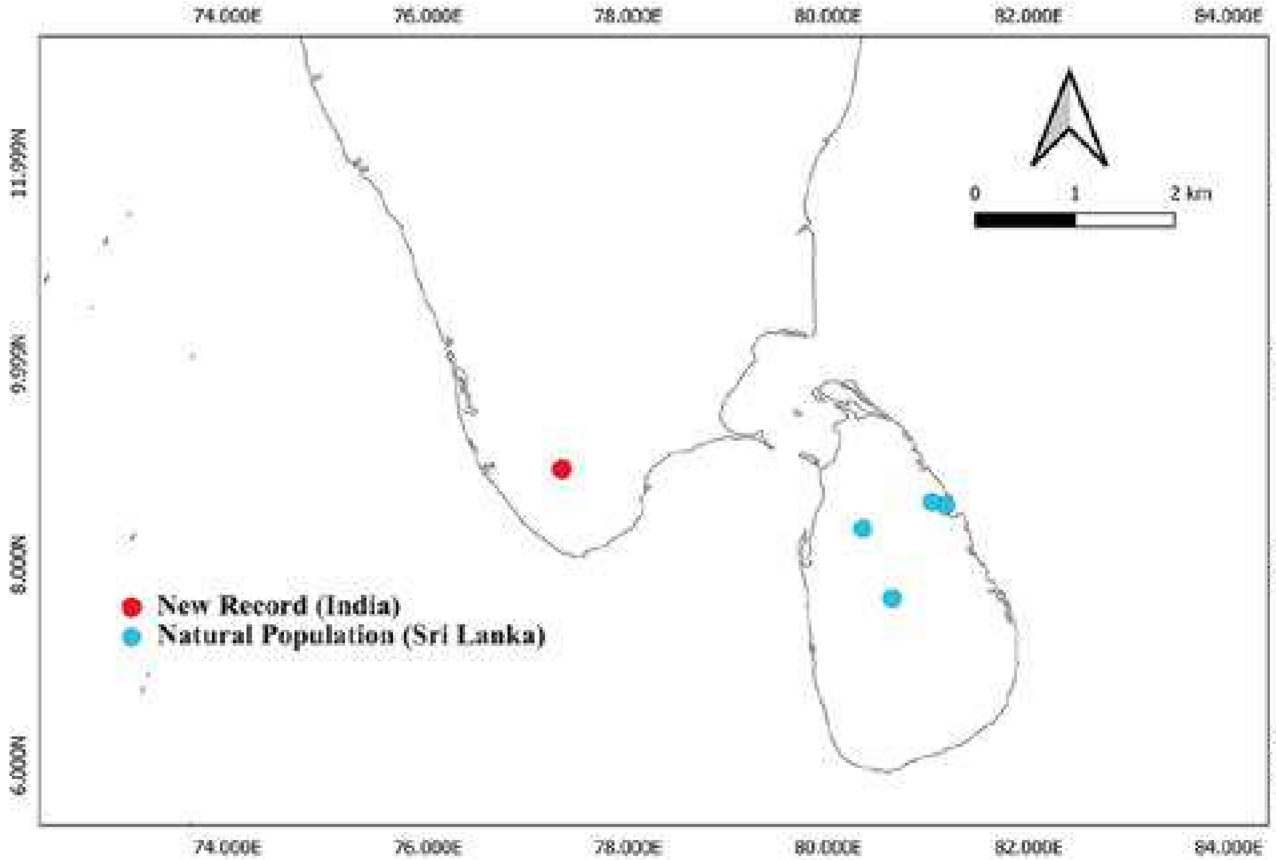
Legs. Mid tibia and hind tibia with one row of spines.

Metasoma. T1 cylindrical, punctate. T2 maximal width 1.44 × T1 maximal width. T2 with pale yellowish lateral felt line. T7 laterally punctate-alveolate, medially smooth. S1–7 punctate.

Material examined. 1 male, INDIA, Tamil Nadu, Thenkashi district, Ukkonam, 8.9515°N, 77.337°E, 165m, 27.VII.2019, B.H.C.K. Murthy & party, ZSI/WGRC/IR/INV. 23150 [ZSIK].

Distribution. India (Tamil Nadu)*, Sri Lanka.

Remarks. The specimen from India varies from that of Sri Lanka in following attributes: 11 mm body length in Indian specimen (9 mm body length in Sri Lankan specimen). Legs black in Indian specimen (Legs brownish in Sri Lankan specimen).



Discussion

During Mesozoic era Sri Lanka was geologically connected to Madagascar, Africa, Southern India and Antarctica (Dissanayake and Chandrajith, 1999), about 180 Mya Gondwana broke into numerous continents which includes India (including Sri Lanka), South America, Africa, Madagascar, Antarctica and Australia (Dittus, 2017). As a result of the glaciation in Antarctica lowered the sea level which opened the land bridge. The periodic low sea levels in the Pleistocene opened the land connection to India and it facilitated two-way dispersion across the Palk Strait (Cooray, 1984). So, there is high probability to find Sri Lankan species in India and vice-versa. Also, Western Ghats of India and Sri Lanka are included among the first 18 global biodiversity hotspots due to high levels of species endemism (Gunawardene *et al.* 2007). Further, elaborate studies are needed that include extensive surveys for observation of the mutillid behaviour, collecting them for identification, prey-predator interaction, etc. This could favour the discovery of still unknown facts of mutillids both from India and Sri Lanka.

Acknowledgements

We are grateful to Dr. Dhriti Banerjee, Director (Zoological Survey of India, Kolkata, India) and Dr. V.D. Hegde, Officer–in–Charge (ZSIK) for providing facilities and encouragements. We are much grateful to Dr. Arkady. S. Lelej for his valuable inputs. JBT thankfully acknowledges authorities of University of Calicut for Ph. D. registration and CSIR for the financial support by means of CSIR–SRF (09/1297(0002)/2019–EMR–I).

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Figures legend

FIGURES 1–6. *Spilomutilla eltola* (Cameron, 1898), male. 1. Habitus, dorsal view; 2. Head, frontal view; 3. Head and mesosoma, dorsal view; 4, 6. Metasoma, dorsal view; 5. Metasoma, ventral view.

FIGURE 7. Distribution Map of *Spilomutilla eltola* (Cameron, 1898).

ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Two new species of Bryophaenocladius Thienemann (Diptera: Chironomidae: Orthocladiinae) from Darjeeling and Kolkata, West Bengal, India with a note on biology of montane species.

***Dipak Kumar Som, Tuhar Mukherjee, Torpita Das and Rima Chakraborty**

Postgraduate Department of Zoology
Maulana Azad College, Kolkata

Abstract

Two new species of *Bryophaenocladius* are proposed and described from West Bengal, India. *Bryophaenocladius kolkataensis* sp.nov. is reported as first Orthoclad from metropolitan areas of Kolkata while *B. pollexus* sp.nov. is reported from the montane regions of Eastern Himalayas biodiversity hotspot. The two species can be separated from other species of *Bryophaenocladius* by the presence of unique inferior volsella and gonostylus. A brief note on the biology of *B. pollexus* sp. nov. with special reference to its habitat preference, larval behaviour and adult swarming has been incorporated. DNA barcode of *B. kolkataensis* sp. n. is also given. A taxonomic key to the adult males of 14 Oriental species of the genus *Bryophaenocladius* is also provided.

Keywords: Chironomidae, Orthocladiinae, *Bryophaenocladius*, new species, chironomid biology

Introduction

The genus *Bryophaenocladius* was erected by Thienemann in 1934 for the species *Orthocladius muscicola* Kieffer, 1906. The genus can be recognized by strong and decumbent acrostichals beginning close to antepronotum; wing membrane bare, with coarse punctation visible at ×40 magnification; tibial spurs strongly developed, with well-developed lateral denticles; tergite IX distinctive, with strongly pigmented, semi-circular band running around posterior margin; anal point large, semi-circular to triangular; virga consisting of simple spines; gonostylus often with a distinctly broadened, strong megaseta (Cranston *et al.* 1989). However, there are significant exceptions to all the generic characters (Du *et al.* 2011). Up to date 14 species have been reported from the Oriental realm, among which only three species have been described from India (Hazra *et al.* 2016, Kong *et al.* 2021).

In this study two new species are described along with a key to the adult males from the Oriental region.

Material and Methods

Sample collection and preparation

Adult midges were collected using pan traps and sweep nets from Maulana Azad College Garden, Kolkata (22° 33'N 88° 19'E; 9.14 m). Montane specimens were collected near the habitat of immature midges in happy valley region (27°3'N 88°15'E, 2100 m) of Darjeeling Himalaya (Figure1). Midge specimens were mounted on glass slides following Wirth and Marston's Phenol Balsam technique (1968). The material examined is temporarily retained in the collection of insects in the Entomology Division, Department of Zoology, Maulana Azad College, Kolkata, West Bengal, India and has deposited to the National Zoological Collections (NZC), Kolkata.

Morphology and Terminology

*Author for correspondence : dipaksom@gmail.com
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Morphology and terminology of larvae, pupal exuviae and adults follow Sæther, 1980. The abbreviations used are: IV – Inner Verticals, OV – Outer Verticals, Po – Post orbitals, AR – Antenna ratio, VR – Veneral ratio, CR – Costal ratio, Fe – Femur, Ti – tibia, Ta – tarsomere, LR – Leg ratio, BV – Beinverhältnisse, SV – Schenkel–Schiene–Verhältnis, BR – Bristle ratio, HR – Hypopygium ratio, HV – Hypopygium value.

Molecular methods

Thorax and one set of legs from one of the collected specimens were processed and outsourced for DNA extraction, amplification using cytochrome c oxidase subunit I (COI) universal primers LCO 1490 and HCO 2198 (Folmer *et al.* 1994) following Lin *et al.* (2018). The amplified products were sequenced by bidirectional Sanger's sequencing. The obtained sequence, trace files and other details were uploaded to the NCBI GenBank.

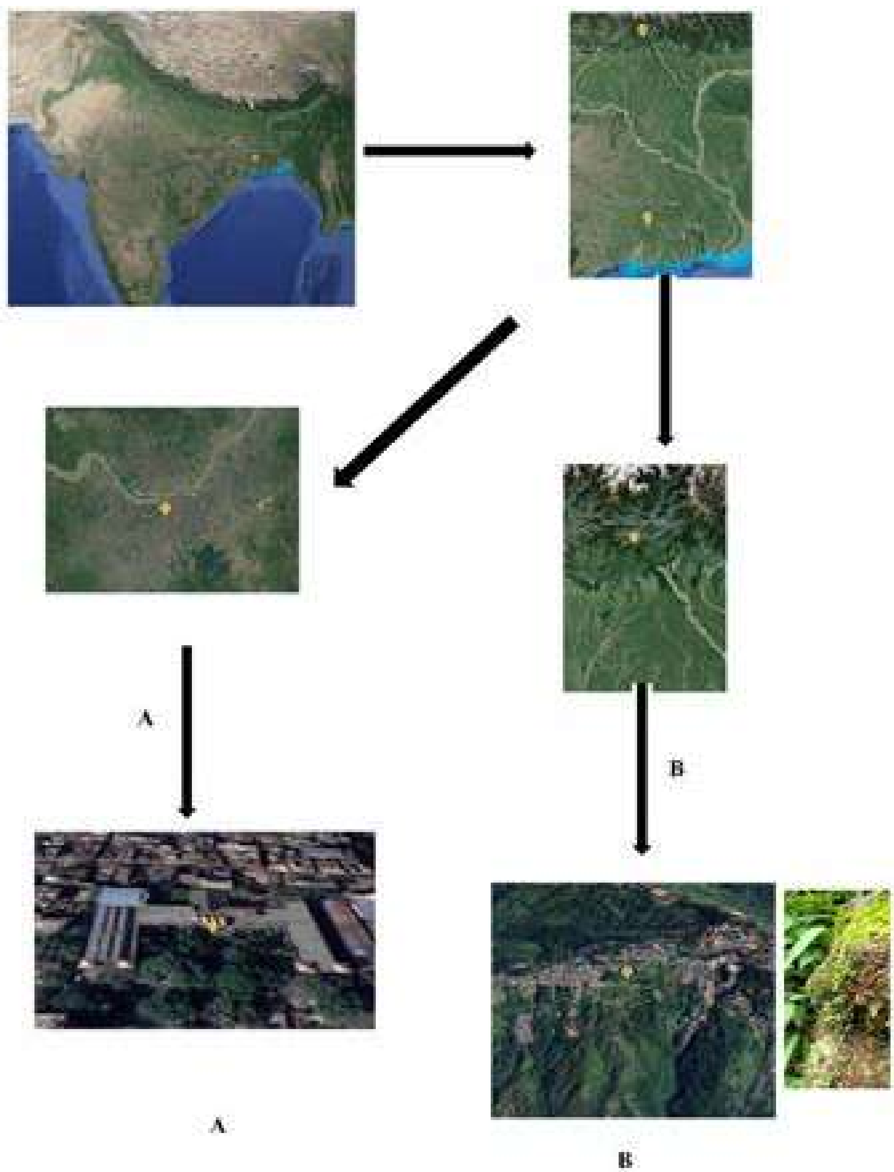

Figure 1. Sites of midge collection (A–B)
A, Maulana Azad College, Kolkata; B, Happy Valley tea Estate, Darjeeling.
(Image source: Google Earth).

Taxonomy

***Bryophaenocladius kolkataensis* sp. nov.**

Etymology *Bryophaenocladius kolkataensis* sp.nov. is named after type locality.

Diagnosis. *Bryophaenocladius kolkataensis* sp.nov. can be recognized by the combination of AR 1.6; gonostylus subapically expanded with well-developed crista; anal point conical.

Material examined. Holotype male: India, West Bengal, Kolkata, Maulana Azad College Garden 22° 33'N 88° 19'E, 9.14 m, 28.vii.2019 Coll. Torpita Das, Regn. No. MAC/DKS 011; paratypes 1 male, data same as holotype Regn. No. MAC/DKS 012.

Genbank accession number. OQ749605

Description

Male imago (n=2)

Total length 1.62-1.67 mm. Wing length 1.47-1.51 mm. Total length/wing length 1.82-1.84. Wing length/length of profemur 2.51-2.53

Colouration Thorax pale, abdomen uniform, legs pale

Head AR 1.6. Ultimate flagellomere 336-364 μm long. Temporal setae 8 (IV 3, OV4, PO 1) clypeus with 8 setae; tentorium 168 μm long, 28 μm wide; palpomere lengths (μm): 36:53:103:110:112; L: 5th/3rd 1.087. Third palpomere without apical digit form projection.

Wing (Fig. 2A) Anal lobe not developed; Coarse punctation easily visible at ×40 magnification. VR 1.1; Costa extension 52 μm long; R with 0 setae; R_1 with 0 setae; brachiolars 1 Squama with 3-4 setae.

Legs Fore tibial spur 56 μm long; mid tibial spurs 58 μm and 27 μm long; hind tibial spurs 62 μm and 37 μm long; Hind tibial comb with 12 spines. Lengths (μm) and proportions of legs as in Table 1.

Table 1. Lengths and proportions of leg segments of *Bryophaenocladius kolkataensis* sp.nov., male (n=2).

	Fe	Ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV
P_1	518	672								
P_2	588	630	196	112	98	84	84	0.31	3.74	6.21
P_3	700	560	322	168	140	70	70	0.57	3.53	3.91

Thorax (Fig. 2B) Antepronotum with 2 lateral setae; dorsocentrals 8; acrostichals 3-4 prealars 5; scutellars 3-4, uniserial.

Hypopygium (Fig. 2C) Anal point triangular, 64 μm long, 28 μm wide; Anal point length/width: 2.3. Tergite IX with 17-18 setae; laterosternite IX with 6 setae; phallapodeme 120 μm long; transverse sternapodeme 98 μm long; Gonocoxite subtriangular 168 μm long; Gonostylus subapically expanded with prominent crista dorsalis, 96 μm long; Megaseta 28 μm long. Inferior volsella narrow, elongated, slightly expanded distally. Virga absent. HR 1.75. HV 2.99.

Remarks. The species is similar to *B. longipenis* Ghosh and Chaudhuri, 1984 in the shape of inferior volsella and AR. However, the shape of anal point, and of gonocoxite are quite different. The new species is similar to *B. manifestus* Ghosh and Chaudhuri, 1984 in the shape of gonostylus, but the anal point of *B. manifestus* is much shorter than in *B. kolkataensis* sp. nov. Inferior volsella of *B. manifestus* is more expanded distally when compared with the proposed new species. The COI sequences of *B. kolkataensis* sp. nov. can be differentiated from other sequenced species by more than ~8% divergence. Among all the sequences available at NCBI GenBank, the barcode sequence of the proposed new species showed least divergence with *Bryophaenocladius huadingensis* with accession number MG301870.

Ecology. The species have been recorded from a small patch of shrub vegetation at Maulana Azad College Garden from Kolkata. Large swarms occur over a tree branch as marker at a height of about 160 cm. Swarming took during the afternoon when weather conditions are hot and humid with temperature ranging from 35°C to 38°C and relative humidity ranged between 87 and 91. The adults of this species are often observed to visit flowers of *Ocimum tenuiflorum* during the daytime and may be considered as one of the potential candidates engaged in pollination activities (Tiusanen *et al.* 2016). However, further study is required in this respect.

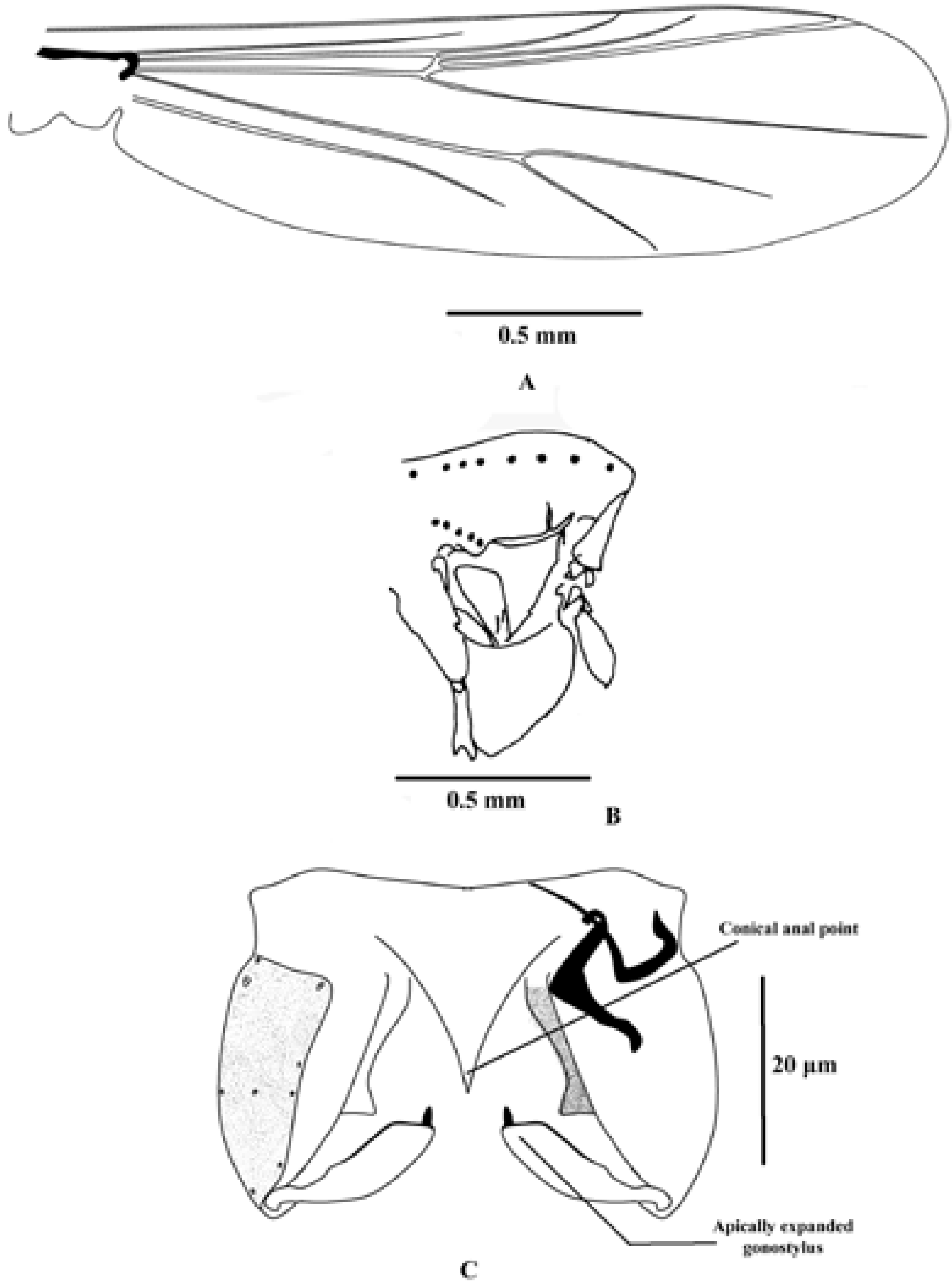

Figure 2. Adult of *Bryophaenocladius kolkataensis* sp.nov.: A: Wing; B: Thorax; C: Hypopygium

***Bryophaenocladius pollexus* sp.nov.**

Etymology *Bryophaenocladius pollexus* sp. nov. is named due to thumb like inferior volsella.

Diagnosis: *Bryophaenocladius pollexus* sp. nov. can be recognized by the combination of thumb-like inferior volsella with 5 strong setae and parallel sided gonostylus.

Material examined. Holotype male: India, West Bengal, Darjeeling, Happy Valley 27°3'N 88°15'E, 2100 m, 10.vi.2002 Coll. D.K. Som, Regn. No. MAC/ DKS 021; paratypes 2 larvae, 2 pupae, 4 males data same as holotype Regn. No. MAC/DKS 022.

Description

Male imago (n=5)

Total length 1.8-2.1 mm. Wing length 1.6-1.7 mm. Total length/wing length 1.1-1.2 Wing length/length of profemur 2.72

Colouration Thorax with lateral and median vittae; abdomen, legs pale

Head AR 1.23-1.33. Ultimate flagellomere 431-432 long. Temporal setae 8-11 (IV 4-5; OV 5-7; PO 0-1); clypeus with 6-8 setae; tentorium 106-112 long, 30-44, wide; palpomere lengths (µm): 28; 44-52; 220-234; 144-148; 243-255. L: 5th/3rd 1.08-1.10.

Wing (Fig. 3A) Anal lobe not developed; Coarse punctation easily visible at ×40 magnification; Costa extension 95-155 long; R with 7 setae; R_1, R_{4+5} with 0 setae; R_{2+3} ends ¼ of distance between R_1 and $R_{4+5;}$ brachiolars 2; Squama bare; VR 1.25; CR 1.16.

Legs Fore tibial spur 36-40 long; mid tibial spurs 28 and 28 long; hind tibial spurs 36 and 38 long; Hind tibial comb with 10 spines. Lengths (µm) and proportions of legs as in Table 2

Table 2. Lengths and proportions of leg segments of *Bryophaenocladius pollexus* sp. nov., male (n=5).

	Fe	Ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV
P_1	628-642	712-726	468-482	296-320	211-223	134	72	0.30-0.31	4.33-4.91	2.86-2.93
P_2	557-571	623-635	187-201	103-112	86-88	84-92	84-90	0.25-0.28	5.03-5.21	6.31-6.43
P_3	689-695	588-602	322-328	173-178	138-143	68-82	72	0.54	4.21-4.33	3.96-4.01

Thorax (Fig. 3B) Antepronotum well developed with 3 lateral setae; dorsocentrals 9, acrostichals 2 decumbent, uniserial, beginning near antepronotum; prealars 4; scutellars 3 uniserial.

Hypopygium (Fig. 3C) Anal point triangular, 64 µm long, 32 µm wide; Anal point length/width 2.0 Tergite IX with 26 setae; laterosernite IX with 4 setae; phallapodeme 128-130 long; transverse sternapodeme 133 µm long; lateral sternapodeme 67 µm long; Gonocoxite cylindrical 256 µm long; Gonostylus parallel sided with prominent crista dorsalis, 149 µm long; Crista reduced; Megaseta 21-24 µm long. Inferior volsella thumb-like, with 5 strong setae. Virga 8-9 long. Hypopygium ratio (HR) 1.61-1.63. Hypopygium value (HV) 2.20

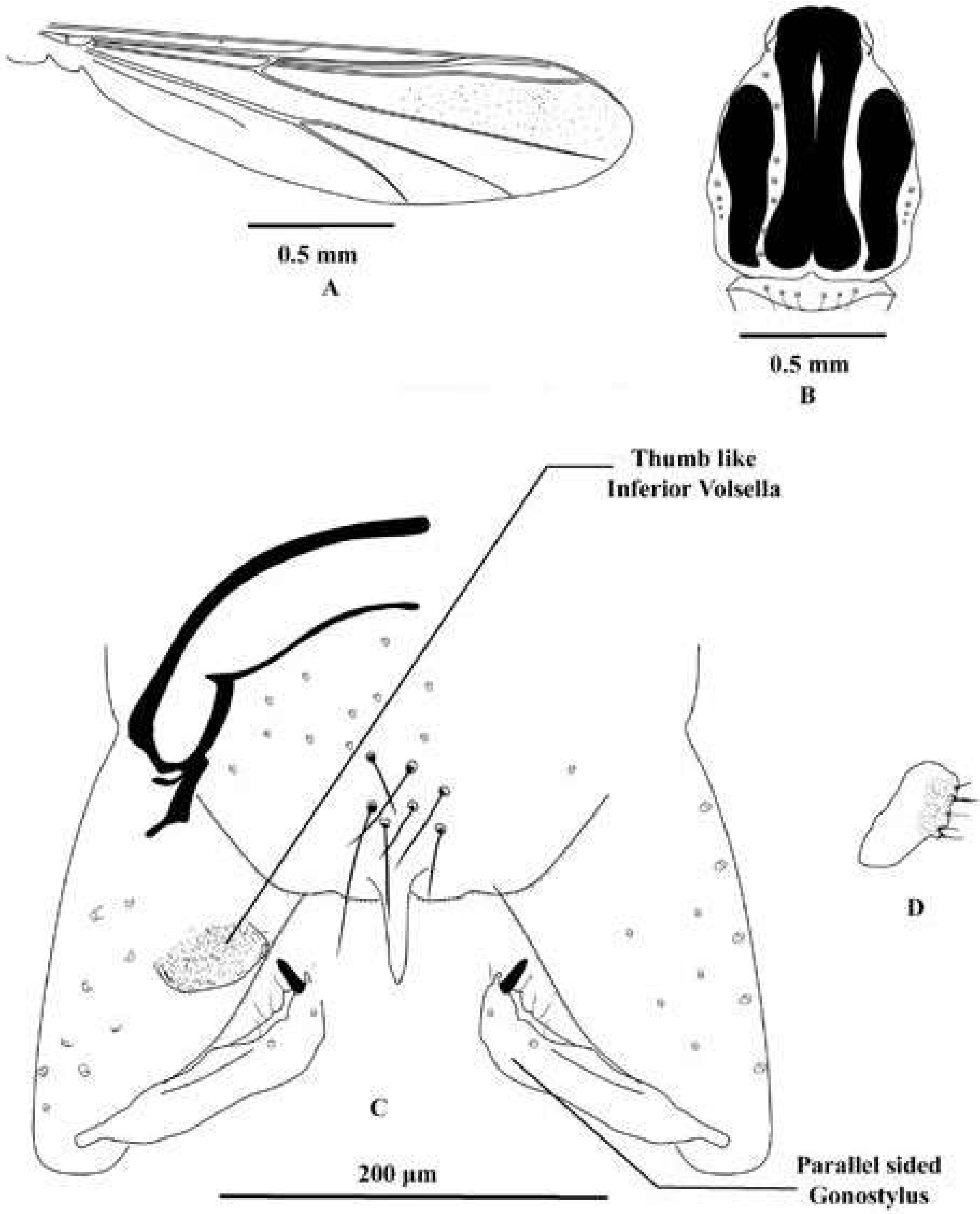

Figure 3. Adult of *Bryophaenocladius pollexus* sp.nov.:
A: Wing; B: Thorax; C: Hypopygium; D: Inferior volsella

Pupa (n= 6)

Total length of exuviae: 2.93. Exuviae transparent, light brown.

Cephalothorax (Fig. 4A): Frontal apotome as in figure; Antennal sheath 700 long in male and 400 long in female.

Thorax (Fig. 4B) Thoracic horn absent; Frontal setae each of 50 long; Anterior and posterior precorneal setae each 70-80 long, spine-like, median precorneal seta absent; median antepronotals three, spine-like, each about 54 long; lateral antepronotals`2; Dorsocentrals 28-30 long; distance between Dc_1 and Dc_2 36-45, between Dc_2 and Dc_3 24-28, between Dc_3 and Dc_4 34-36; wing sheath 0.08 to 0.09 mm long, basal part 0.07 long.

Abdomen (Fig. 4C) Tergites entirely covered by strong shagreen spinules, shagreen spinules distributed from Tergite I to IX. Number of dorsal and lateral setae present form tergites I to VIII are given in Table 3.

Anal lobe (Fig. 4D) 200-300 long, shagreen spinules stronger and marginal spinules small spine-like; Genital sac overreaches anal lobe by 50; anal lobe without fringe and macrosetae.

Table 3. Setae present on segments I-VIII

	I	II	III	IV	V	VI	VII	VIII
Dorsal	0	0	0	0	0	0	0	0
Lateral	1	1	1	1	1	1	1	1

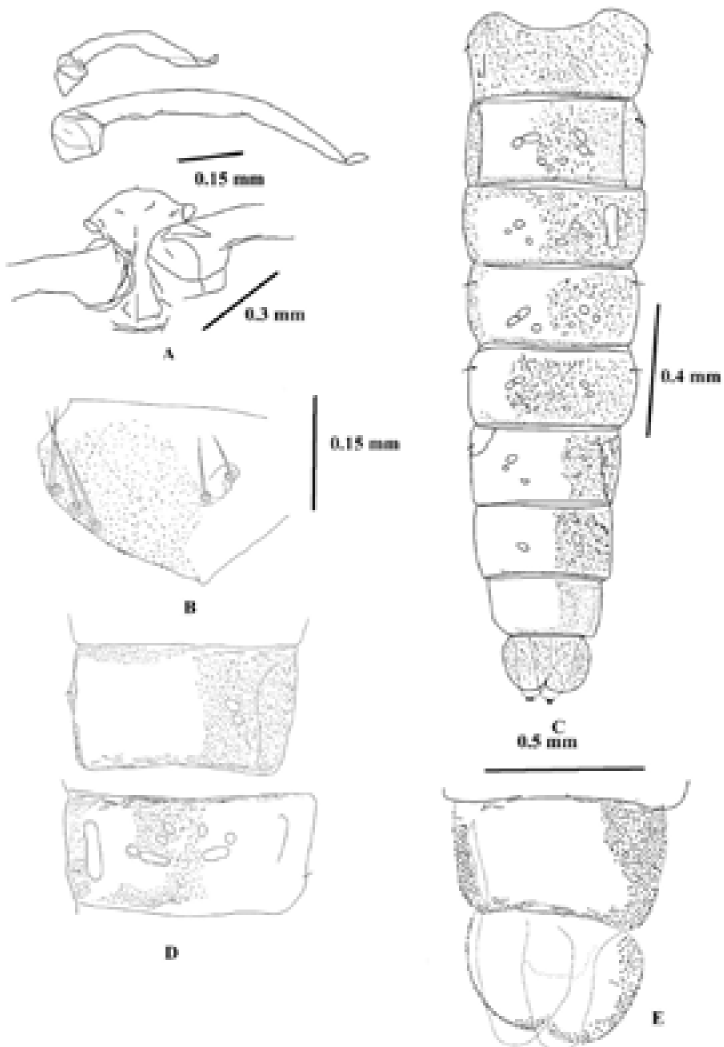

Figure 4. Pupa of *Bryophaenocladius pollexus* sp.nov. (Dorsal view): A: Frontal Apotome, Wing sheath and antennal sheath; B: Anterior part of Thorax; C: Pupal exuviae; D: Tergite VII; E: Tergite VIII and anal lobe

Fourth instar larva (n= 2)

Body colour golden yellow; Body length 3.2 – 4.0 mm; Ventral Head capsule length 0.35 – 0.4 mm.

Head (Fig. 5). Antenna (Fig. 5B), Length ratio of antennal segments (I – V): 18.75 : 16.5 : 2.25 : 3.75 : 1.5. AR 0.78. Basal antennal segment 0.12 mm wide with ring organ 0.015 mm in diameter; distance from base to ring organ 0.019 mm. Blade 0.24 mm long, nearly equal to flagellum; Lauterborn organ 0.008 mm long; *Premandible* (Fig. 5C), 0.065 mm long, with 2 teeth; *Mandible* (Fig. 5D) 0.158 mm long, seta subdentalis sharp spine-like, 0.008 mm long, seta interna with 2 branches; *Mentum* (Fig. 5E) width 0.064 mm with dome-shaped 2 median teeth, total width 0.018 mm, and 4 pairs of lateral teeth; *ventromental plate* 0.008 mm wide, slightly extends beyond outer lateral tooth on flattened mentum; setae submenti 0.012 mm long. *Abdomen* (Fig. 5F): Abdominal segment VIII and posterior parapods bearing segment are flexed at right angle to the rest of the body; posterior parapods separate with minute simple claws; anal tubules not measurable; Procercus absent, seta absent at the end of the body.

Remarks: The proposed new species is similar to *B. nodosus* in the shape of the morphology. However, the shape of gonostylus, HR of *B. nodosus* (2.28) is much higher than the proposed new species.

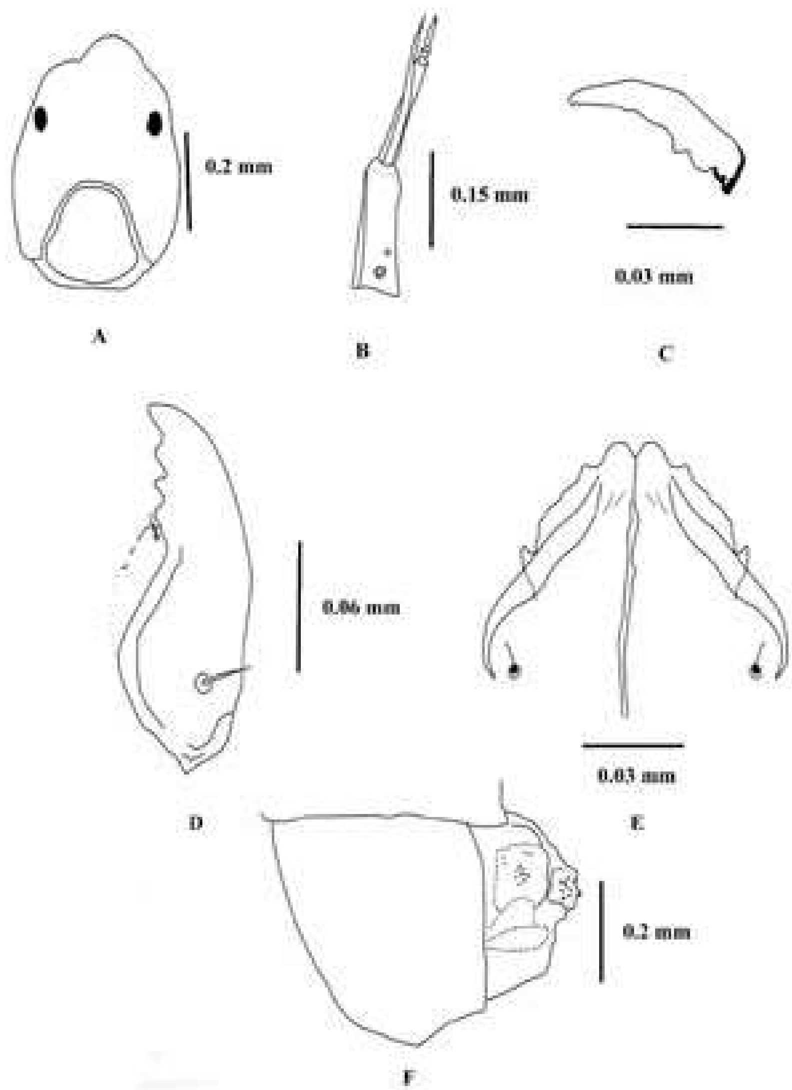

Figure 5. Larva of *Bryophaenocladius pollexus* sp.nov.:
A: Head Capsule; B: Antenna; C: Premandible; D: Mandible; E: Mentum; F: Abdomen

Ecology: Very little is known of the biology of *Bryophaenocladius pollexus* sp. nov. Larvae and pupae of this species are terrestrial in their habitat. Immature are found to live on solid substrata within mat of rhizoids of certain bryophytes and leafy liverworts (*Porella* sp.). This kind of microhabitat holds some humid soil-like particles (Pinder 1995). They are also found on the surface of woody stem of tea plants *Camellia sinensis.* Optimum temperature, sunlight intensity and humid environment probably play important role for their abundance in the montane regions like Darjeeling Himalaya (Armitage *et al.* 1995). Larvae are golden in colour. The abdominal parts of live pupae have golden coloured abdomen while the cephalothorax is light brown coloured. The larvae, when come out of rhizoid mat, do not crawl over the vegetative structure of bryophytes, instead show characteristic jumping movement. After imaginal moult, pupal exuviae are found attached to the vegetative surface of bryophytes. The emergence pattern of *B. pollexus* sp. nov. shows a definite peak during the months of September and October. Adults are day-light swarmer with low height swarming occurs near their habitat indicating ground as visual swarming marker. They are found to swarm over the substratum during sunny weather probably indicating sun light as one of the important swarming cues.

Key to the adult males Oriental species of the genus *Bryophaenocladius*

1. Squama bare -- 2
  - Squama with setae -- 6

2(1). Crista absents -- 3
  -Crista present -- 4

3(2). Costal extension absent; AR>1.0 (India) ------------------------- *B. manifestus* Ghosh and Chaudhuri, 1984
  - Costal extension present; AR<1.0 (China) ------------------------- *B. paricterricus* Lin, Qi and Wang, 2012

4(2). Anal point absent (Japan) ------------------------- *B. iriopequesus* (Sasa and Suzuki, 2000)
  - Anal point present -- 5

5(4). Gonostylus parallel sided; inferior volsella thumb-like (India) ------------------------- ***B. pollexus* sp.nov**.
  - Gonostylus wide at apex; inferior volsella inconspicuous (China) --------------- *B. parimberbus* Du and Wang, 2010

6(1). Squama with more than 5 setae -- 7
  - Squama with less than 5 setae -- 9

7(6). Gonostylus curved; inferior volsella knob-like (India) ------------------------- *B. nodosus* Hazra and Das, 2011
  `- Gonostylus not curved; inferior volsella elongated -- 8

8(7). Anal point pointed; pseudospurs present on tarsomeres 1 and 2 of mid and hind legs (China) ------------------------- *B. mucronatus* Lin, Qi and Wang, 2012
  - Anal point blunt; pseudospurs absent (India) ------------------------- *B. longipenis* Ghosh and Chaudhuri, 1984

9(6). Gonostylus curved; inferior volsella hyaline (China) ------------------------- *B. huadingensis* Kong, Wang and Lin, 2021
  - Gonostylus not curved; inferior volsella not hyaline -- 10

10(9). Gonostylus wide at apex -- 11
  - Gonostylus apically expanded (China) ------------------------- *B. xinglongensis* Du and Wang, 2010

11(10). Gonostylus acutely hooked apically; HR<1.5(Japan, Russia) --------- *B. akiensis* (Sasa, Shimomura and Matsuo, 1991)
  - Gonostylus not apically hooked; HR>1.5 -- 12

12(11). Gonostylus triangular; gonocoxite lobe with strong setae (China, Canary Islands) --------------------------------------- *B. cuneiformis* Armitage, 1987

- Gonostylus not triangular; gonocoxite lobe absent --- 13

13(12). Crista well developed; veins R, R_1 bare (India) --- ***B. kolkataensis* sp.nov**.

- Crista not well developed; veins R, R_1 with setae (China) -------------------------- *B. wufengensis* Du and Wang, 2010

Acknowledgement

The authors are thankful to the Principal, Maulana Azad College, Kolkata and Head, Post graduate Department of Zoology, Maulana Azad College, West Bengal, India for rendering laboratory and library facilities. The authors are thankful to Dr. Martin Spies, Zoologische Staatssammlung München, Germany and Dr. Xiaolong Lin, Associate Professor, Engineering Research Center of Environmental DNA and Ecological Water Health Assessment, Shanghai Ocean University, China and Professor P. K. Chaudhuri for proving literature pertaining to the study.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Taxonomy of the genus *Nala* Zacher, 1910 (Dermaptera: Labiduridae) from India

***Shruti Lekha Dey and K. G. Emiliyamma**

Zoological Survey of India, M-Block, New Alipore, Kolkata West Bengal-700053, India

Abstract

Three species of the genus *Nala, viz*., *Nala lividipes* (Dufour, 1829), *Nala nepalensis* (Burr, 1907) and *Nala basalis* Bey-Bienko, 1970 are known from India. These species are redescribed and illustrated based on detailed morphological characters, the unique male forceps structure and the structures of male genitalia. New additional diagnostic characters, which are more specific to each species are proposed for the identity of these species. A key to the Indian species of the genus *Nala* is provided, along with a systematic list, geographical distributions, type localities, taxonomic remarks, digital images and point distribution map of each Indian species. This study will be useful for the accurate identification of the species by future researchers.

Keywords: Dermaptera, *Nala*, redescription, India.

Introduction

Dermaptera are commonly known as "earwigs" and are primitive group of free-living insects abundant in tropical countries than other regions, comprising around 1,942 species globally (Hopkins *et al*., 2017), of which 285 species are reported from India (Srivastava, 1988, 2003, 2013 and Karthik *et. al*., 2022). The genus *Nala* was erected by Zacher in 1910 with *Forficula lividipes,* as the type species. The genus *Nala* Zacher, 1910 belongs to the subfamily Nalinae Steinmann, 1975 under the family Labiduridae Verhoeff, 1902, which consists of three subfamilies, five genera and twenty-two species from India. Subfamily Nalinae Steinmann, 1975 consists of only one genus *Nala* Zacher, 1910, with eleven species distributed throughout the Ethiopian, Oriental, Australian and South Palaearctic regions (Steinmann 1989 a, b; Vigna 1994; Bivar, 1999) and seven species distributed throughout South-East Asia (Petr, 2006), out of these, three species, *Nala lividipes* (Dufour, 1829), *Nala nepalensis* (Burr, 1907) and *Nala basalis* Bey-Bienko, 1970 are known from India (Srivastava, 2003). *Nala lividipes* (Dufour, 1829) is the most abundant species of the genus in the Indian fauna. The present study represents a review of the genus *Nala* Zacher, 1910 from India, including the redescription of Indian species of this genus, with type localities, geographical distributions, taxonomic remarks, digital images and point distribution map. Keys to all the Indian species of the genus are also given.

Material and methods

The specimens studied were collected and deposited at the National Zoological Collection of Zoological Survey of India, Kolkata, India (NZSI) by different survey parties and also some recent collections made by the authors, from West Bengal and Andhra Pradesh surveys. These specimens of Dermaptera were identified based on morphological characters and the unique structure of male genitalia, following Srivastava (1988, 2003 and 2013). For the study of morphological characters and genitalia, the specimens were examined under Leica EZ4 stereo zoom–microscope. The genitalia extracted from the male specimens by lifting penultimate sternite, and processed in KOH, stained and mounted on slides. The photographs and measurements were taken by a digital camera Leica DMC 4500 attached with Leica M205A stereo-zoom Microscope. The point

*Author for correspondence : shrutilekha1995@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

distribution map was created with QGIS software. For dry preservation specimens were cleaned, stretched and pinned and for wet preservation specimens were preserved in 70% alcohol.

Also study and examined the Holotypes and Paratypes of the species available in IARI, New Delhi and National Zoological Collection of Zoological Survey of India, Kolkata, India (NZSI).

Results

Taxonomy

Family- **Labiduridae**Verhoeff, 1902

Subfamily- **Nalinae** Steinmann, 1975

Genus- ***Nala*** Zacher, 1910

Type species: *Forficula lividipes* Dufour, 1829.

Paralabidura Burr, 1910, (synonymised by Burr, 1911) (treated as synonym of ***Nala*** Zacher, 1910)

Diagnosis:

Representatives of this genus are medium to small sized (up to 16.5 mm in length), usually uniform dark, blackish body colour, legs are yellow with basal half of femora and tibiae blackish. Head convex, hind margin of pronotum firmly rounded, antennae filiform, slender with 20 to 23 segments, elytra and wings well developed and punctate; legs short; abdominal segments convex, body flat parallel-sided. In males, both branches of the forceps are stout, arcuate, apex pointed, with or without basal inner teeth; in females, forceps are simple straight with serrated inner margins. Male genitalia with parameres apically constricted, epimerite absent.

Distribution:

This genus shows distribution throughout the Oriental, African, Ethiopian, Australian and South Palaearctic regions (Steinmann 1989a).

Key to species of the genus *Nala* Zacher, 1910 from India (males only)

(Modified from Srivastava, 2003)

1. Penultimate sternite triangular, hind margin rounded, little emarginate in middle posteriorly (figs. 2H, 5E): parameres about 3-5 times longer than broad, margins are undulated. -- 2

   - Penultimate sternite broad (fig. 7E), hind margin obtusely produced in middle; parameres (figs. 8A, 8B) about seven times longer than broad, both margins are straight, tip acuminate, pointed ---------------- *Nala basalis* Bey-Bienko, 1970

2. Forceps (figs. 2F, 3A-3K) with branches stout, remote, gently incurved, each tapering with apices pointed; parameres (figs. 4A, 4C) three times to four times longer than broad, external margin convex, inner margin straight with little undulations -- *Nala lividipes* (Dufour, 1829)

   - Forceps (figs. 5F,5G) with branches internally dilated, in basal one third, reaching nearly to midpoint, with its inner margin contiguous and strongly serrated, afterwards branches gently incurved; parameres (figs. 6A, 6B) five times longer than broad, both margins are little undulated --- *Nala nepalensis* (Burr, 1907)

***Nala lividipes* (Dufour, 1829)**

Forficula pallipes Dufour, 1820, *Ann gener des Se. Phys. de Bruxelles,* 4; 316, pI. 116, figs. 7, 7a & 7b (Male, Female; Lower Catalonia, Spain).

Forficula lividipes Dufour, 1829, *Annis Sci. Nat.,* 13: 340 (new name proposed since *Forficula pallipes* Dufour, 1820 preoccupied by *Forticula pallipas* Fabricius, 1775).

Labaidura lividipes : Bormans and Krauss, 1900, *Das Tierreich,* 11 : 36.

Nala lividipes : Burr, 1911, *Genera Insect.,* 122: 36.

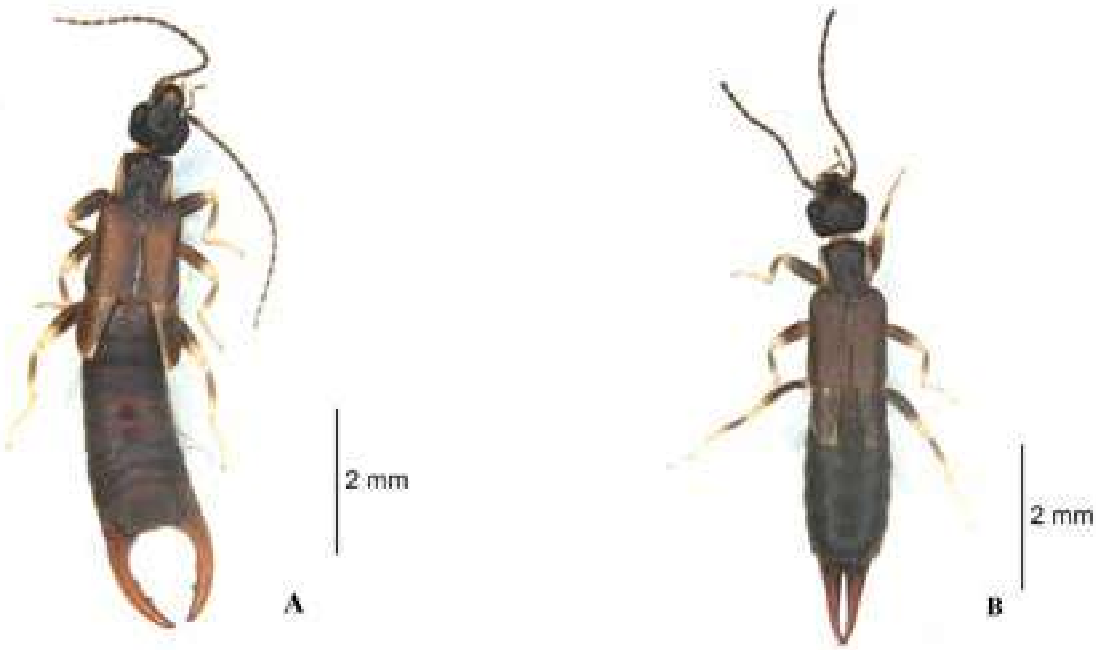


Figure 1. *Nala lividipes* (Dufour, 1829). A, Dorsal view, male; B, Dorsal view, female.

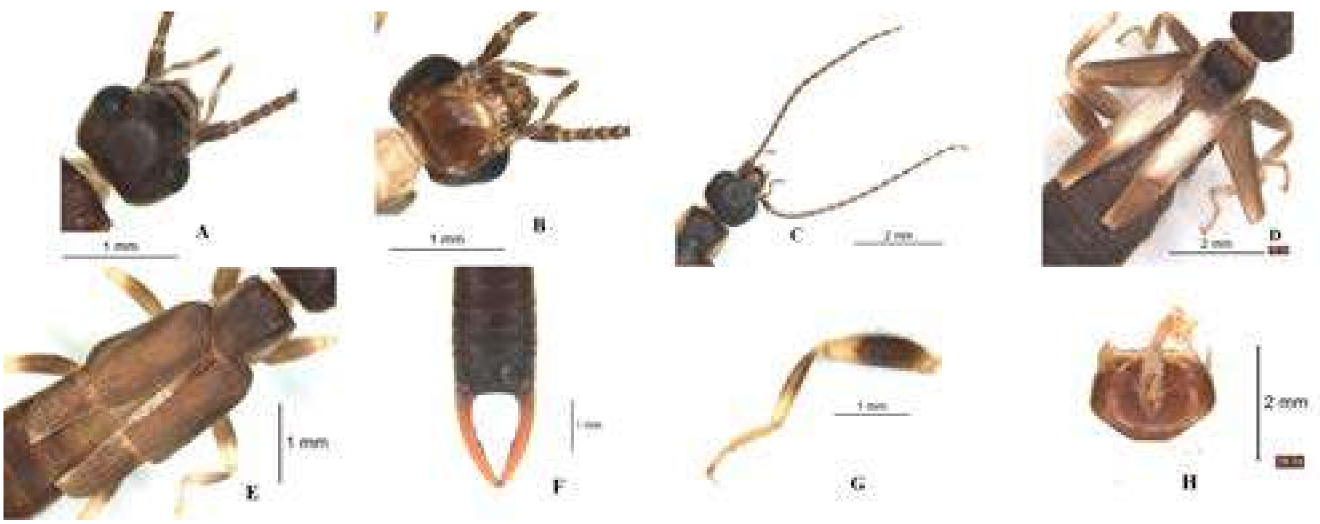


Figure 2. *Nala lividipes* (Dufour, 1829), male. A, head & eye; B, mouth parts, ventral view; C, head with antennae; D, uncovered wings & elytra; E, pronotum, elytra & wing; F, ultimate tergite with forceps; G, leg; H, penultimate sternite with genitalia, ventral view.

Material examined

India: 1 (Paratype male), Madhya Pradesh: Ashok nagar, 21.ix.1963, coll. V. C. Kapoor; 4 , 5 (Reg.No.36554/H5), West Bengal: Purba Bardhaman dist., Memari, 23.179340˚N, 88.09506˚E, altitude: 22.87 m, 07.v.2021, coll. S. L. Dey; 6 , 13 (Reg.No.39483/H5, 39734/H5), Andhra Pradesh: Kurnool: Srisailam, Sunde Penta, 16.058389˚N, 78.867262˚E, Altitude: 522.12 m, 25.iii.2022, coll. K. G. Emiliyamma & party.

Redescription

Male (Figs, 2A-H, 1A)

Small to medium sized body with colour dull blackish brown, sometimes ashy brown; eyes dark black; head more darker than body; antennae (Fig. 2C) dark blackish brown with yellowish white border in basal joints of each antennal segment, few pre-apical antennal segments are yellow; mouth parts (Fig. 2B) brown with yellowish white joints; both sides of pronotum, leg joints, inner wingtips (Fig. 2E) yellow; legs (Fig. 2G) yellow with half to 3/4th of basal femora and tibiae blackish brown to black patch. Sometimes elytra and wings are copper brown in colour with blackish brown outer margin.

Head, legs, antennae, mouth parts, abdomen and forceps evenly covered with fine yellow (golden-yellow) hairs; brown to blackish brown hairs present in margins of head, pronotum, elytra, legs and antennal bases.

Head (Fig. 2A) highly pubescent, convex, slightly longer than broader, hind margin little concave, slightly emarginate in middle, head broader than pronotum, mainly broad in basal eye portion. Antennae 21 (Fig. 2C) segmented, basal segment stout, shorter than the distance between antennal bases, 2nd short, about as long as broad; 3rd long, slender than 4th to 6th; 3rd and 7th are almost equal in length; 4th slightly shorter than 5th to 7th, 5th shorter than 6th & 7th and 6th shorter than 7th; The following segments gradually become shorter and thinner. Eyes (Fig. 2A): dark, prominent, slightly reflexed, shorter than the post-ocular area. Pronotum (Fig. 2E) is slightly broader than long, anterior margin in middle slightly convex, hind margin gently rounded, prozona swollen with distinct suture, metazona depressed, suture is not prominent in metazoan. Elytra (Fig. 2E) and wings (Fig. 2E) well developed, punctate; elytra with parallel longitudinal ridge in costal margin. The part of wings (Fig. 2D) that covered by elytra is membranous, off-white in colour. The total wing length is more than two times of pronotum. The abdomen is highly punctate, with abdominal segments convex and gradually expanded posteriorly. The Penultimate sternite is triangular, has marginal curvature, rounded, and emarginate through its middle posteriorly. Ultimate tergite (Fig. 2F) transverse, slightly depressed medially, swollen above the roots of the inner margin of forceps. Pygidium is invisible in the dorsal view.

Male forceps (Figs. 1F, 3A-L)

There is an immense variation in the male forceps. Forceps with branches stout, remote, gently incurved, each tapering with apices pointed.

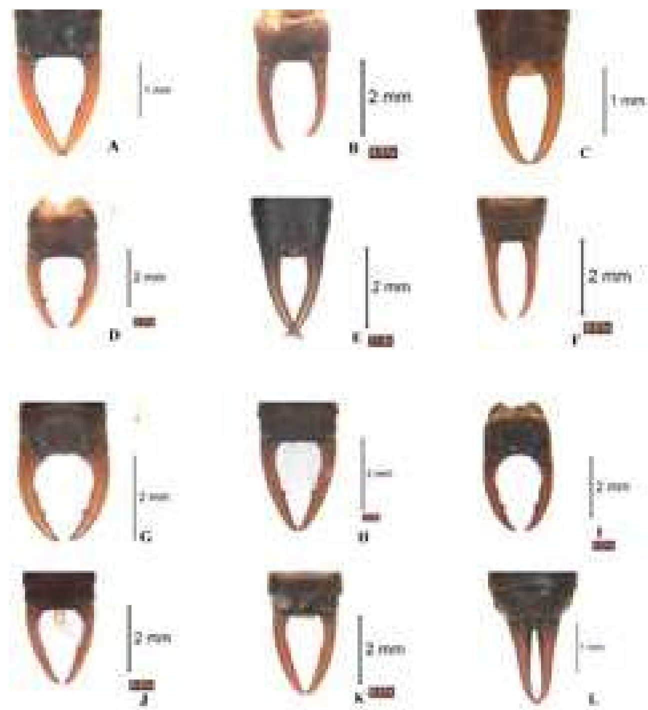


Figure 3. *Nala lividipes* (Dufour, 1829). A-K, male forceps, dorsal view; L, female forceps, dorsal view.

Important variations in Male forceps (Figs. 3A-K).

The inner margin ventrally crenulate (Fig. 3D, 3G, 3I), sometimes crenulated only in basal 1/3rd with a distinct tooth at apical third, or sometimes at apical half and sometimes tooth absent. Ventral side of inner margin entirely crenulated or sometimes very few unevenly distributed crenulation without any tooth (Fig. 3B, 3C, 3K, 3E, 3F). Inner ventral margin with very small tooth like crenulation at basal 1/3rd; apical one third with undulated inner margin and with pointed triangular tooth (Fig. 3G, 3I).

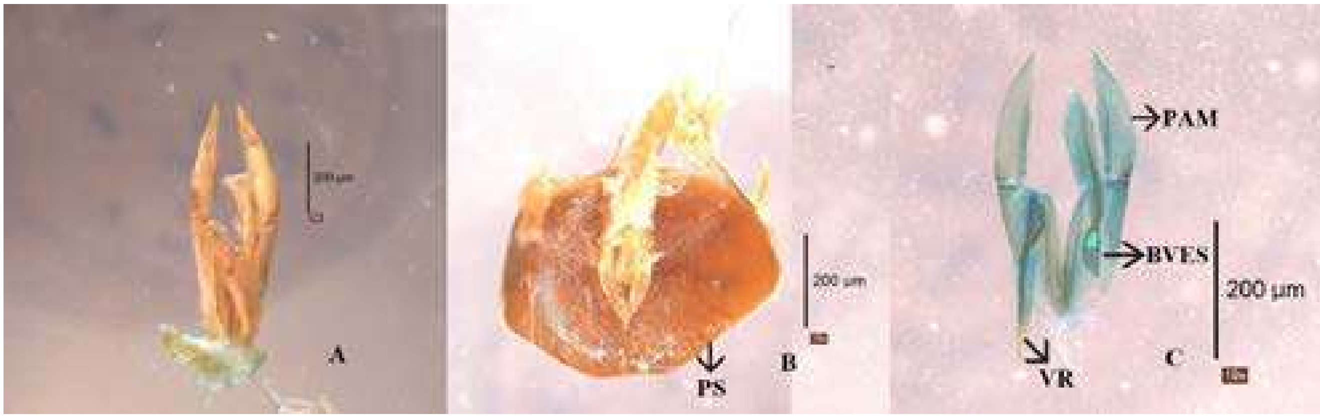


Figure 4. *Nala lividipes* (Dufour, 1829), male. A,C, male genitalia, B, genitalia attached in penultimate sternite; PAM- paramere; VR- virga; BVES- basal vesicle.

Male Genitalia (Figs.4 A-C)

Male genitalia typical for the genus *Nala*, with parameres (Fig. 4A, 4C) near about four times longer than broad, tip acute, external margin convex, inner margin straight with little undulations, virga (Fig. 4C) tubular, prominent, distinct basal vesicles (Fig. 4C) with one margin convex and another margin straight.

Female (Figs. 1B, 3L)

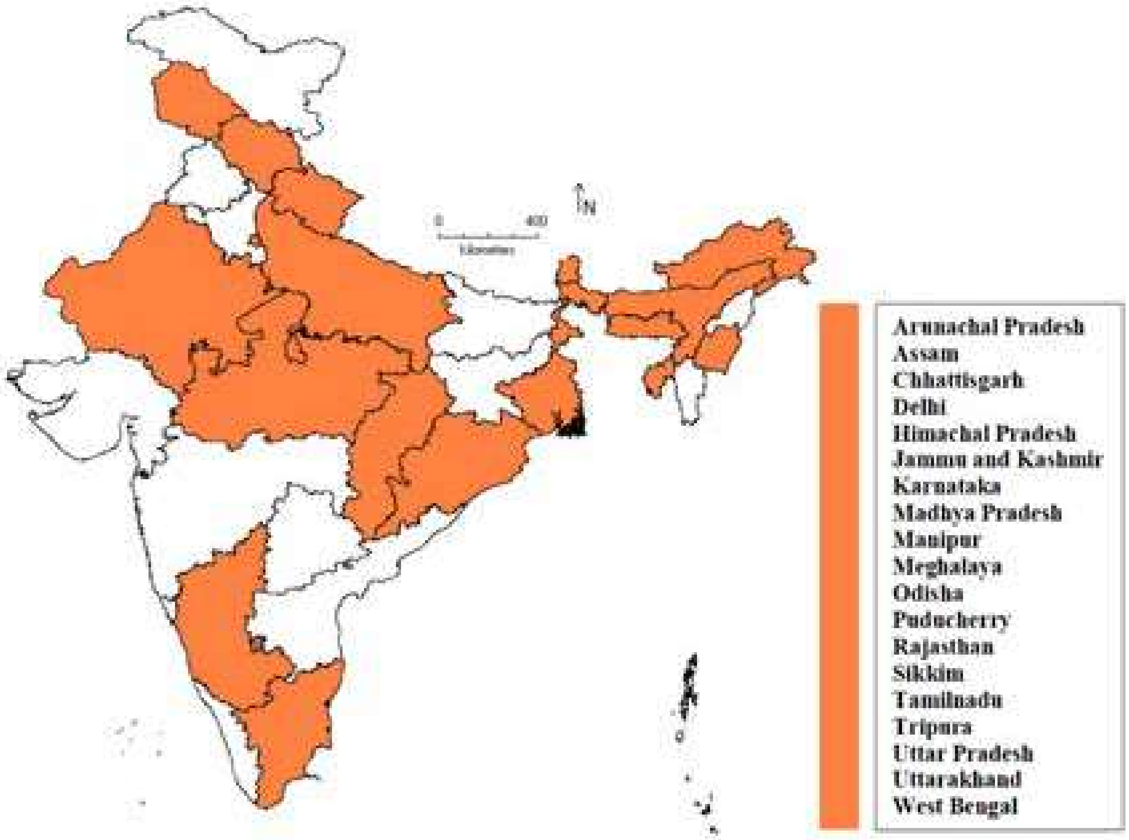
In most characters, females agree with males except the last few abdominal segments and ultimate tergite strongly constricted posteriorly; forceps (Fig. 3L) straight, simple, tapering apically, serrated internally in basal half, apical half brown to reddish brown in colour, tip incurved.

Remarks

Body colour ranges varies from blackish brown to ashy brown, sometimes testaceous brown; male forceps variation is very much an important distinct feature. This species is distributed worldwide. Specimens were collected from multiple habitats viz. underneath stones, debris, loose soil. This species is very much available during the rainy season and attracted to light in large numbers.

Distribution

Nala lividipes (Dufour, 1829) is a cosmopolitan species of Afrotropical origin, gradually distributed across all biogeographic realms, dominant in tropical parts. Distributed almost throughout India, Bhutan, Nepal, Sri Lanka (Srivastava, 2003) and also reported from Australia. The species is widely distributed along the Mediterranean basin recorded from Algeria, France, Italy (including Sicily and Sardinia),Portugal, Malta, Morocco, Spain (including the Balearic and Canary Islands), Turkey, and Tunisia (Albouy and Caussanel 1990; Anlaş and Kočárek 2012; Pages 2012; Mifsud and Taglianti 2008; Rasplus and Roques 2010;). (Koutsoukos, E. *et al.*, 2022).



Map 1. Distrubution of *Nala lividipes* (Dufour, 1829) in India.

***Nala nepalensis* (Burr, 1907)**

Labidura nepalensis Burr, 1907, *Rec. Indian Mus.,* 1 : 208 (Male, Female; Nepal Soondrijal and Pharping); Burr, 1910, *Fauna British India, Dermaptera* : 96, pl. 4, fig. 30.

Paralabidura nepalensis: Burr, 1910, *Trans. ent. Soc. Lond.,* 1910: 185.

Nala nepalensis : Zacher, 1910, *Ent. Redsch.,* 1910: 184.

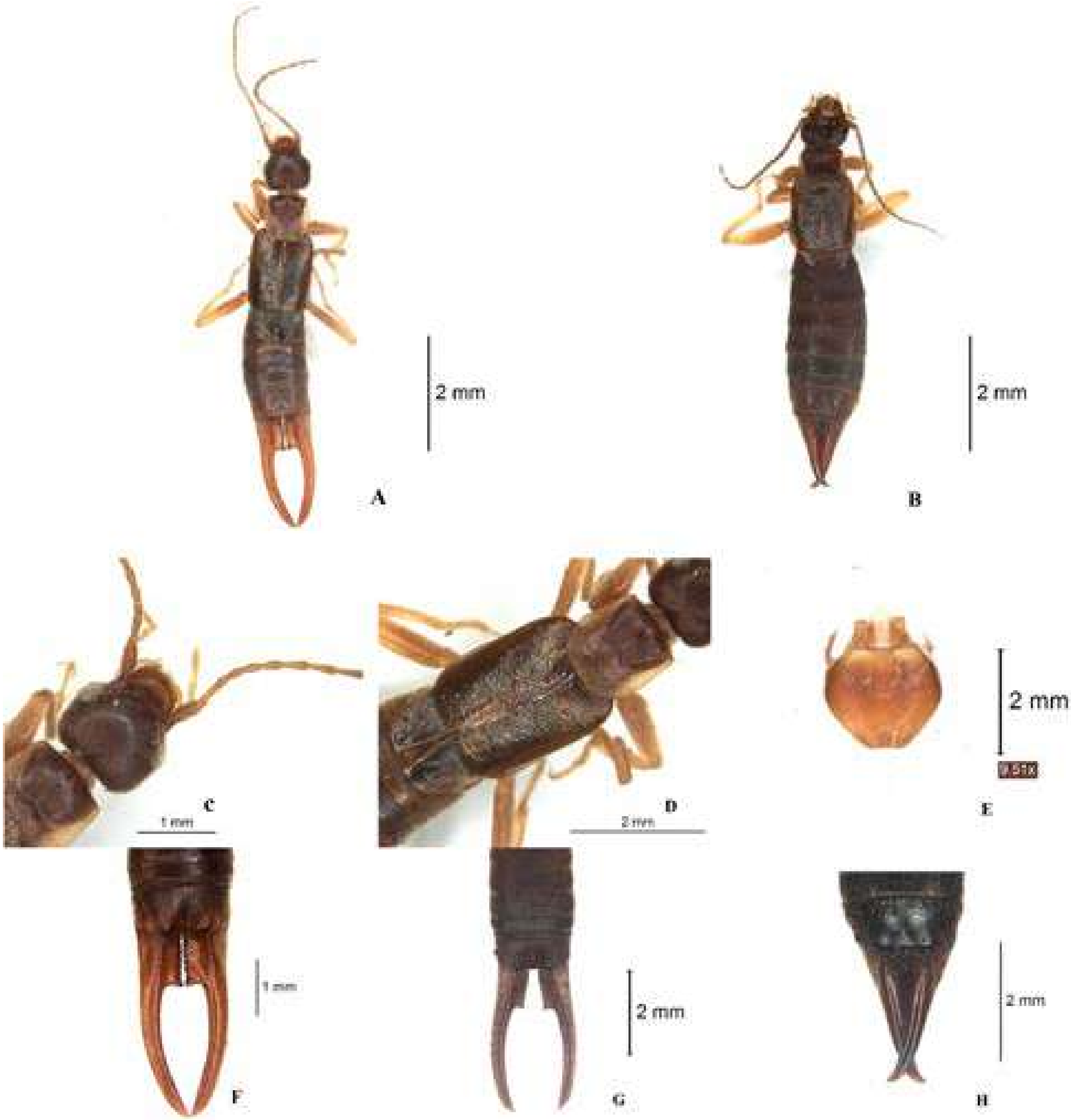


Figure 5. *Nala nepalensis* (Burr, 1907). A, Dorsal view, male; B, Dorsal view, female; C, head, eye, antennae; D, pronotum, elytra, wings; E, penultimate sternite, ventral view; F&G, ultimate tergite with male forceps; H, ultimate tergite with female forceps.

Material examined

1 , 1 (Reg. No. 38499/H5), India: Himachal Pradesh: Mandi, bank of river Beas, 08.ii.1965, coll. A. Husain; 1 , 1 (Reg. No. 38500/H5), Himachal Pradesh: Solan, Giripool, 30°52'54"N, 77°12'36"E, 06.x.2012, coll. V.D.Hedge & Party; 6 , 3 (Reg. No. 37926/H5), Arunachal Pradesh: West Kameng, Ramo camp, 01.ix.1984, coll. R. N. Bhargava.

Redescription

Male (Figs. 5A, 5C-G)

General body colour brownish black; body colour uniformly distributed from head to abdomen; eyes (Fig. 5C) shining black; antennae (Fig. 5C) yellowish brown; legs (Fig. 5A) yellow to brownish yellow with basal half of femora and tibiae shaded blackish brown to black; forceps brown to reddish brown with black shaded.

Head, antennae, mouth parts, abdomen, forceps and legs covered with fine golden-yellow hairs. In the abdomen and ventral body parts pubescence is very dense.

Small to medium sized body; head convex, smooth, approximately same width and length, frons depressed; invisible suture, hind margin straight with little depressed in middle. Antennae (Fig. 5C) 22 segmented, basal segment little shorter than the distance between antennal bases, expanded apically; 2nd short, same length and breath; 3rd long, slender, length about three times of 2nd; 4^{th} to 6^{th} gradually increasing, but shorter than 3^{rd} and longer than 2^{nd}; 7^{th} equal to 3^{rd}; remaining segments gradually become longer. Eyes shining black, compared to the post-ocular area, the eyes are shorter. Pronotum (Fig. 5D) slightly longer than broad, sides straight, a little reflexed in penultimate part, rounded hind margin, prozona tumid, smooth, suture prominent; metazona highly rugose, suture distinct; width of pronotum equal with head. Elytra (Fig. 5D) with straight hind margin, keeled costal margin and the texture rugose, tuberculated; length slightly shorter than two times of pronotum. Wings (Fig. 5D) well developed, major parts concealed under elytra; remaining short triangular, rugose and tuberculated like elytra. Abdomen (Fig. 5A, 5B) is densely punctated and pubescent, in the middle slightly dilated. A tringular, punctated Penultimate sternite (Fig. 5E) is obtuse angular posteriorly, the posterior margin resembles a truncate triangle, and the middle margin is moderately emarginate. Ultimate tergite (Fig. 5F, 5G) is slightly broad, transverse, median line visible in posterior half, hind margin straight, concave in the middle, with protuberance at each base of forceps branch and slightly oblique laterally In the dorsal view, Pygidium is narrowly visible and posteriorly, it is small and rounded.

Male forceps (Figs. 5F,5G)

Forceps with stout branches, very much dilated internally in basal $1/3^{rd}$, sometimes it touches each other or sometimes it is reaching nearly to midpoint, with its inner margin contiguous, strongly serrated and terminating into an incurved blunt tooth; afterwards branches gently incurved, cylindrical, tapering apically with tip pointed.

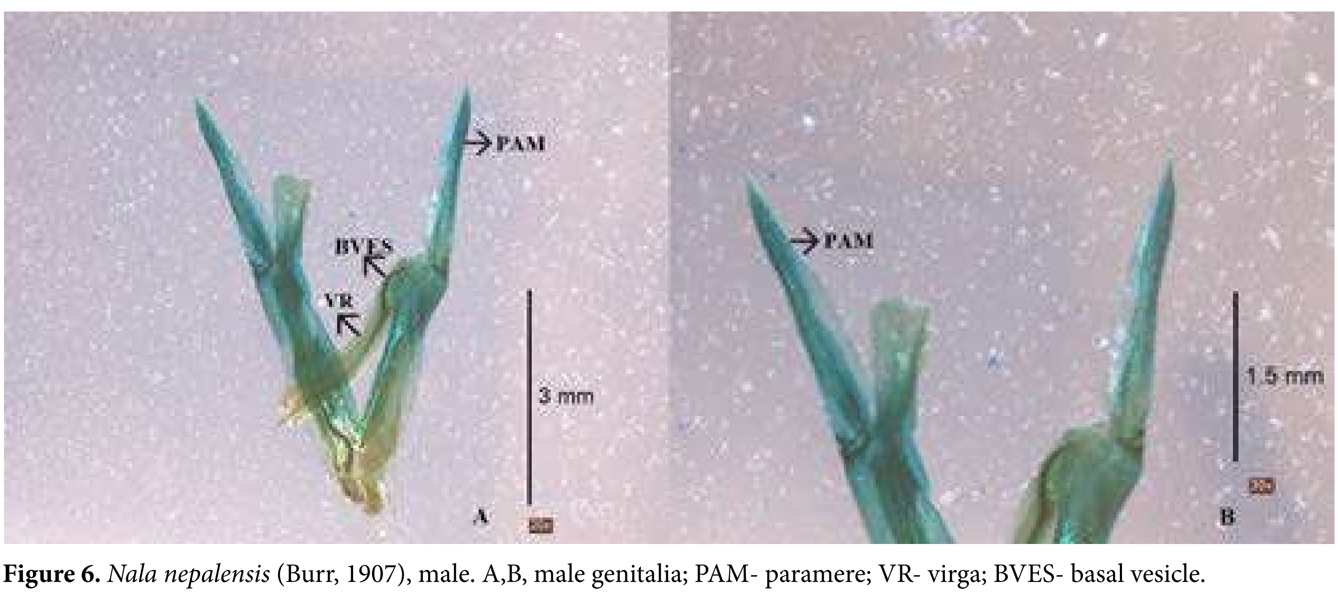


Figure 6. *Nala nepalensis* (Burr, 1907), male. A,B, male genitalia; PAM- paramere; VR- virga; BVES- basal vesicle.

Male Genitalia (Figs. 6A, 6B)

Male genitalia typical for the genus *Nala*, in comparison to the width, the parameres are five times longer, both margins are slightly undulated, penultimate outer margin reflexed, tip acute; virga thin, prominent, distinct basal vesicles.

Female (Figs. 5B, 5H)

Most of the female chatacteristics are similar to male, but differs in, the abdomen, which is slightly wider in the middle, posteriorly constricted ultimate tergite , forceps reddish brown, simple, straight with apices gently incurved, meeting, inner margin irregularly serrated.

Remarks

Nala nepalensis (Burr, 1907) is mainly a mountain-dwelling species. The specimens of this species were collected from underneath stones, on the edge of water bodies, rivers and streams.

General body colour varies from dull brownish black to shining reddish brown.

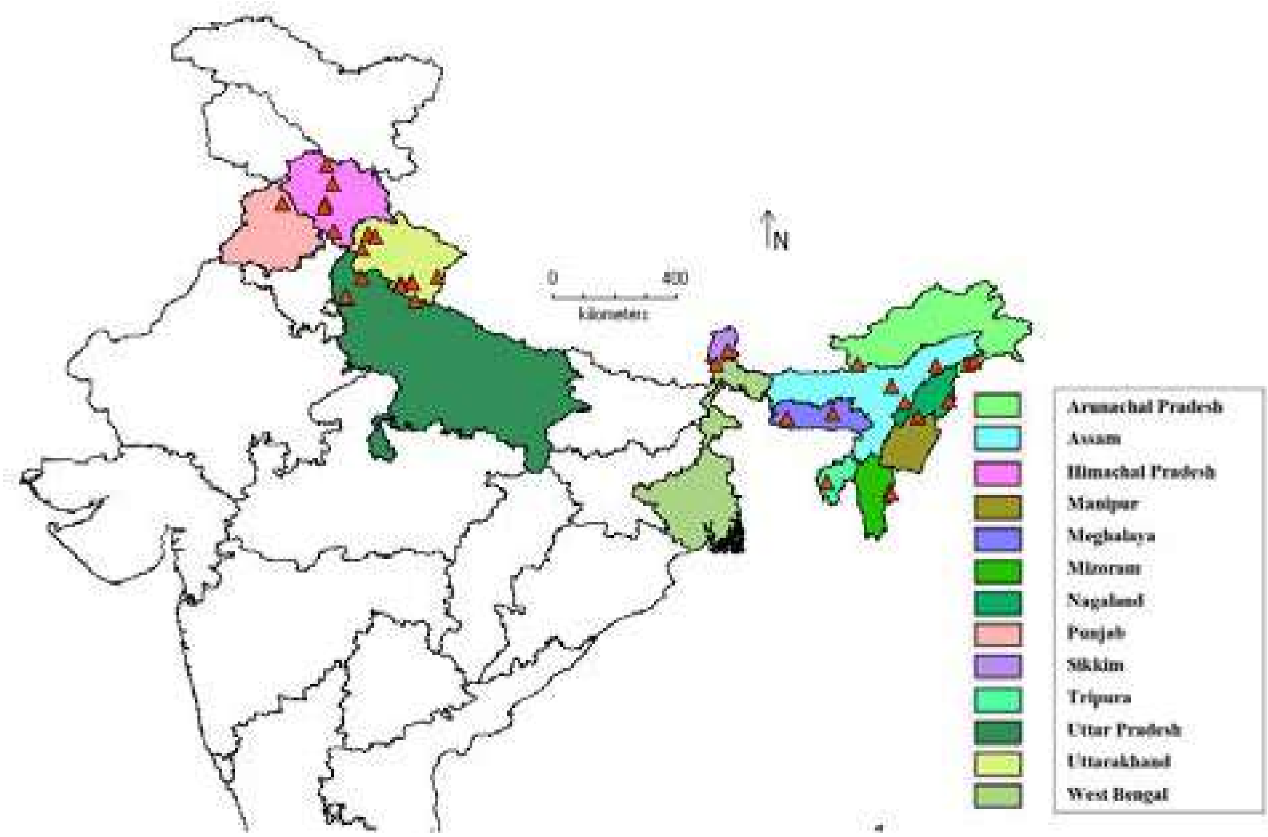
Burr (1907) identified 4 males and 6 females from Nepal but none of them was designated as the Holotype. Burr (1910) identified the Holotype, which is now present in the National Zoological Collections of ZSI HQ, Kolkata. In ZSI HQ, Kolkata one male labelled as "Nepal, Sondrijal, Reg. No. 1285/15" with a handwritten label, by Burr, "*Labidura nepalensis* Burr Type" treated as the Holotype. Besides, five more specimens with Reg. Nos. 1245/15, 1283/15, 1284/15, 1286/15 and 1299/15 are present which are considered as Paratypes (Srivasatava, 2003).

Distribution

India: Arunachal Pradesh, Assam, Himachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Sikkim, Tripura, Uttarakhand, Uttar Pradesh, West Bengal, Jammu and Kashmir. Also distributed in Bhutan, China, Nepal, Pakisthan (Srivastava, 2003).

***Nala basalis* Bey-Bienko, 1970**

Nala basalis Bey-Bienko, 1970, *Zool. Zh.,* 69 : 1814, fig. 9-12 (Holotype Male, Paratypes 2 Females; West Pakistan: 25



Map 2. Distribution of *Nala nepalensis* (Burr, 1907) in India.

km No Rawalpindi; Paratype 7 Females East Afghanistan, Kunnar Tal, 900m); Srivastava, 1984, *Bull. zool. Surv. India,* 5(2&3): 11 (Thailand); Steinmann, 1975, *Folia ent. hung.,* 28: 157, fig. 21 (Male genitalia); Steinmann, 1989, *Das Tierreich,* 105 :433, figs. 687-688; Steinmann,1989, *World Catalogue of Dermaptera* : 358; Sakai, 1982, *Bull. Daito Bunka Uniu.,* 20: 31.

Material examined

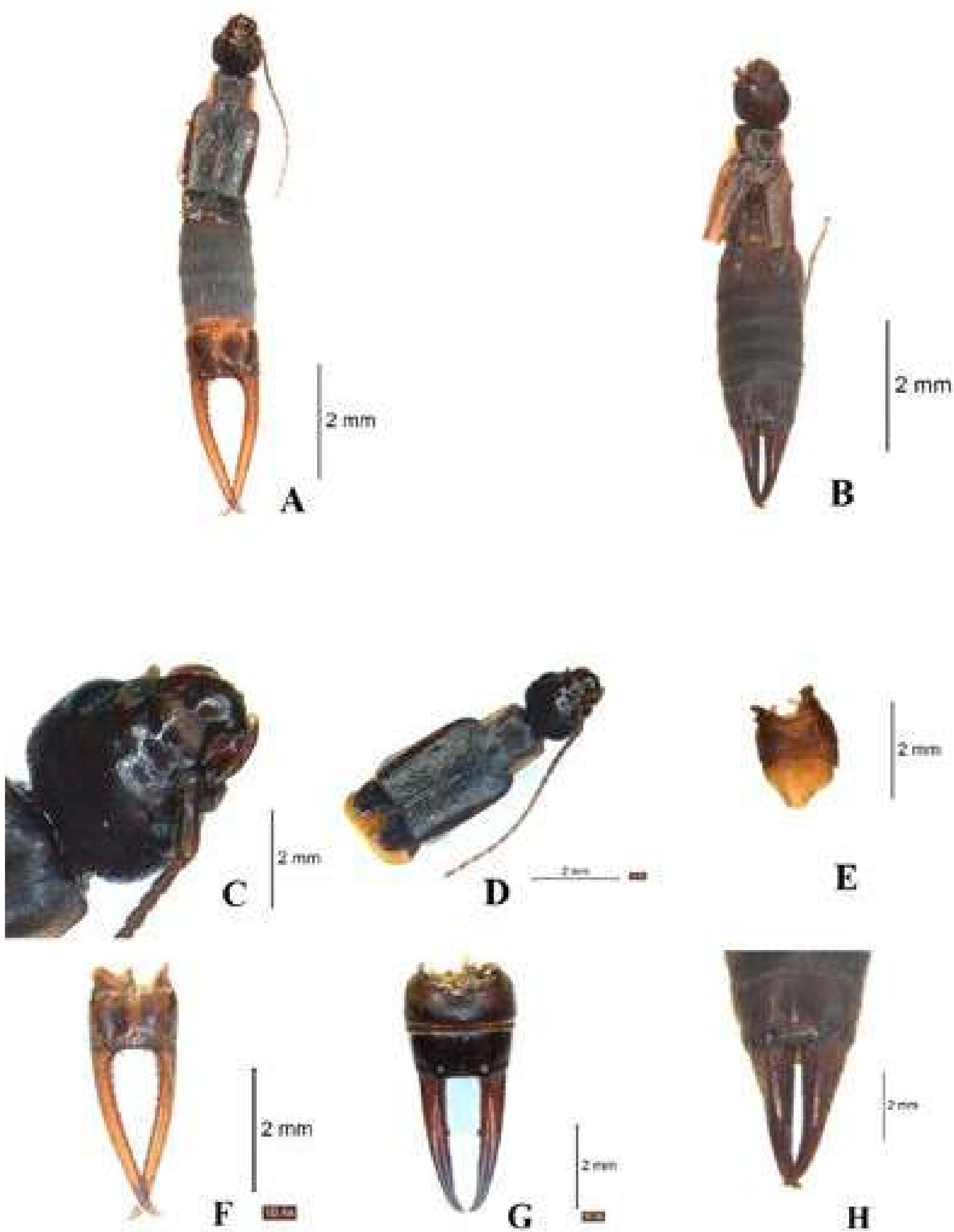


Figure 7. *Nala basalis* Bey-Bienko, 1970. A, Dorsal view, male; B, Dorsal view, female; C, head, eye; D, pronotum, elytra, wings & antennae; E, penultimate sternite; F&G, ultimate tergite with male forceps; H, ultimate tergite with female forceps.

2 , 2 , India: Mizoram: Lawngtlai dist., Kaladan/ Tuipui river bank, 22°06'20"N, 92°50'40"E, 1000 ft, 23.iii.1979, coll. P. T. Cherian; 2 , Manipur: Moreh, 24°15'10"N, 94°18'04"E, 25.x.1975, coll. M. S. Shishodia.

Redescription

Male (Figs. 7A, 7C-G)

Small to medium sized body; head, pronotum, elytra and wings shining dark brownish black; antennae (Fig. 7D) brownish black; mouth parts brown; sides of pronotum and legs brownish yellow with basal half of femora and tibia brownish black, abdomen (Fig. 7A) dull blackish; ultimate tergite (Fig. 7F. 7G) and forceps (Fig. 7F. 7G) brown to reddish brown.

Head, antennae, abdomen, forceps and legs densely pubescent by golden brown hairs; pronotum, elytra and wings without pubescent except few small brown hairs present on the margins only.

Head (Fig. 7C) slightly longer than broad, frons convex, sutures absent, hind margin almost straight. Eyes (Fig. 7C) prominent, dark black, very much shorter than the post-ocular area. Antennae 23 segmented, length of 1st segment shorter than the distance between the bases of the two antennae and the length is equal with the combined length of 2nd and 3rd; length of 3rd and 20^{th} are similar and in comparision with all subsequent segments upto 19^{th} these two are longer; the length of remainig segments increases gradationally from the 4th onwards. Pronotum (Fig. 7D) expanded posteriorly, with wide curve angles along the hind margin; length moderately long compared to the width; prozona little upraised, smooth and separated from flat, rugose metazonal disc;the median suture prominently distinct. Head slightly broader than pronotum. Elytra (Fig. 7D) and wings (Fig. 7D) well developed, shining, rugose; elytra 1.7 times of pronotum, hind margin straight, with prominent ridge along the costal margins. Abdominal segments convex, abdomen highly punctate and pubescent. Both sides of the Penultimate sternite (Fig. 7E) slightly concave, texture uniformly punctate, and in the middle, the hind margin is obtuse. The Ultimate tergite (Fig. 7F, 7G) broad, transverse, elevated above, laterally oblique, slightly depressed, posterior-medially. In front of the hind margin in between two forceps, the hind margin is curved, with an invisible median line in between. Pygidium is convex, constricted apically with rounded tip, and from the dorsal view it is barely visible.

Male forceps (Figs. 7F , 7G)

Forceps brown to reddish brown, slightly lighter than body colour with dense pubescence, basally branches are remote, gradually in-curved from basal one third, subsequently straight, tapering apically with apex gently hooked and tip pointed.

Significant variations in Male forceps (Figs. 7F , 7G)

The basal one fifth forceps look trigonal, later weakly depressed, directed backwards with its inner margin denticulated evenly up to bases, apex touches with each other or crossed; depressed lobe present at the ventral margin of each forceps bases, sometimes basal lobe is slightly larger but narrowed apically, sometimes it looks like triangular basal flap. Occasionally forceps with more stout branches, little less pubescence, internal margin unevenly serrated with blunt tooth in the internal margin of basal half, branches gently incurved, dorso-ventrally flattened, apex tapering, gently hooked without meeting tip.

Male Genitalia (Figs. 8A, 8B)

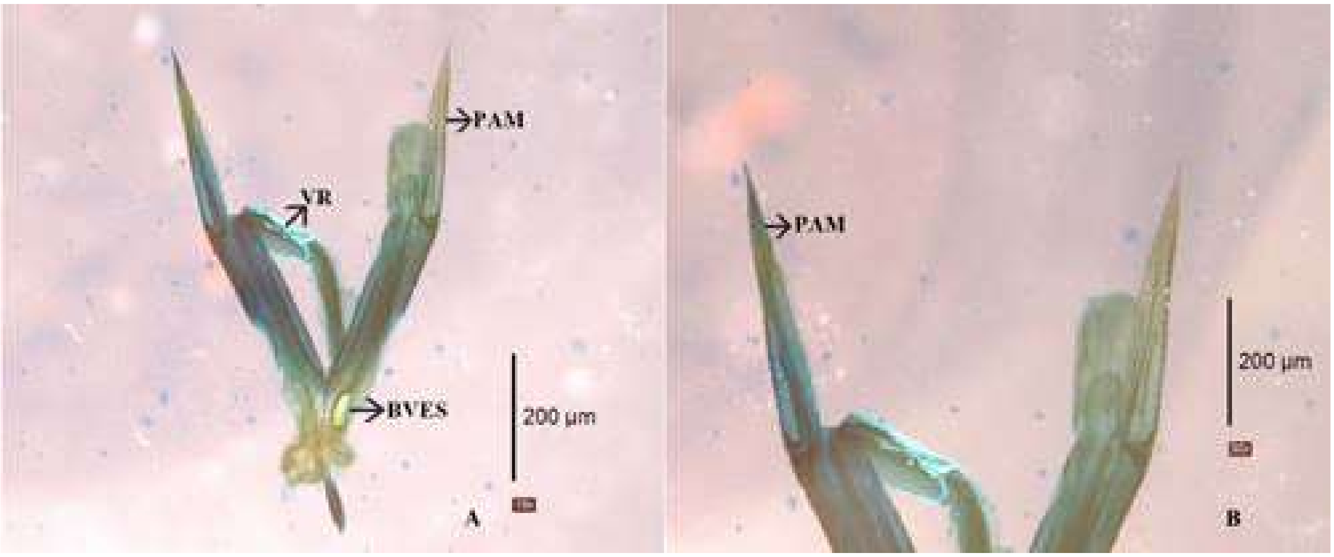


Figure 8. *Nala basalis* Bey-Bienko, 1970, male. A,B, male genitalia; PAM- paramere; VR- virga; BVES- basal vesicle.

Male genitalia typical for this genus; genitalia with parameres about seven times longer than broad, very much narrowed apically, outer and inner margins are more or less straight, very much constricted apex with tip fine, acuminate, pointed; virga tubular, prominent, distinct oval basal vesicles.

Female (Figs. 7H)

Females agree with males in most characters, except ultimate tergite with tapering sides, forceps straight, simple with serrated inner margin in the basal half, and abdomen wider in middle part.

Remarks

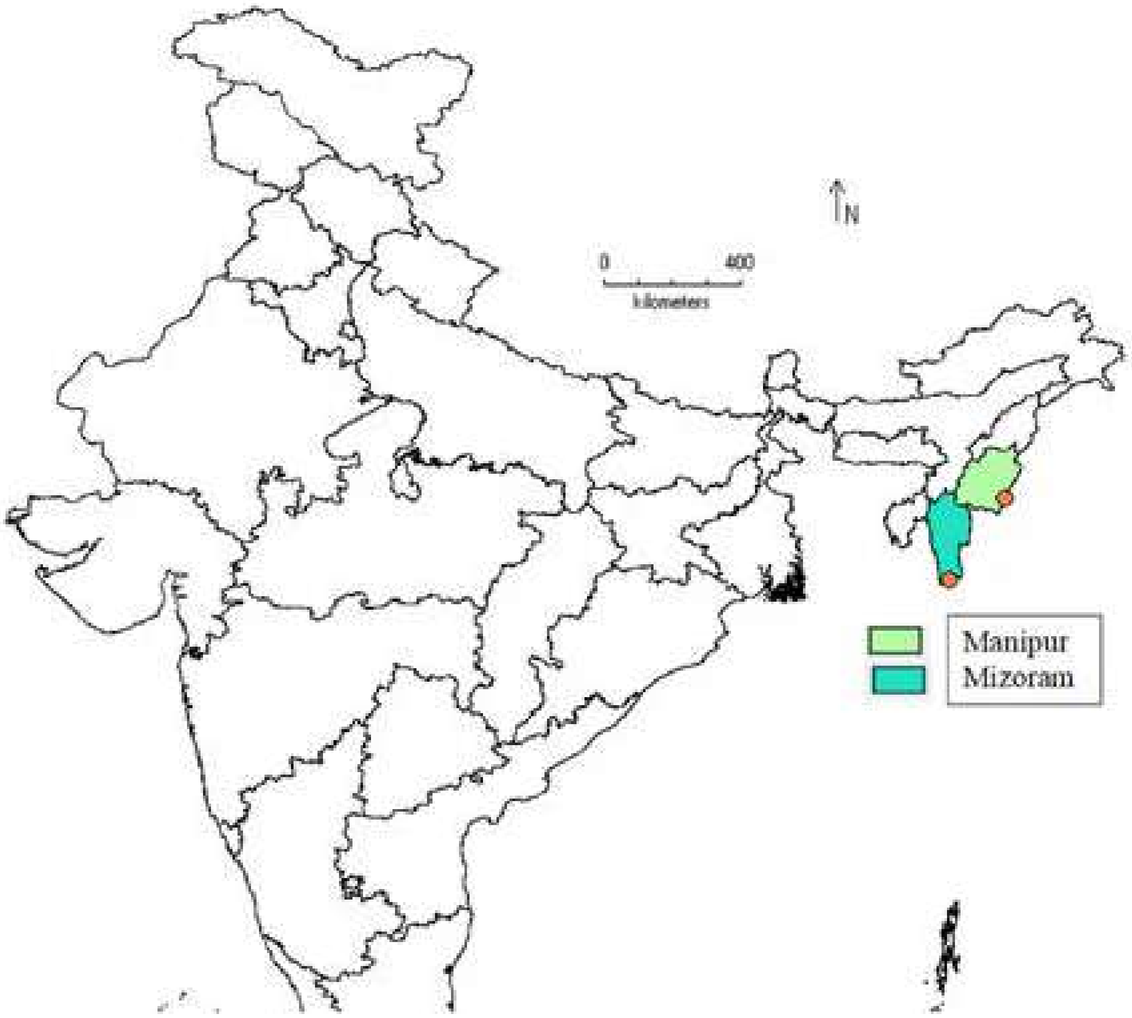
This species shows little resembles with *Nala nepalensis* (Burr, 1907) except penultimate sternite, unique forceps and parameres of genitalia. In this species, forceps (Fig. 7F) are formed differently, the basal fifth appears trigonal, then it depressed weakly with its denticulated inner margin evenly distributed between bases to the apex.; each forceps base has a ventral depressed lobe (Fig. 7F) and apically, parameres (Fig. 8A, 8B) are very narrow with acuminate, pointed tips but *Nala nepalensis* (Burr, 1907) exhibits internally dilated forceps (Fig. 5F, 5G) branches (upto basal one third), with highly serrated inner margin.

The specimens were mainly collected from underneath stones on riverbanks.

The specimens collected from Manipur (Moreh) and Mizoram (Chhimtuipui dist., now it is in Lawngtlai dist.) are preserved in the ZSI HQ, Kolkata at present.

Distribution

India: Mizoram, Manipur. Also distributed in Afghanistan, Pakistan, Thailand and Germany (Srivastava, 2003).



Map 3. Distribution of *Nala basalis* Bey-Bienko, 1970 in India.

Discussion

The three species of the genus under *Nala* Zacher, 1910 is known from India, inhabiting a common habitat, of moist soil, underneath stones, under debris and vegetations. The species, *Nala lividipes* (Dufour, 1829) is one of the most common one, collected from multiple habitats, but the other two species were mainly restricted to a single habitat, underneath stones. The distribution of *Nala lividipes* (Dufour, 1829) in India is very much common, even during heavy monsoon also their population is very high. Whereas, *Nala nepalensis* (Burr, 1907) and *Nala basalis* Bey-Bienko, 1970 are high elevation species and the status of *Nala basalis* Bey-Bienko, 1970 is with restricted distribution, only collected at its type localities. Here, in this paper, we are discussing the variations of male forceps of *Nala lividipes* (Dufour, 1829) for the first time. The male genitalia of three species of *Nala* are unique, species specific and significantly helped in identification and species confirmation. Besides, the new additional diagnostic characters, taxonomic remarks, digital images and distributional mapping will be useful for future researchers and helps to fill the gaps of the Dermapteran taxonomy of India.

Acknowledgements

The authors are grateful to Dr. Dhriti Banerjee, Director, Zoological Survey of India for providing necessary facilities and encouragement. The authors are thankful to Dr. D. Suresh Chand, Scientist-E & Officer-in-Charge, Orthoptera Section, Zoological Survey of India for his help and support.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

An updated checklist of Thrips (Insecta: Thysanoptera) of Sikkim

Th D Songomsing Chiru[1,*], Thang Johnson1, R R Rachana[2] and R Varatharajan[1]

[1]*Department of Zoology, Manipur University, Imphal 795003*

[2]*ICAR-National Bureau of Agricultural Insect Resources, Bengaluru 560024, India*

Abstract

Systematic surveys of thrips were undertaken during 2019-2022 with specific reference to Khangchendzonga National Park in order to understand the species richness of this World heritage habitat. The study revealed presence of 56 species in Sikkim. The suborder Tubulifera is represented by 24 species which can be grouped into 14 genera under two subfamilies such as Phlaeothripinae and Idolothripinae in Phlaeothripidae. Similarly, the collection records have indicated as many as 32 species of terebrantians under Thripidae. All the above said 32 thripids belong to 20 genera which are grouped within four subfamilies, with the lion's share of 25 species in Thripinae, followed by 5 Panchaetothripines, and one each of Dendrothripinae and Sericothripinae. Analysis of the species composition in terms of their feeding habit and habitat reflected that 83% of the thrips are phytophagous, 13% mycophagous and 4% obligate predators. From amongst the phytophagous forms, 27 are phyllophilous, 17 flower dwelling anthophilous species, and 4 poephilous. A close scrutiny also revealed the presence of pests, of which *Sciothrips cardamomi* Ramakrishna*, Thrips palmi* Karny, and *Ceratothripoides claratris* Shumsher are notable pests with appreciable economic importance.

Keywords: Thrips, checklist, Sikkim, survey, pest.

Introduction

Thrips (Order Thysanoptera) play a pivotal role as pollinators (Terry & Mound, 2001; Varatharajan *et al.*, 2016), predators (Ananthakrishnan, 1993), gall inducers (Raman & Ananthakrishnan, 1984), and most significantly, as pests and vectors of tospoviruses (Mound, 1996, 2005). Their importance as serious pests of crops can be attributed to their polyphagous nature, high reproductive capacity, short generation time, high survival of cryptic instars (this is not clear what the authors want to say), and reproduction both by sexual and parthenogenesis, besides acquiring the tendency to develop resistance to insecticides (Amutha & Rachana, 2022).

Over 6000 species, with 329 genera under the suborder Terebrantia and 458 genera under the suborder Tubulifera are known globally (Thripswiki, 2023). For the Indian fauna, a total of 763 species have been reported (Tyagi & Kumar, 2016; Rachana & Varatharajan, 2017), including nearly 200 species recorded from the north-eastern region (Varatharajan, 2005). Compared to other parts of the country, the fauna of Sikkim has been poorly studied. Sen et. al. (1988) were the first to document thrips in this region with a report of 17 species. A recent study (Chiru et. al., 2023) highlighted the occurrence of 44 species. The present paper aims at providing an updated checklist of the thysanopteran fauna of Sikkim, with specific focus on the Khangchendzonga National Park.

Materials and Methods

Study area

The Khangchendzonga National Park (KNP) covers an area of 1784 km^2, constituting 25.14% of the total geographical area of Sikkim. It spreads along 27°30' - 27°55' N latitude and 88°02' - 88°37' E longitude, with an altitude ranging from 1829 m (foothill) to 8585 m asl (Mt. Khangchendzonga peak) (Tambe, 2007; Chhetri, 2005). Nearly 90% of the park lies at an elevation above 3,000 m, and about 70% of the park is located above 4,000 m; thereby displaying varying elevations

*Author for correspondence : songomsing@manipuruniv.ac.in, Orcid id: https://orcid.org/0000-0001-5061-5634
Article Received on: 02.04.2023 Accepted on: 24.04.2023

with just 42 km aerial distance (Sathyakumar *et al.*, 2011; 2014). The KNP presides strategically at the convergence of three biogeographic realms, viz., Palaearctic, Africo-tropical, and Indo Malayan (Mani 1974) and is also one of the important Global 200 Ecoregions (Olson & Dinerstein, 1998). The park is also endowed with three extreme climatic conditions such as high rainfall (380 –550 cm) in the lower and middle zones; high snowfalls at the upper region and relatively high humidity in the whole sector making a unique ecological site (Lavkumar, 1980). The annual rainfall in the region ranges from 750-2750 mm with three main types of vegetations: such as moist temperate forest (1829 –2730 m), sub-alpine forest (2730 –3650m) and alpine forest (>3650m) (Anon., 2000; Champion & Seth, 1968).

Collection and Identification

The insects were collected from their microhabitats such as leaf, flower, twigs, leaf litter, and plan galls by gently tapping on the white board coupled with other trapping methods such as delayed counting, sweeping, and modified Tullgren (Ananthakrishnan, 1984). For further processing, the extracted specimens were preserved in a standard collection fluid comprising 10% ethanol and glacial acetic acid in the ratio 9:1 with a few drops of Triton-X (Bhatti, 1997), and permanent slides were prepared following the standard protocol given by Bhatti (1999). Identification of the collected specimens was carried out using standard keys provided by Ananthakrishnan & Sen, 1980; Bhatti, 1980; Dang *et al.*, 2014; Mound & Minaei, 2007; Mound & Ng, 2009; Sen *et al.*, 1988; Palmer *et al.*, 1989; Varatharajan, 2005. The specimens were also compared with reference slides available at the Insect Museum of Manipur University (IMMU). Some of the specimens were identified with the help of Dr. L. A. Mound, CSIRO, Australia, and final validation was done using ThripsWiki. Voucher specimens were deposited in the National Insect Museum of ICAR-NBAIR, Bangalore, and IMMU.

Systematic accounts

I. Sub-order: Terebrantia

Family: Thripidae

Sub-family: Thripinae Stephens, 1829

Genus: ***Anaphothrips*** Uzel, 1895

1. Anaphothrips latis Bhatti, 1967

Specimen studied: 3 , KNP, Sikkim; Poephilous; ex. *Allium odorum* (Liliaceae).

Distribution: India– Maharashtra, Sikkim; **World** – Ethiopia, Netherlands, Zimbabwe.

2. Anaphothrips sudanensis Trybom, 1911

Specimen studied: 4 , KNP, Sikkim; Poephilous; ex. Grass (Poaceae).

Distribution: Cosmopolitan

Genus: ***Ayyaria*** Karny, 1927

3. Ayyaria chaetophora Karny, 1926

Specimen studied: 2 , 1 KNP, Sikkim; Phyllophilous; ex. *Phaseolus vulgaris (*Fabaceae).

Distribution: India – Andhra Pradesh, Arunachal Pradesh, Assam, Delhi, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Odisha, Tamil Nadu, Uttar Pradesh, West Bengal, Sikkim; **World** – Australia, China, Christmas Island (Indian Ocean), Japan, Philippines, Tahiti, Taiwan.

Genus: ***Ceratothripoides*** Bagnall, 1918

4. Ceratothripoides claratris Shumsher, 1946

Specimen studied: 3 , KNP, Sikkim; Pest; ex. Tomato (Solanaceae).

Distribution: India– Delhi, Maharashtra, Odisha, Sikkim, Manipur, Tamil Nadu; **World**– East Africa, Philippines.

Genus: ***Ctenothrips*** Franklin, 1907

5. Ctenothrips transeolineae Chen, 1979

Specimen studied: 2 , 1 KNP, Sikkim; Phyllophilous; ex. *Pilea pumila (Urticaceae*).

Distribution: India– Himachal Pradesh, Sikkim; **World**– Taiwan.

Genus: ***Dichromothrips*** Priesner, 1932

6. Dichromothrips nakahari Mound 1976

Specimen studied: 3 , 1 KNP, Sikkim; Anthophilous; ex. *Streptosolen jamesonii* (*Solanaceae*)*; Dendrobium* sp. (*Orchidaceae*).

Distribution: India – Assam, Arunachal Pradesh, Meghalaya, Nagaland, West Bengal.

Remark: This species is recorded so far only from India.

Genus: ***Lefroyothrips*** Priesner, 1938

7. Lefroyothrips lefroyi Bagnall 1913

Specimen studied: 2 , 1 KNP, Sikkim; Anthophilous; ex.

Bergenia ciliate (*Saxifragaceae*).

Distribution: India– Assam, Himachal Pradesh, Uttar Pradesh, West Bengal, Nagaland, Sikkim; **World**– Malaysia, Philippines, Indonesia, China, Taiwan.

Genus: *Megalurothrips* Bagnall, 1915

8. Megalurothrips distalis Karny, 1913

Specimen studied: 3 , KNP, Sikkim; Anthophilous; ex. *Phaseolus* sp. (Fabaceae).

Distribution: India– Andaman Island, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, Sikkim; **World**– China, Fiji, Indonesia, Japan, Korea, Philippines, Sri Lanka, Taiwan.

Genus: *Mycterothrips* Trybom, 1910

9. Mycterothrips nilgiriensis Ananthakrishnan, 1960

Specimen studied: 2 , KNP, Sikkim; Anthophilous; ex. *Solanum incanum* (Solanaceae).

Distribution: India– Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh, Rajasthan, Nagaland, Sikkim; **World**–China, Nepal, Australia.

Genus: *Sciothrips* Bhatti, 1970

10. Sciothrips cardamomi Ramakrishna 1935

Specimen studied: 2 , KNP, Sikkim; Pest; ex. *Elettaria cardamom* (*Zingiberaceae*)*; Hedychium coronarium* (*Zingiberaceae*).

Distribution: India – Arunachal Pradesh, Manipur, Tamil Nadu, Sikkim; **World** – China, Costa Rica, Taiwan.

Genus: *Scirtothrips* Shull, 1909

11. Scirtothrips dorsalis Hood, 1919

Specimen studied: 3 , KNP, Sikkim; Phyllophilous; ex. *Maesa chisia* (Primulaceae)*; Capsicum* sp. *(Solanaceae*).

Distribution: Cosmopolitan

Genus: *Smilothrips* Bhatti, 1976

12. Smilothrips productus Bhatti, 1976

Specimen studied: 1 , KNP, Sikkim; Poephilous; ex. *Carex sp.* (Poaceae).

Distribution: **India**– Himachal Pradesh, Jammu & Kashmir, Sikkim; **World**– China.

Genus: *Stenchaetothrips* Bagnall, 1926

13. Stenchaetothrips biformis Bagnall, 1913

Specimen studied: 3 , 1 KNP, Sikkim; Poephilous; ex. *Bambusa* sp. (Poaceae); *Oryza sativa* (Poaceae).

Distribution: India – Arunachal Pradesh, Delhi, Himachal Pradesh, Karnataka, Madhya Pradesh, Manipur, Meghalaya, Odisha, Punjab, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal; **World** – Brazil, Indonesia, Japan, Malaysia, Pakistan, Philippines, Romania, Taiwan, Thailand, UK, Vietnam.

Genus: *Taeniothrips* Amyot & Serville, 1843

14. Taeniothrips orchidi Ananthakrishnan, 1968

Specimen studied: 4 , 1 KNP, Sikkim; Anthophilous; ex. *Rhododendron* sp. (*Ericaceae).*

Distribution: India– Uttar Pradesh, Sikkim.

Remark: This species is recorded so far only from India.

15. Taeniothrips major Bagnall, 1916

Specimen studied: 2 , KNP, Sikkim; Anthophilous; ex. *Hydrangea macrophylla* (*Hydrangeaceae*).

Distribution: India– Uttar Pradesh, Himachal Pradesh, Manipur, Nagaland, Sikkim; **World**– Nepal

Genus: *Thrips* Linnaeus, 1758

16. Thrips atactus Bhatti, 1967

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Phaseolus* sp. (*Fabaceae*).

Distribution: India– West Bengal, Sikkim; **World**– Nepal, Laos, Thailand, Japan.

17. Thrips beharensis Ramakrishna & Margabandhu, 1939

Specimen studied: 3 , KNP, Sikkim; Anthophilous; ex. *Magnolia* sp. (*Magnoliaceae*); *Solanum indicum* (Solanaceae).

Distribution: India – Bihar, Manipur, Sikkim, West Bengal.

Remark: This species is recorded so far only from India.

18. Thrips carthami Shumsher, 1946

Specimen studied: 4 , KNP, Sikkim; Phyllophilous; ex. *Zanthoxylum acanthopodium* (*Rutaceae*).

Distribution: India– Jammu and Kashmir, Himachal Pradesh, Delhi, Nagaland, Sikkim; **World**– Pakistan, Bhutan, Iran.

19. Thrips cedri Bhatti, 1980

Specimen studied: 4 , KNP, Sikkim; Phyllophilous; ex. *Ficus* sp. (Moraceae); *Cedrus deodara* (*Pinaceae*).

Distribution: India– Himachal Pradesh, Sikkim.

Remark: This species is recorded so far only from India.

20. Thrips flavus Schrank, 1776

Specimen studied: 3 , KNP, Sikkim; Anthophilous; ex. *Kalanchoe blossfeldiana* (*Crassulaceae*); *Solanum indicum* (Solanaceae).

Distribution: India – Arunachal Pradesh, Delhi, Goa, Haryana, Himachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Punjab, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal;**World** – Austria, China, Croatia, England, Germany, Iran, Japan, Korea, North America, Pakistan, Taiwan, Slovakia.

21. Thrips florum Schmutz 1913

Specimen studied: 3 , KNP, Sikkim; Anthophilous; ex. *Amaranthus spinosus* (*Amaranthaceae*); *Citrus maxima* (Rutaceae).

Distribution: Cosmopolitan

22. Thrips formosanus Priesner, 1934

Specimen studied: 4 , KNP, Sikkim; Phyllophilous; ex. *Piper betle* (*Piperaceae*).

Distribution: India– Kerala, Manipur, Nagaland, Tamil Nadu; **World**– China, Nepal, Taiwan.

23. Thrips hawaiiensis Morgan, 1913

Specimen studied: 3 , KNP, Sikkim; Anthophilous; ex. *Lantana camara* (Verbenaceae)*; Ricinus communis* (*Euphorbiaceae*).

Distribution: India – Andaman Island, Assam, Arunachal Pradesh, Delhi, Karnataka, Manipur, Meghalaya, Sikkim, West Bengal; **World** – Australia, China, Fiji, Hawaii, Indonesia, Iran, Jamaica, Japan, Mexico, Sri Lanka, Tahiti, Taiwan, USA.

24. Thrips palmi Karny, 1925

Specimen studied: 6 , 1 KNP, Sikkim; Pest; ex. *Coelogyne cristata* (*Orchidaceae*)*; Urena lobata* (*Malvaceae*).

Distribution: India – Arunachal Pradesh, Delhi, Karnataka, Manipur, Odisha, Punjab, Sikkim; **World** – Australia, Brazil, China, Guam, Hong Kong, Indonesia, Japan, Malaysia, Mauritius, Nigeria, Pakistan, Philippines, Singapore, Sri Lanka, Sudan, Taiwan, Thailand, USA.

Genus: *Vulgatothrips* Han, 1997

25. Vulgatothrips smilax Bhatti, 1976

Specimen studied: 1 , KNP, Sikkim; Phyllophilous; ex. *Artemisia nilagirica* (Asteraceae).

Distribution: India– Himachal Pradesh, Sikkim; **World**– Nepal.

Sub-family: Panchaetothripinae

Genus: *Astrothrips* Karny, 1921

26. Astrothrips tumiceps Karny, 1923

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Hedychium gardenium* (Zingiberaceae).

Distribution: India- Assam, Arunachal Pradesh, Delhi, Karnataka, Madhya Pradesh, Manipur, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal, Sikkim; **World**- Australia, Indonesia, Java, Pakistan, Philippines, Thailand.

Genus: *Heliothrips* Haliday, 1836

27. Heliothrips haemorrhoidalis Bouche, 1833

Specimen studied: 3 , KNP, Sikkim; Phyllophilous; ex. *Capsicum annum* (*Solanaceae*)*; Ficus* sp. (Moraceae).

Distribution: India- Andamans, Arunachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Nagaland, Tamil Nadu, Sikkim; **World**- Australia, China, Germany, England, Finland, Sri Lanka, Suriname, Taiwan.

Genus: *Helionothrips* Bagnall, 1932

28. Helionothrips aino Ishida, 1931

Specimen studied: 2 , KNP, Sikkim; Anthophilous; ex. *Strobilanthes capitatus* (Acanthaceae)*; Cyrtococcum* sp. (*Poaceae).*

Distribution: India- Himachal Pradesh, Sikkim. **World**- China, Japan, Taiwan.

Genus: *Monilothrips* Moulton, 1929

29. Monilothrips kempi Moulton, 1929

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Matteuccia struthiopteris* (*Onocleaceae*)*; Dryopteris* sp. (*Dryopteridaceae).*

Distribution: India – Madhya Pradesh, Manipur, Nagaland, Tamil Nadu, Uttar Pradesh, West Bengal, Sikkim; **World** – Africa, China, Taiwan, U.S.A.

Genus: *Selenothrips* Karny, 1911

30. Selenothrips rubrocinctus Giard, 1901

Specimen studied: 3 , KNP, Sikkim; Pest; ex. Guava (Myrtaceae).

Distribution: India– Andaman Island, Assam, Arunachal Pradesh, Karnataka, Kerala, Manipur, Meghalaya, Nagaland, West Bengal, Sikkim; **World**–

Bangladesh, China, Hondurus, Mexico, Myanmar, Philippines, Sri Lanka, Taiwan, Thailand.

Sub-family: Dendrothripinae Priesner, 1925

Genus: ***Dendrothrips*** Uzel, 1895

31. Dendrothrips stannardi Ananthakrishnan, 1958

Specimen studied: 2 , 1 KNP, Sikkim; Phyllophilous; ex. *Maesa indica* (Primulaceae)*; Schima wallichii* (*Theaceae).*

Distribution: India – Arunachal Pradesh, Manipur, Nagaland, Tamil Nadu, Sikkim; **World** – China.

Sub-family: Sericothripinae Karny, 1921

Genus: ***Neohydatothrips*** John, 1929

32. Neohydatothrips samayunkur Kudo, 1995

Specimen studied: 5 , KNP, Sikkim; Phyllophilous; ex. *Magnolia champaca* (Magnoliaceae).

Distribution: India – Andaman Island, Arunachal Pradesh, Delhi, Himachal Pradesh, Karnataka, Maharashtra, Manipur, Uttarakhand, Sikkim; **World** – Australia, China, Costa Rica, El Salvador, Japan, Kenya, Mexico, Sri Lanka, Taiwan, U.S.A.

II. Sub-order: Tubulifera

Family: Phlaeothripidae Uzel, 1895

Sub-family: Phlaeothripinae Uzel, 1895

Genus: ***Adraneothrips*** Hood, 1925

33. Adraneothrips disjunctus Ananthakrishnan, 1972

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Urtica dioica (Urticaceae).*

Distribution: **India** – Arunachal Pradesh, Andhra Pradesh, Manipur, Sikkim.

Remark: This species is recorded so far only from India.

Genus: ***Dolichothrips*** Karny, 1912

34. Dolichothrips indicus Hood, 1919

Specimen studied: 3 , KNP, Sikkim; Poephilous; ex. *Thysanolaena maxima* (Poaceae); *Albizia myriophylla* (Fabaceae).

Distribution: **India** – Delhi, Karnataka, Kerala, Manipur, Meghalaya, Tamil Nadu, West Bengal, Sikkim; **World** – Guam, Sri Lanka, Taiwan.

35. Dolichothrips montanus Ananthakrishnan, 1964

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Ficus sp.* (Moraceae)*; Lantana camara* (Verbenaceae).

Distribution: India – Arunachal Pradesh, Assam, Manipur, Nagaland, Tamil Nadu, Sikkim.

Remark: This species is recorded so far only from India.

Genus: ***Gigantothrips*** Zimmermann, 1900

36. Gigantothrips elegans Zimmermann, 1900

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Ficus* sp. (Moraceae).

Distribution: India – Arunachal Pradesh, Bihar, Delhi, Karnataka, Manipur, Odisha, Punjab, Tamil Nadu, Sikkim; **World** – Australia, China, Indonesia, Philippines, Taiwan, Thailand.

Genus: ***Haplothrips*** Amyot & Serville, 1843

37. Haplothrips bagrolis Bhatti, 1973

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Artemisia nilagirica* (Asteraceae).

Distribution: India – Himachal Pradesh, Manipur, Sikkim.

Remark: This species is recorded so far only from India.

38. Haplothrips ganglbaueri Schmutz, 1913

Specimen studied: 3 , KNP, Sikkim; Anthophilous; ex. *Tridex procumbens* (Asteraceae)*; Boungainvillea bonsai* (Nyctaginaceae).

Distribution: India – Arunachal Pradesh, Andaman Island, Andhra Pradesh, Delhi, Haryana, Karnataka, Madhya Pradesh, Manipur, Meghalaya, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, Sikkim; **World** – Australia, China, Egypt, Indonesia, Iran, New South Wales, Pakistan, Sri Lanka, Sudan, Sumatra, Japan.

39. Haplothrips gowdeyi Franklin, 1908

Specimen studied: 5 , KNP, Sikkim; Anthophilous; ex. *Millettia pinnata* (Fabaceae)*; Tagetes* sp. (Asteraceae).

Distribution: Cosmopolitan

40. Haplothrips longisetosus Ananthakrishnan, 1955

Specimen studied: 3 , KNP, Sikkim; Phyllophilous; ex. *Ficus sp.* (Moraceae).

Distribution: India– Assam, Kerala, Manipur, Sikkim, Tamil Nadu, Uttar Pradesh.

Remark: This species is recorded so far only from India.

41. Haplothrips tenuipennis Bagnall, 1918

Specimen studied: 2 , KNP, Sikkim; Anthophilous; ex. *Ipomea* sp. (Convolvulaceae).

Distribution: India – Andaman Island, Arunachal Pradesh, Assam, Madhya Pradesh, Maharashtra, Manipur, Rajasthan, Tamil Nadu, West Bengal, Sikkim;

World – China, Indonesia.

Genus: *Liothrips* Uzel, 1895

42. Liothrips aberrans Muraleedharan & Sen, 1978

Specimen studied: 2 , 2 KNP, Sikkim; Cecidogenous; ex. *Strobilanthes capitatus* (Acanthaceae).

Distribution: India – Assam, Arunachal Pradesh, Nagaland, Sikkim, West Bengal.

Remark: This species is recorded so far only from India.

43. Liothrips himalayanus Ananthakrishnan & Jagadish, 1970

Specimen studied: 2 , 1 KNP, Sikkim; Phyllophilous; ex. *Quercus serrata* (Fagaceae)*; Aconogum mole* (Polygonaceae).

Distribution: India – Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, West Bengal, Sikkim.

Remark: This species is recorded so far only from India.

Genus: *Mesothrips* Zimmermann, 1900

44. Mesothrips perlucidus Muraleedharan & Sen, 1981

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Urtica dioica* (Urticaceae).

Distribution: India– Manipur, Nagaland, Tripura.

Remark: This species is recorded so far only from India.

Genus: *Podothrips* Hood, 1913

45. Podothrips odonaspicola Kurosawa, 1937

Specimen studied: 1 , KNP, Sikkim; Poephilous; ex. *Carex paniculate* (Cyperaceae).

Distribution: India– Andaman, Sikkim, West Bengal; **World**– Japan.

Genus: *Praepodothrips* Priesner & Seshadri, 1953

46. Praepodothrips priesneri Ananthakrishnan, 1955

Specimen studied: 2 , KNP, Sikkim; Phyllophilous; ex. *Lawsonia* sp. (Lythraceae). **Distribution: India** – Andaman Island, Arunachal Pradesh, Manipur, Nagaland, Tamil Nadu, Sikkim.

Remark: This species is recorded so far only from India.

Genus: *Stephanothrips* Trybom, 1913

47. Stephanothrips occidentalis Hood & Williams, 1925

Specimen studied: 2 , KNP, Sikkim; Mycophagous; ex. Mixed leaf litter**.**

Distribution: India – Arunachal Pradesh, Andhra Pradesh, Kerala, Manipur, Tamil Nadu, Tripura, West Bengal, Sikkim; **World** – Angola, Australia, Jamaica, Japan, Malaysia, Mexico, Philippines, South Africa, Taiwan, Thailand, Trinidad, USA.

Genus: *Thlibothrips* Priesner, 1952

48. Thlibothrips manipurensis Muraleedharan, 1982

Specimen studied: 2 , 1 KNP, Sikkim; Cecidogenous; ex. *Muanthemum bifolium* (*Asparagaceae*).

Distribution: India – Manipur, Nagaland, Sikkim.

Remark: This species is recorded so far only from the north-east India.

Genus: *Urothrips* Bagnall, 1909

49. Urothrips tarai Stannard, 1970

Specimen studied: 1 , KNP, Sikkim; Mycophagous; ex. Leaf litter of *Quercus.*

Distribution: India – Arunachal Pradesh, Manipur, Nagaland, Uttar Pradesh, Sikkim.

Remark: This species is recorded so far only from India.

Genus: *Xylaplothrips* Priesner, 1928

50. Xylaplothrips ligs Ananthakrishnan & Jagadish, 1971

Specimen studied: 1 , KNP, Sikkim; Mycophagous; ex. *Hydrangea macrophylla* (*Hydrangeaceae).*

Distribution: India – Andhra Pradesh, Delhi, Manipur, Karnataka, Sikkim.

Remark: This species is recorded so far only from India.

51. Xylaplothrips debilis Ananthakrishnan & Jagadish, 1971

Specimen studied: 2 , KNP, Sikkim; Mycophagous; ex. Herbs.

Distribution: India– Andhra Pradesh, Arunachal Pradesh, Delhi, Karnataka, Kerala, Manipur, Sikkim, West Bengal; **World**– Indonesia.

Sub-family: Idolothripinae Bagnall, 1908

Genus: *Elaphrothrips* Buffa, 1909

52. Elaphrothrips curvipes Priesner 1929

Specimen studied: 3 , KNP, Sikkim; Mycophagous; ex. *Mangifera indica* (Anacardiaceae)*; Bambusa* sp. (Poaceae).

Distribution: **India** – Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Sikkim, Tamil Nadu, West Bengal; **World** – Bhutan, Germany, Indonesia, Laos, Malaysia, Thailand.

53. Elaphrothrips denticollis Bagnall, 1909

Specimen studied: 3 , KNP, Sikkim; Mycophagous;

ex. *Mangifera indica* (Anacardiaceae)*; Bambusa* sp. (Poaceae).

Distribution: India – Arunachal Pradesh, Assam, Karnataka, Kerala, Manipur, Meghalaya, Sikkim, Tamil Nadu, Tripura, West Bengal; **World** – Indonesia, Malaysia, Myanmar, Sri Lanka.

54. Elaphrothrips procer Schmutz, 1913

Specimen studied: 2 , KNP, Sikkim; Mycophagous; ex. *Bambusa* sp. (Poaceae); *Carica papaya* (Caricaceae).

Distribution: **India**– Kerala, Manipur, Nagaland, Tamil Nadu, Sikkim; **World**– China.

55. Elaphrothrips spiniceps Bagnall, 1932

Specimen studied: 2 , KNP, Sikkim; Mycophagous; ex. *Bambusa* sp. (Poaceae); *Carica papaya* (Caricaceae).

Distribution: **India**– Kerala, Manipur, Nagaland, Tamil Nadu, Sikkim; **World**– China.

Genus: *Nesothrips* Kirkaldy, 1907

56. Nesothrips brevicollis Bagnall, 1914

Specimen studied: 2 , KNP, Sikkim; Mycophagous; ex. Mixed leaf litter **Distribution**: **India**– Kerala, Manipur, Nagaland, Tamil Nadu, Sikkim; **World**– China.

Results and Discussion

The present study has resulted in bringing the total number of thrips collected from Sikkim to 56 species. The suborder Terebrantia is represented by a single family Thripidae, with 32 species in 22 genera, while the family Phlaeothripidae of the suborder Tubulifera is represented by 24 species in 14 genera. The four subfamilies of Thripidae, namely, Thripinae, Panchaetothripinae, dendrothripinae, and Sericothripinae are represented by 25, 5, 1, and 1 species respectively. Phlaeothripinae forms a major subfamily in the suborder Tubulifera with 19 species in 12 genera, while the subfamily Idolothripinae is represented by 5 species in 2 genera.

The plant dependent phytophagous thrips constitute the major share of 45 species, followed by 9 species of mycophagous forms feeding on fungal spores & mycelia, while the predatory thrips were comprise two species. It is also noteworthy to mention that some pest species, viz., *S. dorsalis, S. cardamomi* and *T.palmi* were collected. Considering the strategic location of the study area with a wide range of ecosystems and elevations the current figure of 56 species can be considered an understatement. There should be many more species that are yet to be recorded, and further surveys are needed.

Acknowledgements

We expressed our sincere gratitude to the Ministry of Tribal Affairs, Government of India for the NFST Fellowship grant to carry out this work. The authors acknowledge the Sikkim Forest Department, Government of Sikkim, Deorali for granting permission to undertake this survey in the KNP. Thanks are due to Dr. Laurence Mound, CSIRO, Australia, for determining the identity of some species and to the Head, Department of Zoology, Manipur University, Canchipur, for providing the necessary facilities. Dr. K. Tilotama Devi, Scientist (Plant Taxonomy), ORDC, Hengbung, Manipur and Dr. Sanatombi, Department of Botany, Manipur University, are also acknowledged for identifying the host plants.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

New records of Collembola (Hexapoda) from West Bengal with notes on their taxonomy

Pritha Mandal, Guru Pada Mandal*, K. K. Suman, K. K. Bhattacharya and Dhriti Banerjee

Apterygota Section, Zoological Survey of India, Prani Vigyan Bhawan, M Block, New Alipore, Kolkata- 700053, West Bengal, India

Abstract

This study deals with a total of 21 species of collembola under 14 genera of 6 families, which has been recorded for the first time from the state of West Bengal. A descriptive note on their taxonomy with proper illustrations is provided with an approach to improve the faunistic understanding of collembolans from the state. The new records were found from the collections of the survey undertaken during the year 2018 to 2022 as well as examining some of the previous state survey materials of the NZC depository at Apterygota section. Compiling previous literature on collembola from the state, the current study has updated the collembolan taxon list from 75 species to a total of 96 species.

Keywords: Entomobryomorpha, springtails, soil invertebrates, taxonomy, new record.

Introduction

Collembolans are minute, wingless, and highly abundant soil organisms that contribute to soil structure formation and nutrient cycling through litter decomposition and fungal foraging (Hopkin, 1997). They exhibit a range of habitat preferences such as forest litter, desert, mountain snow caps, caves and littoral zone. Some members of the Tribe Cyphoderinae were also found to invade termite mounds and ant nests (Delamare-Deboutteville, 1948). Genera such as *Lepidocyrtus, Salina, Callyntrura, Dicranocentroides, Cyphoderus,* and *Homidia* are ubiquitous in distribution while, *Tomocerus* are limited to high altitudes, and *Spheredia, Sminthurus, Xenylla* are prevalent on agroecosystems of the plains.

Pioneering work on Indian Collembola was undertaken by Imms (1912), later researchers like Mitra (1966, 1967, 1974, 1995), Hazra & Chowdhari (1981), and Mandal (2011) contributed to this field. Mandal (2018) reported a total of 342 species of collembola from India, out of which only 75 collembolan species belonging to 13 families were studied from the state of West Bengal (Mandal *et al.*,2018). The state exhibits a wide range of landforms, ecosystems, climatic variations, and soil types, starting from the Himalayan terai in the north, dry deciduous forest in the east, and the mangroves at the coast of the Bay of Bengal. Such diverse eco-geographic regions favor the occurrence of a large number of discriminative collembolan species therefore, more exploration and extensive study is required from the state to enrich the knowledge of the collembolan taxonomy and diversity.

Materials and methods:

Several surveys and explorations of various habitats from the state were taken using different collection methods (aspirator, pan-trap, soil extraction, bush beating, etc.) during this study. The collected specimens were preserved in 70% alcohol and carried to the laboratory for later studies. Family-wise sorting of specimens was done under a Leica M205A stereo microscope attached to a Leica DMC6200 camera. Individual specimens were de-pigmented with Nesbitt's solution (Krantz, 1978) and later mounted on slides using Hoyer's media (Krantz, 1978) under a cover slip. Slides were dried on a hot plate for 48 - 72 hours until completely dried. Taxonomic identification and chaetotaxy

*Author for correspondence : gpmandal.zsi@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

study of the fresh specimens were carried out under Leica 2500 D binocular microscope following the standard key of Bellinger *et. al.*, 1996 – 2023. The identified specimens were deposited at the NZC of the Zoological Survey of India.

Abbreviations used in text: Abd.—Abdominal segment; Ant.—antennal segment; mac—macrochaetae; PAO—postantenal organ; Th.—thoracic segment; Tita—tibiotarsus; VT—ventral tube; NZC—National Zoological Collection.

Results:

Systematic Account

Class Collembola Lubbock, 1870 sensu Bellini & al, 2022

Family Dicyrtomidae Börner, 1906, sensu Deharveng, 2004

Subfamily Dicyrtominae Richards, 1968 sensu Bretfeld, 1999

Genus *Calvatomina* Yosii, 1966

Type species: *Dicyrtomina (Calvatomina) cruciata* Yosii, 1966

Genus diagnosis: Globular body, some abdominal segments fused, Ant IV much shorter than third. Neosminthuroid setae present.

1. ***Calvatomina trivandrana*** Prabhoo, 1971 (Fig.1, Plate – 1)

   1971, *Dicyrtomina trivandrana* Prabhoo, *Bull. Ent.* **12**: 44-31; figs. 24-31.

   Material examined: 17 exs in alcohol, India: West Bengal: Kunti river embankment, collected from leaf litter, Singur, Hooghly dist., 09.vii.2022, 22.872°N, 88.277°E, coll. P. Mandal, (3303/ H14).

   Diagnosis: Colour light brown with longitudinal bands of yellowish brown on the habitus, scattered deep blue patches present on the ventral area and legs. Ant.I-III yellowish with black ridges. Manubrium and dens joining has a black pigment patch. Body clothed with short plain setae. Unguis with pseudonychia and median teeth formulae- 1,2,2. Axial filament of the fore leg is longer, lacks clavate tenent hair. Nine dorsal smooth setae on manubrium, ratio of dens: mucro–2.93:1, inner lamella of mucro with 37-39 and outer lamella with 30-32 serrations.

   Distribution: India: West Bengal (Hooghly*); Jharkhand, Kerala.

   Remarks: Endemic to India. First time recorded from West Bengal.

Family Hypogastruridae Börner, 1906

Genus *Xenylla* Tullberg, 1869

Type species: *Xenylla maritima* Tullberg, 1869

Genus diagnosis: Four or five ocelli present on each side, PAO absent. Apical organ of Ant IV formed with 2 papillae. Mandible without long apex, apical teeth large.

2. ***Xenylla reducta*** Prabhoo, 1971 (Fig.2, Plate – 1)

   1971. *Xenylla reducta* Prabhoo, *Oriental Insects,* **5**: 7-9, fig. 28-32.

   Material examined: 58 exs in alcohol, India: West Bengal: East Kolkata wetlands, collected from soil, Nalban, Kolkata dist., 25.iv.2019, 22.29°N, 88.22°E, coll. G.P. Mandal, (2660/ H14)

   Diagnosis:

   Body setae less in number. Unguis without tooth, 2 non-clavate or weekly clavate tenent hair. Anal spines short, curved and mounted on distinct papillae.

   Distribution: India: West Bengal (Kolkata*); Odisha, Kerala.

   Remarks: Endemic to India. First time recorded from West Bengal.

Family Hypogastruridae Börner, 1906

Genus *Xenylla* Yosii, 1966

Type species: *Xenylla maritima* Tullberg, 1869

3. ***Xenylla welchi*** Folsom, 1916 (Fig.3, Plate – 1)

   1916, *Xenylla welchi* Folsom, *Pros. of the USNM*, **50:** 495,497

   Material examined: 70 exs in alcohol, India: West Bengal: Rajarbathan village, collected from vegetable litter, Singur, Hooghly dist., 13.ii.2022, 22.872°N, 88.277°E, coll. P. Mandal; (3334/H14).

   Diagnosis:

   Adult body length average 0.8mm. 5+5 ommatidia on black eye patches. Body usually violate to blackish. Length of head: antennae–1.14: 1.Unguis unidented, unguiculus absent. Knobbed tenent hair present, formula– 1, 2, 2. Ratio of dens: mucro – 2.03: 1. Mucro and dens are demarked by an articulation. Broad mucro is characteristic.

   Distribution: India - West Bengal (Hooghly*), Kerala.

Elsewhere: Europe, Australia, Caribbean mainland, Africa, America.

Remarks: Newly recorded from West Bengal.

Family Brachystomellidae Stach, 1949

Genus *Brachystomella* Ågren, 1903

Type species: *Brachystomella maritima* Ågren, 1903

Genus diagnosis: PAO present, 8+8 eyes present, Pseudocelli absent. No papillae on prothorax. Mandible not present quadrate maxilla with many anteriorly projecting teeth. Farcula present with lamellate mucro.

4. ***Brachystomella contorta*** Denis, 1931 (Fig.4, Plate – 1)

1931, *Brachystomella contorta* Denis, *Boll. Lab. Zool. Portici,* **25**, 69,111-120.

Material examined: 1 exs on slide, India: West Bengal: Jute Agricultural Research Institute, Barrackpore, North 24 Parganas dist., 15.x.1980, 22.75°N, 88.42°E, coll. S. K. Mitra, (903/H14).

Diagnosis:

Average body length 0.82 mm, colour deep purple, dark pigment scattered all over the body. Finely granulated integument with short and simple setae. Ant.IV with apical bulb with two guard setae, presence of six sensory setae. PAO rosette shaped with 6-7 peripheral elements, eyes with 8+8 subequal ocelli. Elongated buccal cone with four pre labral setae. Unguis with one small inner tooth and a rarely visible lateral tooth. Furcual short, dens with dorsal granulations and 5 setae. Spoon shaped mucro present with broad outer lamellae.

Distribution: India: West Bengal (North 24 Parganas*), Kerala.

Elsewhere: Cosmopolitan.

Remarks: Newly recorded from West Bengal.

Family Isotomidae Schäffer, 1896

Subfamily Proisotominae Stach, 1947

Genus *Ballistura* Börner, 1906

Type species: *Isotoma schoetti* Dallan Torre, 1895

Genus diagnosis: Eyes present. Body cuticle not granulated. Antenna and legs lacks truncate or blunt setae. Straight projecting setae absent on Abd VI. Manubrium without ventral setae. Dens have smooth surface dorsally and more than 1+1 ventral setae. Mucro slightly longer.

5. ***Ballistura fitchi*** (Denis, 1933) Potapov, 2001 (Fig.5, Plate – 1)

1933. *Proisotoma fitchi* Denis, *Boll. Lab. Zool. Portici,* **27**: 234-235, 315, 319; figs.14-20.

Material examined: 1 exs on slide, India: West Bengal: Jute Agricultural Research Institute, Barrackpore, North 24 Pargana dist., 18.viii.1980, 22.75°N, 88.426°E, coll. S. K. Mitra, (900/H14).

Diagnosis: Body deep blue pigmented, PAO ovulated. Unguis without any teeth, a small setae present at its base. Two clavate tenent hair present. Dens roughly lobulated on the dorsal side. Mucro bidented and lamellate.

Distribution: India: West Bengal (North 24 Parganas), Tamil Nadu.

Elsewhere: Brazil, Caribbean mainland, Europe, Mediterranean, Malaysia.

Remarks: First time recorded from West Bengal.

Family Isotomidae Schäffer, 1896

Subfamily Proisotominae Stach, 1947

Genus *Cryptopygus* Willem, 1901

Type species: *Cryptopygus antarcticus* Willem, 1902

Genus diagnosis: Body surface smooth, covered with simple setae. Mandible with molar plate, PAO with simple rim. Abd V and Abd VI separated. Dens larger than manubrium and 2-6 ventral manubrial setae present. Mucro bidented with lamellae.

6. ***Cryptopygus indicus*** Brown, 1932 (Fig.6, Plate – 1)

1932. *Proisotoma (Isotomina) indica* Brown, *Proc. Haw. Ent. Soc.* **8**: 35-36; figs.1-5.

Material examined: 4 exs in alcohol, 1 on slide, India: West Bengal: Village Karicha, collected from leaf litter, Singur, Hooghly dist., 09.vii.22, 22.872°N, 88.277°E, coll. P. Mandal, (3337/ H14).

Diagnosis:

Body length 0.75 mm, general colour dull, black pigment on the head. Ocelli 5+5, partly pigmented. Uniformly scattered short setae all over the body, posterior segments with slightly larger ones. PAO ovoid with a slight constriction in middle. Unguis monodented, tenent hair absent. Two strong ventral bristles present at the apex of manubrium. Dens dorsally crenulated, mucro with two equal size teeth.

Distribution: India: West Bengal (Hooghly*), Assam, Odisha, Tamil Nadu.

Remarks: Endemic to India. Newly recorded from West Bengal.

Family Isotomidae Schäffer, 1896

Subfamily Proisotominae Stach, 1947

Genus *Cryptopygus* Willem, 1901

Type species: *Cryptopygus antarcticus* Willem, 1902

7. ***Cryptopygus tridentatus*** (Handschin, 1929) (Fig.7, Plate – 2)

1929, *Proisotoma tridentate* Handschin, *Revue Suisse de Zoologie*, **36** (16): 229-262.

Material examined: 50 exs in alcohol, 1 on slide, India: West Bengal: Susunia forest, collected from leaf litter, Bankura dist., 01.xii.2022, 23.399°N, 86.973°E, coll. G. P. Mandal, (3279/H14).

Diagnosis:

Body dark blue with paler extremities and abdominal areas, pigmentation more pronounced towards the back. Segmentation areas are lightly coloured. 8+8 ommatidia present; PAO elongated, oval and with lateral thickening. Abd V and Abd VI fused. Unguis with a internal tooth, empodial appendages with basal lamella and a strong club tenent hair. Dents are heavily ringed. Mucro tridented with short and straight apical tooth.

Distribution: India: West Bengal (Bankura*), Tamil Nadu.

Remarks: Endemic to India. First time recorded from West Bengal.

Family Isotomidae Schäffer, 1896

Subfamily Isotominae Schäffer, 1896

Genus *Isotoma* Bourlet, 1839

Type species: *Cryptopygus antarcticus* Willem, 1902

Genus diagnosis: Eyes 6+6 or 8+8. Body setae normal, ventral manubrial setae spine like. Distinct PAO present. Three or more teeth present on mucro. Pseudonychia absent, small lateral teeth on unguis. Tita without clavate setae. Abd II-IV lack bothriotricha. Spines absent from crenulated dens.

8. ***Isotoma plumosa*** (Salmon, 1969) Lawrence, 1978 (Fig.8, Plate – 2)

1969. *Rhodanella plumosa* Salmon, *Zool. Publ. Victoria Univ.* Wellington, **51**:47: figs.29-34.

1978. *Isotoma plumosa* Lawrence, *Rev. Ecol. Biol. Sol*, **15**:369.

Material examined: 20 exs in alcohol, 1 on slide, India: West Bengal: Neora Adventures Base Camp, Lava Park, Darjeeling dist., 26.xi.2019, 27.085°N, 88.65°E, coll. G.P.Mandal, (2931/H14).

Diagnosis:

Length about 0.82mm. Ground colour pale brown with irregular dark brown patches. Head: Antenna ratio – 1: 1.12. Antennae uniformly brown, darker at the apex. Coxa and lateral tooth with gray patches. PAO ovoid, presence of pin setae on Ant IV unguis with a lateral tooth, unguiculus with a conspicuous corner tooth. Mucro with 4 teeth, without basal spine.

Distribution: India: West Bengal (Darjeeling*), Assam, Sikkim.

Elsewhere: Himalayan Region.

Remarks: Newly recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily Paronellinae Börner, 1906 sensu Zhang et al, 2019

Genus *Cyphoderus* Nicolet, 1842

Type species: *Delamarerus immsi Mitra, 1976*

Genus diagnosis: Body without pigmentation and eyes. Mandibles reduced. Lanceolated unguiculas with a broad outer tooth. Dens crenulated with large strong leaf-like scales.

9. ***Cyphoderus assimilis*** Borner, 1906 (Fig.9, Plate – 2)

1906, *Cyphoderus assimilis* Borner, *Mitt. Naturhist. Mus.* Hamburg **23**:181

Material examined: 1 exs in alcohol, 1 on slide, India: West Bengal: Village Rajarbathan, collected from rotten banana bark, Singur, Hooghly dist., 25.xii.2023, 22.869°N, 88.279°E., coll. P. Mandal, (3339/H14); 21 exs in alcohol, 1 ex. on slide, India: West Bengal: Near Pond, Pathar Beria, collected from wood log, South 24 Parganas dist., 18.xi.2022, 22.464°N, 88.124°E, coll. K.K.Bhattacharya, (3301/H14).

Diagnosis:

Absence of body pigmentation, Head lacks eyes and PAO, with four segmented antennae. Unguis of the foreleg is relatively larger and with a basal and two small distal teeth, single curved tenent hair present. Dens with two rows of sphere shaped scales, six in number. Mucro relatively large, straight and bidented.

Distribution: India: West Bengal (Hooghly*, South 24

Parganas*), Andhra Pradesh, Maharashtra, Odisha.

Elsewhere: South Africa, South East Asia, Mediterranean.

Remarks: First time recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily Paronellinae Börner, 1906 sensu Zhang et al, 2019

Genus *Pseudocyphoderus* Imms, 1912

Type species: *Pseudocyphoderus annandalei* Imms, 1912

Genus diagnosis: Mouth cone directing downwards, mandibles present. Unguis with three teeth and without inner projection. Dens with feather like scales and setae. Small mucro, teeth may present or absent.

10. *Pseudocyphoderus annandalei* Imms, 1912 (Fig.11, Plate – 2)

1912. *Pseudocyphoderus annandalei* Imms, *Proc. Zool. Soc. Lond.*: **81**, 116-117; figs. 87-89.

1992. *Cyphoderus* (*Pseudocyphoderus) annandalei* Yosii, *Contr. boil. Lab. Kyoto Univ.* **28**: 113.

Material examined: 50 exs in alcohol, 1 exs on slide, India: West Bengal: Jute Agricultural Research Institute, Barrackpore, North 24 Pargana dist., 03.vii.1984, 22.872°N, 88.277°E, coll. S. K. Mitra, (1955/H14).

Diagnosis:

Body colour creamy white. Cockroach-like body, compressed laterally, with small rounded scales. Ant. IV without terminal bulb, other Ant. segments with strong setae. Hypognathous mouthparts greatly reduced, with thick ciliated prelabral setae. Unguis small, without inner distal tooth and tunica, with a weakly developed tenent hair and wing-like outer basal teeth. Large unguiculas with a broad outer tooth. 10 spinous setae in 'L' arrangement on trochantral organ. Dens with winged scales, 5 outer and 2 inner, with 3 basal and 2 inner small setae. Terminally blunt short mucro present.

Distribution: India: West Bengal (North 24 Parganas*), Andhra Pradesh, Maharashtra, Odisha.

Remarks: Endemic to India. First time recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily Paronellinae Börner, 1906 sensu Zhang et al, 2019

Genus *Delamarerus* Mitra, 1977

Type species: *Delamarerus immsi* Mitra, 1977

Genus diagnosis: Body lacks pigmentation, eyes usually absent. Mandibles with well developed molar plate. Mostly five apical teeth and single fringed inner tooth present on unguis, clear tunica present. Dens with large flattened scales and setae. Bidented mucro subequal with dens.

11. *Delamarerus immsi* Mitra 1977 (Fig.10, Plate – 2)

1977. *Delamarerus immsi* Mitra, *Rev. Ecol. Biol. Sol.* **13** (4): 645-652; figs.1-3.

Material examined: 57 exs in alcohol, 1 exs on slide, India: West Bengal, Kenduah, Siuri, Birbhum dist., 07.xi.1974, 23.88 °N, 87.72 °E, coll. S. K. Mitra, (472/H14).

Diagnosis:

Triangular head with 2 sense-bulbs on Ant-III. Unguis with large tunica or fringe membranous structure and a distal teeth, one of the paired inner teeth is modified in a slender process. Unguiculas lanceolate.Weakly developed trochanteral organ with 15 tiny spines. Dens distinctly shorter than manubrium. Elongated, slender mucro bidented. Dens with five outer and two inner hyaline scales.

Distribution: India - West Bengal (Birbhum*), Andhra Pradesh, Maharashtra, Odisha.

Remarks: Endemic to India. Newly recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily Troglopedetinae Borner, 1913

Genus *Cyphoderopsis* Carpenter, 1917

Type species: *Cyphoderopsis kempi* Carpenter, 1917

Genus diagnosis: Body without pigment, scales present, head with 6+6 or fewer eyes. Ant IV not subdivided. Metathorax and mesothorax are not humped. Mucro sharply demarcated and four times or more long than width.

12. *Cyphoderopsis kempi* Carpenter, 1917 (Fig.12, Plate – 2)

1917. *Cyphoderopsis kempi* Carpenter, *Rec. Ind. Mus. Calcutta,* **8** (9): 561-568.

Material examined: 15 exs in alcohol, India: West Bengal: Suntalyekhola bridge, Samsing Range, Neora Valley National Park, Kalimpong dist., 07.vi.2018, 26.59°N, 88.47°E, coll. G.P. Mandal, (2855/H14); 1 exs in alcohol, 1 on slide, India: West Bengal: Chiple khola pool, Samsing Range, Neora Valley National Park, Kalimpong dist., 08.vi.2018, 27.012°N, 88.47°E, coll. G.P. Mandal, (2860/H14).

Diagnosis: Body usually white in colour, approx length 1.5mm. Ant I & II with scales, Ant IV with many sensory setae and devoid of apical bulb. Eyes absent. Unequal paired inner proximal teeth and one small distal tooth present on unguis. Unguiculas lanceolate and spatulate tenent hair present. Trochantral organ with 20 small spine like setae arranged in 'L' shape. VT with 3+3 anterior and 25 posterior setae. Manubrium and dens are ventrally scaled , dens with 2 rows of short spines. Mucro bidented with a third basal serrated tooth.

Distribution: India: West Bengal (Kalimpong*), Andhra Pradesh, Maharashtra, Odisha.

Remarks: Endemic to India. Newly recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily: Paronellinae Borner, 1913 sensu SotoAdams *et. al.,* 2008

Genus *Callyntrura* Borner, 1906

Type species: *Paronella anopla* Borner, 1906

Diagnosis: Scales present on body, head with 8+8 eyes, 4 well segmented antenna and vertex with 2+2 macrochaetae. Occipital and genal areas with 1+1 or without mac. Spines absent on manubrium and dens. Three or more teeth present on mucro.

13. *Callyntrura (Callyntrura) semiviolacea* (Handschin, 1929) (Fig.13, Plate – 3)

1929. *Microphysa semiviolacea* Handschin, *Rev. Suisse Zool.*, **36**: 229-262.

1964. *Aphysa semiviolacea* Salmon, *Bull. Roy. Soc., N. Z.*, (7) **2**: 145-644.

1974, *Callyntrura (Callyntrura) semiviolacea* Mitra, *Rev. Ecol.Biol.Sol.,* **11** (3): 397-439**.**

Material examined: 16 exs in alcohol, 1 on slide, India: West Bengal: Hill stream, Suntalyekhola, Samsing Range, Neora Valley National Park, Kalimpong dist., 06.vi.2018, 27.022°N, 88.47°E, coll. G.P. Mandal (2849/H14); 5 exs in alcohol, 1 on slide, India: West Bengal: Singalila National Park, Darjeeling dist., 27.ii.2021, 27.151°N, 87.233°E, coll. K.K.Suman, (3042/H14); 35 exs in alcohol, India: West Bengal: Gorumara Beat, Gorumara National Park, Jalpaiguri dist., 26.vi.2019, 26.471°N, 88.499°E, coll. G.P. Mandal, (2794/H14).

Diagnosis:

General body colour pale yellow with variable violate to blue pigment patches along the margins Th.II-II and Abd.I-III. Bases of antennae and legs with diffused violate patches. Femora with a darker patch placed distally. Body covered with various types of setae and lanceolate scales, legs with long acuminate setae. Head with 4+4 frontal spines, ocelli 8+8. Smooth labral setae, formula – 5, 5, 4. Unguis with paired basal, two unpaired distal teeth and a external basolateral teeth. Unguiculus almost lanceolate, clavate tenent hair finely ciliated. Mucro with 6 striated teeth, two short spines on dens near the base of mucro.

Distribution: India: West Bengal (Darjeeling*, Jalpaiguri*, Kalimpong*), Kerala, Odisha, Puducherry, Tamil Nadu.

Remarks: Endemic to India. First time recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily: Paronellinae Borner, 1913 sensu Soto Adams *et. al.,* 2008

Genus *Callyntrura* Borner, 1906

Type species: *Paronella anopla* Borner, 1906

14. *Callyntrura (Callyntrura) variabilis* Mitra, 1974 (Fig.14, Plate – 3)

1974. *Callyntrura (Callyntrura) variabilis* Mitra, *Rev. Ecol.Biol.Sol.* **11**: 426-429; figs 22-24.

Material examined: 4 exs in alcohol, 1 on slide, India: West Bengal: Madarihat, Jalpaiguri dist., 08.xi.1974, 26.68°N, 89.26°E, coll. T. Sengupta, (2522/H14).

Diagnosis:

Ground colour of body yellow to brown patched with dark blue-black pigment. Dirty brown antenna, Ant I-III each distally with a narrow blue ring, Ant IV pigmented blue. Th III, Abd I & II pigmented laterally. Most of the specimens with three median triangular patches on Abd. IV. A median longitudinal marking present on Th II to apex of Abd IV. Incomplete violate rings are present on legs, blue black coxae, tita are no pigmented distally. Body with lanceolate scales and flexed setae. 13- 14 mac present horizontally on either side of Abd IV. labral setae – 5,5,4 smooth, with 4 anterior tubercle. Unguis with paired basal, two unpaired, one small apical and one external basolateral teeth. Unguiculas toothless and lanceolate. Dental scale appendage absent. Six teeth present on mucro.

Distribution: India: West Bengal (Jalpaiguri*), Bihar, Uttarakhand, Uttar Pradesh.

Remarks: Endemic to India. Newly recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily: Paronellinae Borner, 1913 sensu Soto Adams *et. al.,* 2008

Genus *Dicranocentroides* Imms, 1912

Type species: *Dicranocentroides fasciculatus* Imms, 1912

Genus diagnosis: Body scale present, 8+8 eyes present, mesothorax and metathorx are not strongly bent. Vertex of head with mac. Three mac present on genal and occipital areas. Dens with two rows of spines. Mucro with 3 or more teeth, markedly separated from dens.

15. *Dicranocentroides fasciculatus* Imms, 1912 (Fig.15, Plate –3)

1912. *Dicranocentroides fasciculatus* Imms, *Proc. Zool. Soc. London*: 80-125.

1957. *Dicranocentroides fasciculatus* Salmon, *Acta Zool. Cracov*.**11** (14): 313 –362.

1975. *Dicranocentroides fasciculatus* Mitra, *Rec. Zool. Surv. Ind.,* **71**:57-95.

Material examined: 1 exs in alcohol, 1 on slide, India: West Bengal: Hill stream, Suntalyekhola, Samsing Range, Neora Valley National Park, Kalimpong dist., 06.vi.2018, 27.012°N, 88.47°E, coll. G.P. Mandal (2857/H14); 4 exs in alcohol, 1 on slide, India: West Bengal: Red Panda Project Site, Singalila National Park, Darjeeling dist., 28.ii.2021, 27.151°N, 87.233°E, coll. K.K.Suman, (3041/H14).

Diagnosis: Average body length 2-3 mm. Males are darker and larger than females. Body clothed with various shaped pseudoscales. Th II with reddish brown pigment and Abd III-IV with dark brown pigment, Abd IV-V are somewhat lightly pigmented. Pear shaped head with 8+8 ocelli. Six- Seven strong, spiniform setae present on the inner and lateral margin of each tita. Unguis slightly curved with external basolateral teeth. Well developed trochantral organ present. Three elongated vesicle along with two anterior small vesicles present on ventral tube. Mucro with 5-6 teeth.

Distribution: India: West Bengal (Darjeeling*, Kalimpong*), Andaman and Nicober Islands, Arunachal Pradesh, Bihar, Maharashtra, Manipur, Mizoram, Nagaland, Sikkim, Tripura, Uttarakhand, Uttar Pradesh.

Elsewhere: Sino- Japanese and continental South East Asia.

Remarks: Newly recorded from West Bengal.

Family Paronellidae Borner, 1913

Subfamily: Paronellinae Borner, 1913 sensu Soto Adams *et. al.,* 2008

Genus *Dicranocentroides* Imms, 1912

Type species: *Dicranocentroides fasciculatus* Imms, 1912

16. *Dicranocentroides salmoni* Mitra, 1975 (Fig.16, Plate – 3)

1975**.** *Dicraanocerntroides salmoni* Mitra, *Rec.Zool. Surv. India***. 71**:57-95**.**

Material examined: 18 exs in alcohol, 1 on slide, India: West Bengal: Hill stream, Suntalyekhola, Samsing Range, Neora Valley National Park, Kalimpong dist., 06.vi.2018, 27.012°N, 88.47°E, coll. G.P. Mandal, (2852/H14); 6 exs in alcohol, 1 on slide, India: West Bengal: Upper Gairibus, collected from leaf litter, Jhalong, Kalimpong dist., 09.ii.2023, 27.012°N, 88.47°E, coll. P. Mandal, (3340/H14); 17 exs in alcohol, 1 on slide, India: West Bengal: Chapramari Beat, Gorumara National Park, Jalpaiguri dist., 06.vi.2018, 26.548°N, 88.514°E, coll. G.P. Mandal, (2795/H14).

Diagnosis:

Body with variable colour pattern; Th. III and Abd I- II with deep pigmentation. Lateral and transverse bands of pigment present on Abd IV. Body covered with scales and brush setae. Abd III with 2+2 and Abd IV with 16+16 mac placed medially on each side. Elongated unguis with a pair of external basolateral and inner teeth; a distal unpaired subapical tooth present. Acuminate unguiculas with one tooth on outer lamella. 6-7 spine like setae present on each tita. Corpus of retinaculum with a median setae. Two rows of stout spines present on each dens.

Distribution: India: West Bengal (Jalpaiguri*, Kalimpong*), Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Uttar Pradesh, Uttarakhand.

Remarks: Endemic to India. Newly recorded from West Bengal.

Family Entomobryidae Schäffer, 1896 sensu Zhang et al, 2019

Subfamily Lepidocyrtinae Wahlgren, 1906 sensu Zang et al, 2019

Genus *Lepidocyrtus* Bourlet, 1839

Type species: *Lepidocyrtus curvicollis* Bourlet, 1839

17. *Lepidocyrtus (Allocyrtus) lepidornatus* (Handschin, 1930) Yoshii, 1982

(Fig.17, Plate – 3)

1930, *Acanthurella lepidornata* Handschin, *Phililp. J. Sci.* **42**:411, 416-417; p1.2 fig.20-23.

1982, *Lepidocyrtus (Allocyrtus) lepidornatus* Yosii, *Ent. Rep. Sabah. For. Res. Eenter,* **5**: 7, 22-23, 39, 47; Fig.12, 25.

Material examined: 45 exs in alcohol, 2 on slide, India: West Bengal: Mathurkur, collected from leaf litter, Polba-Dadpur, Hooghly dist., 01.i.2023, 22.889°N, 88.219°E., coll. P. Mandal, (3342/H14).

Diagnosis:

Body colour pale yellow, oval hyaline body scales showing a characteristic pattern, frontal scales of the head are dark violate. Ant II – IV are distally dark blue. 8+8 ommatidia on each side. Dark scales are scattered all over the body, characteristic square pattern observed on Abd IV. Unguis with three unpaired inner teeth and with a club shaped tenent hair. Bidented mucro with a basal spine. Dents have four strong pointed spines at its base.

Distribution: India: West Bengal (Hooghly*), Himachal Pradesh, Ladakh.

Elsewhere: Japan, Malaysia.

Remarks: First time recorded from the state.

Family Entomobryidae Schäffer, 1896 sensu Zhang et al, 2019

Subfamily Lepidocyrtinae Wahlgren, 1906 sensu Zang et al, 2019

Genus *Lepidocyrtus* Bourlet, 1839

Type species: *Lepidocyrtus curvicollis* Bourlet, 1839

Genus diagnosis: Body covered with finely striated rounded scales. Head with 8+8 eyes, Abd VI without projection. Dens with scales and basal appendix, without spines. Mucro have two teeth.

18. *Lepidocyrtus (Acrocyrtus) cryptocephalus* Handschin, 1929 (Fig.20, Plate – 4)

1929. *Lepidocyrtus cryptocephalus* Handschin, *Rev.suisse Zool.* **36**: 230, 240-241, 261; fig. 14-16.

Material examined: 44 exs in alcohol, 1 on slide, India: West Bengal: Ashalay Coachbai (8 Mile), Samsing Range, Neora Valley National Park, Kalimpong dist., 09.vi.2018, 27.02°N, 88.47°E, coll. G.P. Mandal, (2925/H14); 50 exs in alcohol, India: West Bengal: Neora Forest near Neora Bridge, towards Gorubathan, Neora Valley National Park, Kalimpong dist., 08.vi.2018, 26.581°N, 88.455°E, coll. G.P. Mandal, (2960/H14).

Diagnosis:

Adult body length near 2mm. General body colour pale yellow, Ant III & Ant IV entirely violate. Apex of the forehead pigmented deep- black. Abd I and II often with black bandage, proximal part of Abd IV and Abd V- VI are completely covered with blue pigment.

Large, dense setae present at the extremities of body and And VI. Acuminate, large bothriotricas are present on middle portion of Abd IV. Hyaline body scales present at the border of the segments and over the furca. Mesothorax overhangs on head in a hood-like manner.

Distribution: India: West Bengal (Kalimpong*), Assam, Daman, Diu, Dadra and Nagar Haveli, Odisha, Puducherry, Tamil Nadu.

Remarks: Endemic to India. First time recorded from West Bengal.

Family Entomobryidae Schaffer, 1896 sensu Zhang F *et al*, 2019

Subfamily Lepidocyrtinae Wahlgren, 1906 sensu Zang *et al*, 2019

Genus *Seira* Lubbock, 1870

Type species: *Degeeria domestica* Nicolet, 1842

Genus diagnosis: Eyes with 8+8 or 6+6 ommatidia. Body covered with scales, four segmented antennae present. Dens possess scales. Mucro vestigial or falcate.

19. *Seira (S.) cinerea* Yosii, 1966 (Fig.18, Plate – 4)

1966. *Seira cinerea* Yosii, *Res. Kyoto U. Exped. Karakoram* **8**: 364-365; fig.21A-F.

Material examined: 1 exs on slide, India: West Bengal, North 24 Parganas dist., 19.x.1979, 23.88 °N, 87.72 °E, coll. S. K. Mitra, (1802/H14).

Diagnosis:

Average body length 1.32 mm. 6+6 ocelli present. Body bluish gray with brown scales. Ant III- IV darker anteriorly. Ventral portion of the head, Th II- III and

Abd II with bluish tint. Bluish gray pigment spreads over Th III continued to Abd V. Furca basally pigmented. Straight unguis with one basal and two distal unpaired teeth.

Distribution: India: West Bengal (North 24 Parganas*), Lakshadweep, Maharashtra, Punjab.

Remarks: Endemic to India. First time recorded from West Bengal.

Family Entomobryidae Schaffer, 1896 sensu Zhang F *et al*, 2019

Subfamily Lepidocyrtinae Wahlgren, 1906 sensu Zang *et al*, 2019

Genus *Seira* Lubbock, 1870

Type species: *Degeeria domestica* Nicolet, 1842

20. ***Seira (S.) punctata*** (Ritter, 1911) (Fig.19, Plate – 1)

1911. *Drepanura punctata* Ritter, *Ann.K.K.naturh. Hofmus/ Wein* 24:383-384; figs.13-15

Material examined: 11 exs in alcohol, 1 exs on slide, India: West Bengal: East Kolkata wetlands, Tardaha, Naskarait pond, collected from litter, Kolkata dist., 26.iv.2019, 22.29°N, 88.22°E, coll. G.P. Mandal, (2651/ H14).

Diagnosis:

General body colour dirty yellow, segment extremities and Abd VI are pigmented with deep blue colour. Ant IV is the longest and entirely blue. Abd I–III are completely purplish-blue pigmented. Culb hairs not present, feathered hair or setae are densely present on antennae, legs and furca. Antenna half in length as of the body. Unguis with three unpaired teeth placed distally, unguiculas 2/3 of unguis and toothless. Clubbed tenent hair is longer than the unguis. Apical part of the dens strongly curved, falcate mucro placed distally.

Distribution: India: West Bengal (Kolkata*), Daman, Diu, Dadra and Nagar Haveli, Maharashtra.

Remarks: Endemic to India. Newly recorded from West Bengal.

Family Entomobryidae Schaffer, 1896 sensu Zhang F *et al*, 2019

Subfamily Lepidocyrtinae Wahlgren, 1906 sensu Zang *et al*, 2019

Genus *Seira* Lubbock, 1870

Type species: *Degeeria domestica* Nicolet, 1842

21. ***Seira (Seira) arunachala*** Mitra, 1976 (Fig.21, Plate – 4)

Siera arunachala Mitra, 1976. *Oriental Insects,* **10** (2): 143:149.

Material examined: 1 exs in alcohol, 1 on slide, India: West Bengal: Village Rajarbathan, collected from Leaf litter and rotten banana bark, Singur, Hooghly dist., 25.xi.2022, 22.869°N, 88.279°E., coll. P. Mandal, (3341/ H14).

Diagnosis: Pale yellow body with two blue colour patch on the targal margins of Th III, Abd I-III and on the posterior side of Abd IV; Th II, Abd V-VI are devoid of pigment. Body clothed with flexed mac and scales. Paired inner teeth and a subapical unpaired tooth present on the unguis, nondented and lanceolate unguiculas present. 17 spines arranged in a quadrate on the trochanteral organ. VT with 4+4 mac and 4+4 nonciliated setae. Dens crenulated with a falcate mucro without basal spine.

Distribution: India: West Bengal (Hooghly*), Arunachal Pradesh, Bihar.

Remarks: Endemic to India. First time recorded from

Fig.1: Collection site of the first time recorded species from the state of West Bengal.

1. Singallila National Park, Darjeeling.
2. Neora forest, near bridge, Kalimong.
3. Samsing range, Neora Valley NP, Kalimpong.
4. Suntalyekhola bridge, Kalimong.
5. Chapramari National Park, Jalpaiguri.
6. Gorumara beat, Gorumara National Park, Jalpaiguri.
7. Kendua, Siuri, Birbhum.
8. Susunia forest, Bankura.
9. North 24 Pargana.
10. Mathurkur, Polba-dadpur, Hooghly.
11. Jute Agricultural Research Institute, North 24 Pargana.
12. Nalban, Kolkata.
13. Patharberia, South 24 pargana.

West Bengal.

Discussion:

The present study represents a total 21 species of collembola belonging to 14 genera of 6 families for first time reported from the state of West Bengal. Earlier, Mandal *et. al.*, (2018) recorded a total of 75 collembolan species belonging to 43 genera under 13 families from the state. Different landforms, soil types and distribution of plant species enable the state to encompass a rich diversity of collembolan fauna. Seven species of the new records which were found from the districts of North Bengal (Fig.1), mainly from the fam. Paronellidae and out of the 21 first time records, 11 species belonging to the order Entomobryomorpha are predominantly found in the plain areas (Fig.1), that are quite relevant to the previous study conducted in the state by Mandal, 2020, showing a concentrated distribution of collembolan fauna towards plains. Therefore, more expeditions and investigations are required from the plains as well as higher altitudes to improve the morpho-taxonomic knowledge of collembola and to have a comparative understanding of their distributional ranges from the state.

Acknowledgement:

We express our sincere gratitude to Dr. Dhriti Banerjee, Director, Zoological Survey of India for providing us all sorts of facilities during the present work. We would like to thank all the sectional staff of 'Apterygota sction', ZSI, for constantly supporting us during the present study. We are also thankful to all the official and non-official staff for their direct and indirect contribution.

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Plate- 1

Fig. 1: ***Calvatomina trivandrana*** Prabhoo, 1971

Fig.2: ***Xenylla reducta*** Prabhoo, 1971

Fig.3: ***Xenylla welchi*** Folsom, 1916

Fig.4: ***Brachystomella contorta*** Denis, 1931

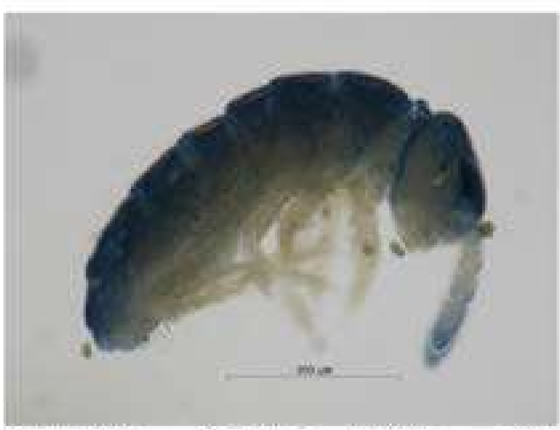

Fig.5: ***Ballistura fitchi*** (Denis, 1933) Potapov, 2001

Fig.6: ***Cryptopygus indicus*** Brown, 1932

Plate- 2

Fig.7: ***Cryptopygus tridentatus*** (Handschin, 1929)

Fig. 8: ***Isotoma plumosa*** (Salmon, 1969) Lawrence, 1978

Fig. 9: ***Cyphoderus assimilis*** Borner, 1906

Fig. 10: ***Delamarerus immsi*** Mitra 1977

Fig. 11: ***Pseudocyphoderus annandalei*** Imms, 1912

Fig. 12: ***Cyphoderopsis kempi*** Carpenter, 1917

Plate - 3

Fig.13: ***Callyntrura (Callyntrura) semiviolacea*** (Handschin, 1929)

Fig.14: ***Callyntrura (Callyntrura) variabilis*** Mitra, 1974

Fig.15: ***Dicranocentroides fasciculatus*** Imms, 1912

Fig.16: ***Dicranocentroides salmoni*** Mitra, 1975

Fig.17: ***Lepidocyrtus (Allocyrtus) lepidornatus*** (Handschin, 1930)

Plate - 4

Fig.18: ***Seira (S.) cinerea*** Yosii, 1966

Fig.19: ***Seira (S.) punctata*** (Ritter, 1911)

Fig.20: ***Lepidocyrtus (Acrocyrtus) cryptocephalus*** Handschin, 1929

Fig.21: ***Seira (Seira) arunachala*** Mitra, 1976

ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Unusual abundance of invasive *Tilapia* species in coastal waters of Devipattinam, Palk Bay, India

Swarnendu Bera, Soumili Paul, Muthusamy Anand*, Kannan Rangesh

Department of Marine and Coastal Studies, School of Energy, Environment and Natural Resources, Madurai Kamaraj University, Madurai- 625021, Tamil Nadu, India

Abstract

Worldwide, *Tilapia* sp. has gained a reputation as a highly sought-after, culturable species in the aquaculture industry thanks to its higher growth rate, excellent adaptive nature, low disease rate, and prolific breeding. Aquaculture is the only means to satisfy the dietary demand for fish protein in India, which has the highest population in the world. The first Tilapia species used for extensive aquaculture was *Oreochromis mossambicus*, which was introduced in India in the early 1950s under government patronage. Since then, aquaculture farms have been developed to culture Tilapia all over India, from the warmer tropical brackish waterbodies of Tamil Nadu to the cooler Himalayan regions.

The past few decades have witnessed a huge surge in Tilapia abundance in various natural water bodies, posing a serious threat to indigenous fish species. These highly adaptive fishes have now been observed surviving in fully marine environments in Palk Bay. Local fishermen are aware of the presence of these invasive species and regularly harvest them from the inshore waters. Several specimens of different ages have been found and recorded during a survey in coastal areas near Devipattinam, Tamil Nadu. It is assumed that these exotic species have found their way to the ocean from local aquaculture farms to local canals, eventually ending up in the ocean.

In a recent survey in January, 2023, adult specimens with fertile gonads were recorded. But most of the specimens found were juveniles and sexually immature, indicating that the inshore water of the Palk Bay region serves as a breeding and nursery ground for young ones. Surveys have shown that they are more abundantly found in coastal waters with an average depth of 2–5 meters, dominated by several sea grass species. Survival success is influenced by their ability to withstand oceanographic conditions and their interactive credibility with native indigenous species.

Keywords: *Tilapia* sp, abundance, invasive, Palk Bay.

1. Introduction

Tilapia, which is considered as world's most invasive species is found to be a threat to the indigenous fishes in majority of the countries. Tilapia is a native cichlid food fish species in the tropical eastern coastal waters of Africa (Trewavas, 1981). Tilapia has remarkable trophic plasticity and can obtain sexual maturity at a very early age, as a result they get overpopulated and become a competition for other fish species in terms of habitat and food (Gaikwad et al., 2017) we have explored the gut microbial community structure of tilapia using 16S rRNA gene sequencing on the Illumina Miseq platform. Our study showed significant differences in tilapia gut microbiota collected from different habitats (i.e. river and lakes. This cichlid fish are extremely hardy, and can tolerate polluted and poor water quality, temperature fluctuations, environment variations and even water with low dissolve oxygen content (Pérez et al., 2006)an issue of particular focus among conservation biologists. Colonizing

*Author for correspondence : anandm21@yahoo.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

a novel environment presents a genetic challenge to invading species because such species surely have not experienced the selective pressures presented by the environment. Here we ask, by what mechanisms and processes do alien species genetically naı¨ ve to their new environment, become successful invaders? We attempt to resolve this paradox by considering the interplay between an invader's ability to modify its new environment, and genetic modifications imposed by the new environment. We postulate that epigenetic adaptations, and adaptive mutations are likely play a role in enhancing invasion success.", "container-title": "Biological Invasions", "DOI": "10.1007/s10530-005-8281-0", "ISSN": "1387-3547, 1573-1464", "issue": "5", "journal Abbreviation": "Biol Invasions", "language": "en", "page": "1115-1121", "source": "DOI.org (Crossref. This cichlid fish species was introduced in many countries, including India, in the early years for aquaculture, fishing games, controlling pests etc. (Pullin et al., 1997). In 1952, Mozambique Tilapia was experimentally introduced in the Indian water bodies (Sugunan, 1995), as a rich source of fish protein, which later even proved to be a success, as claimed by several aquaculture experts (Eknath and Hulata, 2009), but the species dominated the indigenous food fish communities, as the former being a prolific breeder and hardy in nature (Kumar, 2000). Later on, other Tilapia species populations were also introduced such as *Tilapia zilli* (1986), *Oreochromis urolepis* (date unknown), *O. niloticus* (1987) and red hybrid Tilapia (date unknown) (Keshavanath et al., 2004). Tilapias are the second most important group of non-cyprinid fishes after carps, with a total production of 6.6 million tons in 2019 (Bardhan et al., 2021) and was forecasted to grow 3.7 percent in 2022, breaking the **6 million- metric-ton** barrier, according to the Global Seafood Alliance's (GSA) annual production survey (Evans, 2021).

Tilapia in India are widely cultured in ponds, cages, raceways and tanks, while polyculture with carps and shrimps have been reported from the states of Andhra Pradesh, Gujarat and Tamil Nadu (Menaga and Fitzsimmons, 2007). Other states, particularly coastal states like Orissa, West Bengal are gearing up for the culture of *O. niloticus* and other closely related species (Singh et al., 2014) as they are one of the easiest and profitable fish to farm. Government of India, after realising the culturing of Tilapia by the farmers, without proper quarantine, biosecurity, and planning because of the numerous undocumented imports of Tilapia in the country, led out proper guidelines to expand the industry in a proper fashion. Incidents of inadvertent releases and escapement of *Tilapia* from aquaculture facilities frequently occurs (Singh et al., 2014). However, recent unusual abundance of *Tilapia* in the marine inshore water of Devipattinam coast along Palk Bay has been recorded. Wide size range of *Tilapia* sp. from juveniles to mature, were observed in the wild inshore waters of the Palk Bay, particularly in an area where Tilapia is hardly cultured. This scenario prompted us to study the population characteristics i.e., the abundance, size range, GaSI, GSI, maturity. The study was undertaken to ascertaining the invasion and colonization of the escapee *Tilapia* sp. through natural population in the marine inshore Palk Bay waters.

2. Study Area

The present study was conducted near the coastal area of Devipattinam, an ancient port town from Ramnathapuram district, near to Vaigai River estuary of Tamil Nadu (Figure 1). The study area falls in the Vaigai River basin, one of the important river basins which ends up in Palk Bay. The nearby mangrove ecosystem along Vaigai estuary has high nutrient inflow. The sediment is dominantly sandy, with coarse sand and silt. The inshore waters have high assemblage of Seagrass meadows, serving as a highly productive ecosystem by providing habitat, breeding, and feeding ground for various marine species and support as the backbone for fisheries. The muddy water of these study area is productive and boosting with life. But waste water run-off, high anthropogenic activities like fishing has played a significant role among the area. Local mechanised as well as non-mechanised boats operate in this region. *Nandu-valai*, *Thangu-valai* are some of the nets which is used to capture the crabs and fishes from here (Figure 2).

3. Materials and Methods

3.1 Physicochemical parameters

The water and atmospheric temperatures were recorded from the sampling sites using a digital thermometer. Samples were kept in dark at 20°C for 5 days, further processed by addition of phosphate buffer. After incubating in BOD incubator, the samples `were analysed by modified Winkler's method. The equation used to calculate BOD:

$$BOD\ (mg/L) = (DO - DO_5) \times \text{dilution factor},$$

where DO = volume of Oxygen in blank set and DO_5 = volume of oxygen in incubated set.

3.2 Fish Sampling

Samples of Tilapia fish were collected along Devipattinam coast, between the pre-monsoon months of January and February, 2023. Fishermen of that area, generally used bottom set gill net and push net (*thalluvala*i) for fishing purpose. *Thalluvalai* is indigenous gear, operated from plank built boats and these resembles a mini trawl net (Rajamani and Palanichamy, 2009). Fishes were collected from the study site and were identified using keys for fish identification from Jhingram, 1975 and FAO identification sheet as FAO, 2010. Total length (to nearest cm) was measured and weighed (g) using standard graduated scale and portable digital balance respectively. From the total catch, the abundance index of Tilapia was calculated using the formula:

$$AI = \frac{n(k) \times 100}{N}$$

Where, AI = abundance index,

n(k) = number of Tilapia caught at study site,

N = number of all fish species caught at the site.

3.3 Biometric studies

With the help of measuring board and graduated scale, the total length of each fish was calculated from tip of the snout to the extended tip of the caudal fin. Body weight is measured using portable digital balance to nearest grams (Fafioye and Oluajo, 2005) (Figure 3).

Importance of Length-Weight Relationship

In early research methodologies, Log transformed mean weights of fishes with different lengths were used to calculate Length- weight relationships (Nomura, 1962). Erzini, 1994 the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology", "DOI": "10.1111/j.1439-0426.1994. tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue": "1", "journalAbbreviation": "J Appl Ichthyol", "language": "en", "page": "17-41", "source": "DOI.org (Crossref, reported the importance of Length weight relationship in fishery population dynamics. The size of a fish is generally related to its age, as most of the ecological as well as physiological parameters are proportional to age (Santos et al., 2002). Researchers use the length-weight relationships (LWR) of fish species to understand and estimate their population dynamics, stock assessment and ecological status as by Erzini, 1994; King, 1996; Petrakis and Stergiou, 1995; Santos et al., 2002the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology", "DOI": "10.1111/j.1439-0426.1994. tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue":"1", "journalAbbreviation": "J Appl Ichthyol", "language": "en", "page": "17-41", "source": "DOI.org (Crossref. Reports on fish stock composition, life span, mortality and growth can also be obtained using the length-weight relationship (Bolger and Connolly, 1989).

The knowledge on LWR of fish species helps to understand the weight-at-age from total recorded catch weight and length-frequency distribution and to estimate the condition of fish samples and also to compare the life history of fish species between regions (Petrakis and Stergiou, 1995). LWR helps to build mathematical relation between variables and record variations from expected weight for length of fish samples (Le Cren, 1951).

Length-Weight Relationship of *Tilapia* sp.

The length weight relationship of *Tilapia* sp. was studied with samples collected along Devipattinam coast, Palk Bay, Tamil Nadu, India. The following equation was used to estimate the parameters of Length- Weight relationship of fish samples (Le Cren, 1951; Ricker, 1973) (Fig. 3).

$$W=aL^b$$

Where, W= weight of the fish (g)

L= length of fish (cm)

a = initial growth coefficient or y-intercept

b = growth coefficient or slope

This also has the logarithmic form as equation to know whether the growth is isometric (b=3) or allometric (positive if b>3 and negative if b<3) (Ricker, 1973), is determined using LWR. The regression coefficient (r^2), significance level of r^2 and confidence limit of 95% of parameters 'a' and 'b' were estimated.

3.4 Gut content analysis (GaSI)

The intestines of the collected Tilapia fishes were dissected and fixed in 5% formalin solution for further inspection under microscope (Hynes, 1950) . The gut were placed on a petri dish and observed under the compound microscope in order to know more about the diet and feeding habits of the species (Figure 4).

Different taxa of food were identified and counted, also gastro somatic index (GaSI) was calculated using the equation (Biswas, 1993)

$$GaSI = \frac{\text{Total weight of the Gut (including food contents)}}{\text{Weight of fish}} \times 100$$

3.5 Gonado Somatic Index (GSI)

The collected fish samples were brought to the laboratory for sex determination. Tilapia fish generally do not exhibit external dimorphism, and the sex can be determined only after cutting open the abdomen and studying the gonads. Gonads are removed from the fish and weighed (to the nearest cm), GSI was calculated using the equation

$$GSI = \frac{\text{Total weight of Gonad}}{\text{Total weight}} \times 100$$

3.6 Fecundity

Eggs present in the ovary of female mature fish sample was weighed and the following formula was used to measure fecundity of the fish sample.

Fecundity=number of eggs in one gm of ovary x total weight of ovary (g)

4. Result

The physicochemical components of the study site are represented in table 1. Temperature ranged between 27 and 28 °C, while the pH ranged between 8.30 and 8.37. Total alkalinity of the study site was recorded between 1923-2100 µmol/kgSW. Site 2 of the study area, recorded a comparative lower dissolved oxygen of 5.78 mg/l, while the other two sites had DO of 6.78 and 6.11 mg/L. The site 3 had the highest BOD count of 7.08 mg/l, while the salinity of the water ranged between 32-33 PSU (Table 1). ODV plots were plotted against salinity and temperature with respect to depth at the study sites (Figure 6). The abundance index of *Tilapia* sp. was found to be 13. 59%, during the study. The size of the fish samples was found to be 18.9 ± 3.99 cm.

Length-weight relationship of the present investigation revealed that Tilapia of both the males and females collected from Devipattinam showed an isometric growth (nearly b=3), which means the weight increases proportionally to the cube of the length as the exponent value observed was almost 3 (table 2).

Gut analysis of the specimen revealed that the food items mainly include crustaceans (majorly including copepods) for 40%, molluscs (including bivalves, small snails, and cephalopods) for 18%, smaller plankton for 12%, polychaete worms for 5%, fish parts for 4% and the remaining 21% consisted the miscellaneous unidentified items (Figure 5). The unidentified food remains could not be identified as they were found in advance stages of digestion. Gonadal examination of the sampled fishes from different sites revealed that all life stages (immature, maturing and matured) fishes were available in the study waters. The current sampled pool contained more numbers of mature female specimens (table 3). Gonads of examined specimens revealed Gonado-somatic index (GSI) of 2.89 – 3.04. The calculated absolute fecundity ranged between 778.14 and 820 (table 3). During the study period, several other fish samples were like Mullets, *Lutjanus* sp., *Plotosus* sp., *Scatophagus argus*, *Monodactylus argenteus*, *Arothron immaculatus*, *Rastrelliger kanagurta*, *Atule mate*, *Peneus monodon*, Nurse shark and Sting rays were identified in the catch.

5. Discussion

In early research methodologies, Log transformed mean weights of fishes with different lengths were used to calculate Length- weight relationships (Nomura, 1962). Erzini, 1994the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology", "DOI": "10.1111/j.1439-0426. 1994. tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue":"1", "journalAbbreviation": "J Appl Ichthyol", "language": "en", "page":"17-41", "source":"DOI. org (Crossref, reported the importance of Length weight relationship in fishery population dynamics. The size of a fish is generally related to its age, as most of the ecological as well as physiological parameters are proportional to age (Santos et al., 2002). Researchers use the Length-weight relationships of fish species to understand and estimate their population dynamics, stock assessment and ecological status as by Erzini, 1994; King, 1996; Petrakis and Stergiou, 1995; Santos et al., 2002 the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology","DOI": "10.1111/j.1439-0426.1994. tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue": "1", "journal Abbreviation": "J Appl Ichthyol", "language": "en", "page": "17-41", "source": "DOI.org (Crossref. Reports on fish stock composition, life span, mortality and growth can also be obtained using the Length-weight relationship (Bolger and Connolly, 1989).

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In this study, the b values got for pooled samples was 2.962, signposted a high growth in this environment. The females grow superior to the males generally due to their large ovary size and this is the reason for increased b values in female fishes. The energy gained by food and oxygen consumption by female fishes was not consumed on fights with other fishes or for reproduction which a male fish usually does, hence the females have an increase in b value than male (Laxmikanth et al., 2022, Laxmikanth et al., 2023). Physicochemical parameters play a main role in signifying an area that is healthy or contaminated. This study reveals that maximum salinity in Devipattinam coast was 33 PSU and maximum temperature was 28°C. Dissolved oxygen in this region was 6.78 mg/l which is more than optimum water quality condition due to that the area has rich in seagrass ecosystem. The average pH in Devipattinam was 8.32 which is higher than ambient level pH of Southeast coast of India. And, the total alkalinity value was 2100 μmol/kgSW. Both pH and total alkalinity indicated that the ecosystem health in terms of ocean acidification phenomenon (Anand et al., 2021, Ravichandran et al., 2022, Devi et al., 2023). The details about seasonal variations in physicochemical parameters of the Palk Bay is further required to represent the key ecosystem health and it will help researchers to study the dynamics in this region. The effects of pollution, climate change and seasonal variation can also easily be detected by studying the water, air and soil quality. This study helps to find the determined critical areas in the Palk Bay and quality issues of the coastal regions.

As concluding remarks from the results of this study, Tilapia is considered a world's most invasive species, it is found to be a threat to the indigenous fishes in Palk Bay, India. The present investigation revealed that Tilapia of both the males and females collected from Devipattinam showed an isometric growth, which means the weight increases proportionally to the cube of the length as the exponent value observed was almost 3. This in turn reveals that the Palk Bay is suitable for good growth of Tilapia although its population is frequently occurrence along the Devipattinam site region hence further investigation have to be taken to survey in entire Palk Bay region to conserve the innate species.

Figures

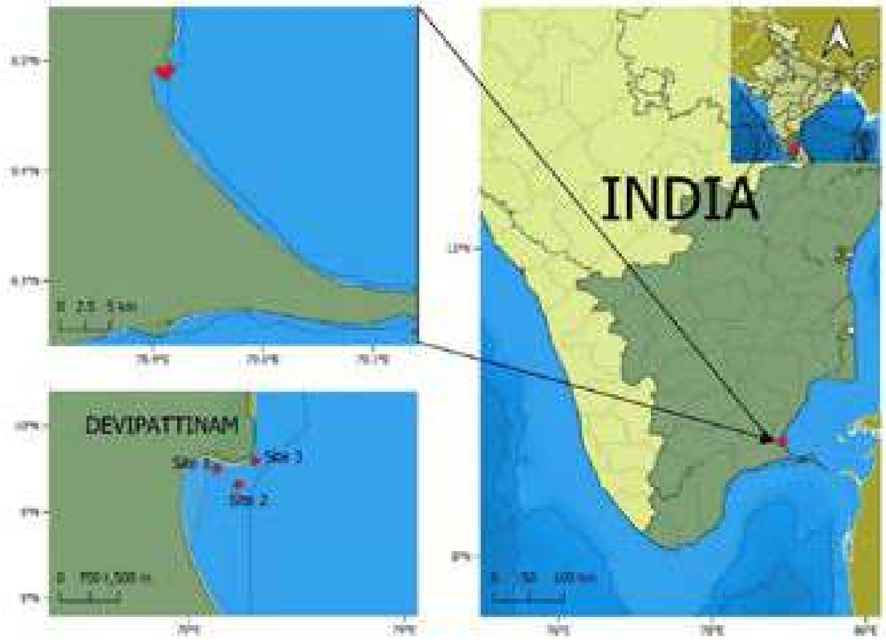

Figure 1. Map showing selected study sites along Devipattinam coast, Palk Bay

Figure 2. Sampling of *Tilapia* sp.

Figure 3: Determining the length of the fish samples.

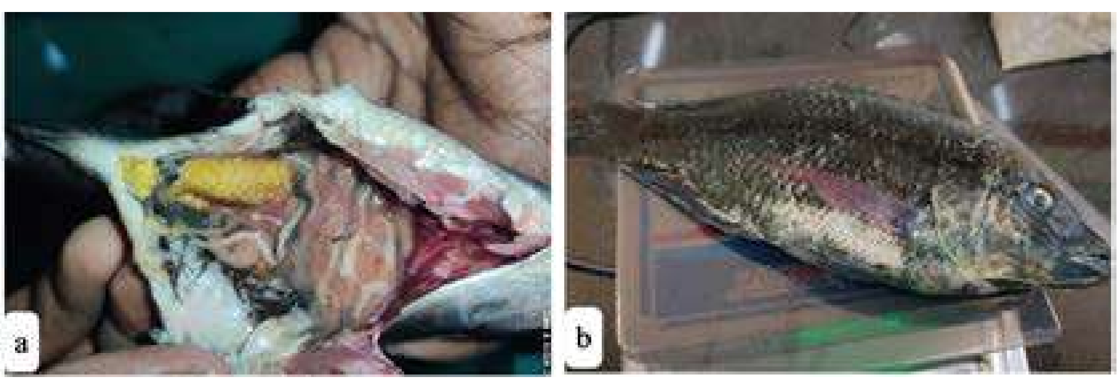

Figure 4: a) Gut analysis of the fish sample and b) Weighing of the fish sample

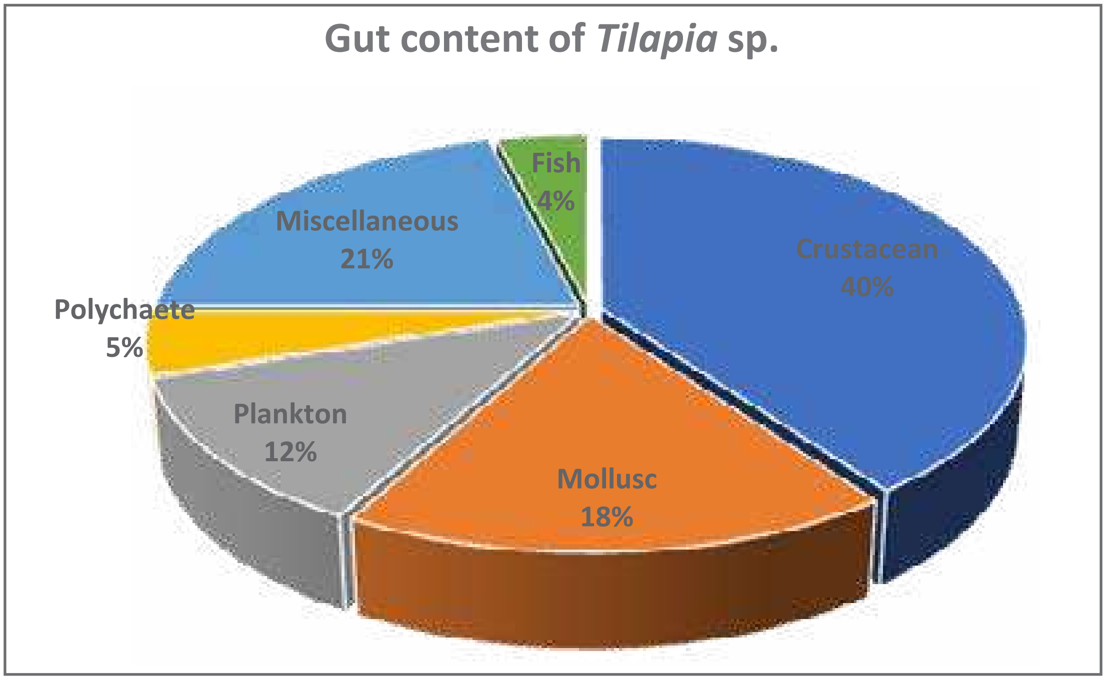

Figure 5: Gut content of the fish sample

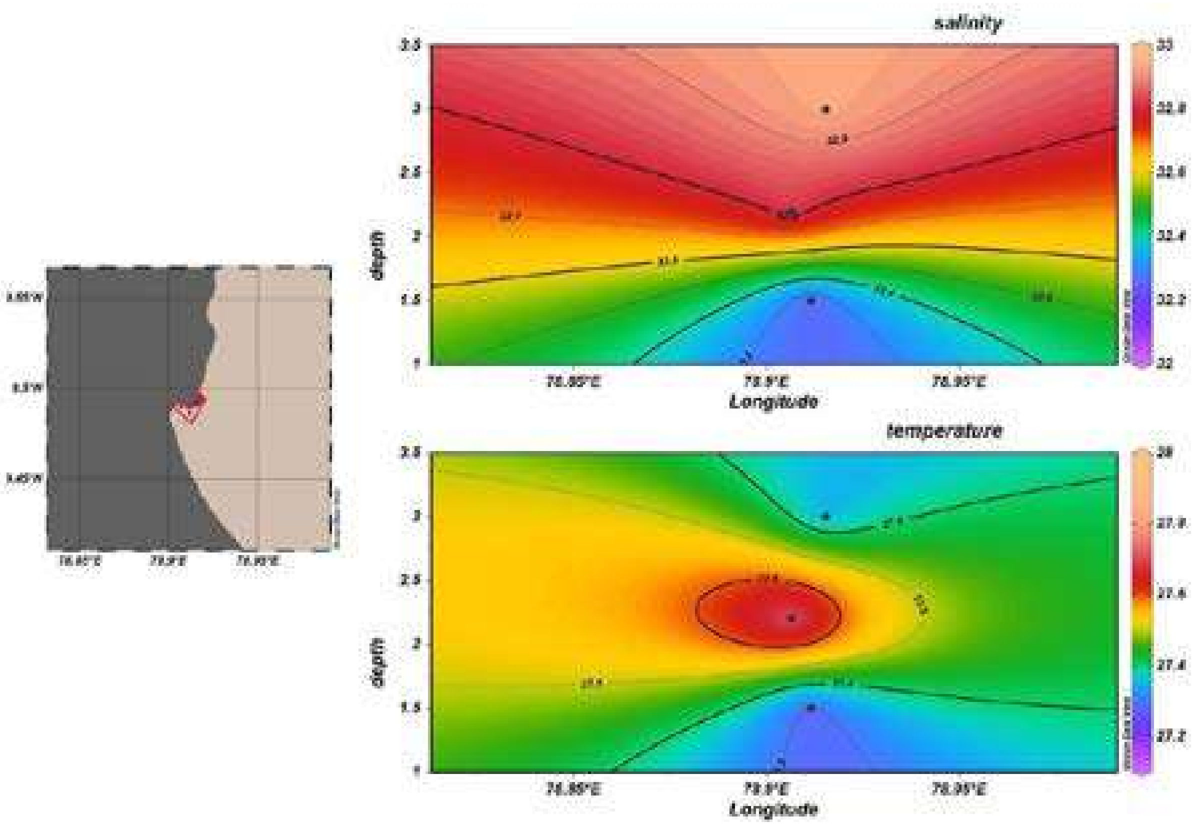

Figure 6. ODV plots representing salinity and temperature at the study sites

Tables

Table 1. Physicochemical parameters in different sites in Devipattinam, Palk Bay

Parameters	Site-1	Site-2	Site-3
Temperature (°C)	27.1	28	27.2
pH	8.37	8.30	8.31
DO (mg/L)	6.78	5.78	6.11
Salinity	32	33	33
Water depth	1.5	2.2	3
BOD (mg/L)	6.42	6.75	7.08
Total alkalinity (µmol/ kgSW)	1923	1929	2100

Table 2: Statistical description of LWR parameters of *Tilapia* sp.

Sex	N	Length (cm)			Weight (gm)			Parameters of LWR		
		Min	**Max**	**Mean±SD**	**Min**	**Max**	**Mean±SD**	**a**	**b**	**r^2**
Pooled samples	7	11.4	24.1	18.9 ± 3.99	27	239	159 ± 67.07	0.024	2.962	0.928

Table 3: Catch contribution and Biometry of *Tilapia* sp. captured from study site

Year	Abundance (%) of Tilapia sp.	Length range (cm)	Weight range (gm)	GaSI	Sex Ratio		GSI	Fecundity
					Female	**Male**		
Jan, 2023	13.59%	11.4-24.1	27-239	3.18-4	5	2	2.89-3.04	778.14 - 820

6. Acknowledgment

The authors are grateful to the Department of Marine and Coastal Studies, Madurai Kamaraj University for their financial support and for providing infrastructure facilities of RUSA, MKU and MoES-NCCR project facilities in completing this study.

7. Refernces

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Substratum preferences of Ascidians in Natural and Artificial Reef Environment, Andaman and Nicobar Islands

Jhimli Mondal* and C. Raghunathan

Zoological Survey of India, Prani Vigyan Bhawan, M – Block, New Alipore, Kolkata – 700053, West Bengal, India

Abstract

Ascidians are one of the significant bio-fouling organisms causes great economic loss, as they grow on offshore shellfish and finfish culture system, ship hulls, pontoons, jetties, buoys etc. This study carried out to estimate the fouling preferences of ascidians in variation with depth, season, and substrate at Pongibalu (natural reef) (11°30.958'N; 92°39.201'E) and North Bay (artificial reef) (11°43.006'N; 92°45.465'E) of Andaman and Nicobar Islands. Panels (concrete, glass, ceramic and metal) of 30 X 20 cm^2 were placed at the depth of 10 m and 20 m from January 2015 to December 2015 by SCUBA diving. The data collection was made in every four months interval. Altogether 35 species of ascidians belonging to five families were settled on the panels including 12 species under the family Didemnidae. A total of 29 species of ascidians were recorded from Pongibalu whereas, only nine species were recorded from the North Bay during the study period. It is interesting to note that, *Pyura lanka* was found on the settlement panels only, instead of reef areas of Pongibalu; similarly, *Symplegma brakenhielmi* and *Symplegma rubra* were observed on the panels at North Bay although they were not observed in the reef areas of North Bay during the study period. Both *P. lanka* and *S. brakenhielmi* is considered as cryptogenic in nature and status of *S. rubra* is yet to be established. Among four types of settlement panels, concrete and ceramic panels showed significant coverage of ascidian settlement at both experimental stations. It was observed during the study that the panels of natural reef area showed the higher diversity, species richness, lesser dominance, and lesser coverage. Whereas, panels of artificial reef areas showed lesser diversity and species richness, and higher dominance (90.20%) of three species coverage which indicates an early sign of species invasion.

Keywords: Biofouling, Substrate specificity, Natural reef, Artificial reef, Ascidians

Introduction:

Fauna under class Ascidiacea is commonly known as sea-squirts. This exclusively marine sessile faunal community has free-swimming larval stage. These larvae are commonly known as ascidian tadpole larva. After few minutes to several hours of swimming these larvae find suitable substratum to settle and metamorphose into adults. Ascidians are considered as macro bio-fouler and have significant role in macrofouling community (Cheng *et al*., 2022; Palaniswamy *et al.*, 2018; Meenakshi, 2010; Rocha *et al.,* 2009; Venkat *et al.*, 1995) of coastal ecosystems. These macro-biofoulers cause a great economic loss every year by settling on the mussels of the mussel culture, ship hulls, pontoons etc. (Giangrande *et al*., 2023; Rocha *et al.,* 2009; Lambert and Lambert, 2003, Lambert, 2005). Beside the natural habitat *i.e.* reef environment, hard rocks, stones, roots, sea grasses, sea weeds etc., the submerged man-made structures like ship hulls, piers, pilings, buoys, harbour installations, materials used for aquaculture, ropes etc. are preferred as the substratum for the ascidians for carrying out their settlement (Meenakshi, 2010). Being bio-foulers, they invade into non-native places

*Author for correspondence : jmjhimli@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

and become the global threat to marine biodiversity (Micael *et al.*, 2022; Molnar *et al.*, 2008). Bio-invasion is a rising ecological issue and represents a solemn risk to marine as well as terrestrial biodiversity, existence of native species and economy (Jaffarali et al., 2014). Non-indigenous species e.g., algae, octocorals, annelids, molluscs, barnacles, shrimps, bryozoans, sea urchins, sea stars, ascidians, fishes etc. are visible in world's ocean. These animals are effortlessly settled on the ship hulls, pontoons etc. and are spread to other non-native area.

Apart from the natural substrates, artificial marine structures have accelerated the distribution of several non-indigenous species world-wide (Bulleri and Airoldi, 2005). The settlement pattern of ascidians is studied carefully across the globe (Goodbody, 2003; Shenkar, 2008; Rocha *et al*, 2009) along with the settlement of other groups i.e., rock oyster, tube worms, bryozoans, crustose coralline algae, sponges, corals etc. (Bae *et al.*, 2022; Bowden *et al.*, 2006; Perkol-Finkel *et al.*, 2006; Perkol-Finkel and Benayhu, 2005; Brown, 2005; Watson and Barnes, 2004; Knott *et al.*, 2004; Qiu *et al.*, 2003; Bailey-Brock, 1989; Wendt, 1989; Hatcher, 1998; Brown and Swearingen, 1998). Seasonal variation of settlement was conducted by several researchers to conclude the availability of larva and their settlement depending on the changing physical parameters (Shenkar, 2008). It was also tried to establish the eradication method for these bio-foulers as well as for non-indigenous ascidians (Palaniswamy *et al.*, 2018; Cahill *et al.*, 2012; Holt and Cordingley, 2011; Murugan and Ramaswamy, 2003). From the four three decades, emphasis on the settlement of the faunal group on the artificial reef has been carried out (Bae *et al.*, 2022; Shenkar, 2008; Bowden *et al.*, 2006; Brown and Swearingen, 1998; Bailey-Brock, 1989) to understand the process of marine habitat restoration (Perkol-Finkel and Benayahu, 2007). The studies on settlement on depth and orientation have been carried out (vertical and horizontal) to understand the species composition in different depth and the larval settlement nature (Shenkar, 2008). In India, studies were conducted by several researchers to understand the settlement pattern of ascidians, viz., studies on bio-fouling community conducted New Mangalore Port (Venkat *et al.,* 1995), Mumbai harbor (Swami and Chhapgar, 2002; Swami *et al.*, 2011), Kalpakkam coast of southeast India (Sahu *et al.*, 2011). As, Andaman and Nicobar Islands are surrounded by the channels, straits and seas, the inter-island transportation and communication is mostly dependent on shipping services along with small boat/dinghy services for the inhabitant of those islands. The records of bio-fouling as well as non-indigenous species are important to prevent invasion in these area as a part of conservatory measures. The objective of the present study was to collect the data on the settlement pattern of the ascidian larvae to understand their substratum preferences (concrete, glass, ceramic and metal) seasonally and depth wise from two different areas *i.e.,* natural reef (Pongibalu) and shipwreck (North Bay).

Material and Methods

Study Area: Two sites were selected to study the settlement pattern of ascidians on different substrates as well as different depths. The first selected study area was Pongibalu (Lat: 11°30.958'N; Long: 92°39.201'E) of South Andaman. It was studied because of the presence of natural reef. While the artificial reef (ship wreck) at North Bay (Lat: 11°43.006'N; Long: 92°45.465'E) (Fig. 1) was selected as second study area. Pongibalu is situated at South Andaman region of Andaman and Nicobar Islands and located in the periphery of Mahatma Gandhi Marine National Park. The depth of the area varies between 1.3 to 41m. The area is predominantly covered by hard corals. The diversity of the hard corals is greater up to the depth of 18m while scanty cover of the reef habitat is recorded up to 35m. Shipwreck is situated at North Bay, South Andaman region and it supports the formation of artificial reef in this area. As the main harbor of Andaman and Nicobar Islands is nearby, the settlement in this area is influenced by the nearby natural reef as well as through the larvae dispersed from the ballast water.

Experimental Design: *In situ* studies on settlement pattern of ascidians were carried out at Pongibalu and North Bay at the depth of 10m and 20m during January 2015 to December 2015 by using four artificial substrates (30×20 cm^2) such as Concrete, Glass, Ceramic and Tin panels. All the panels were kept in vertical manner for the settlement of ascidians (Figs. 2). Panels were replaced by the new panel and the old panels with settlement were collected in every 4 months interval. Before collecting the panels, it was observed carefully with a hand lens for tiny ascidians which may have been missed or damaged during the collection. *In-situ* digitization was made by Canon G15 and Canon 1X Mark II with marine Pack. Collected panels were brought to the laboratory and examined to assess the settlement of small ascidians also. After measuring the settlement coverage, all the specimens were scrapped from the panels and defecated and narcotized with the help of magnesium sulphate and menthol crystal respectively. All the narcotized specimens were preserved in 4% formaldehyde-seawater solution. Preserved specimens were dissected under the microscope (Labomed CZM4) and digitization of detailed taxonomical characters was carried out under Leica M205A DFC 500 stereo zoom microscope to record the species composition in an individual panel. Species were identified in conjunction with Kott (1985, 1990, 2001), Monniot and Monniot (2001) and Renganathan (1984). Dominance of the species in a particular panel is measured by its settlement coverage. Coverage of the ascidian settlement was measured under the microscope. The total settlement coverage of each species was calculated in the following manner:

Results and Discussion

A total of 35 species of ascidians belonging to 5 families were settled on the experimental panels (Table 1). Among them, 29 species of ascidians were recorded from Pongibalu, whereas only 9 species were recorded from the North Bay during the period of study (Table 1 & Fig. 3). The maximum number of species was documented from Pongibalu area at the depth of 10m (22 species) and the least number of species were documented from the North Bay at the depth of 20m (5 species) (Table 1). Among them, *Didemnum molle, Didemnum psammathode, Phallusia arabica, Herdmania pallida, Pyura sacciformis, Rhopalaea bilobata, Eusynstyela latericius, Halocynthia spinosa* and *Styela canopus* were common species in Andaman and Nicobar Islands. It is interesting to note that although *Pyura lanka* was not recorded from the reef area of the Pongibalu, the species was found on the settlement panels. Similarly, *Symplegma rubra* and *Symplegma brakenhielmi* were observed on the panels at North Bay although they were not observed in the reef area of North Bay during the study period.

In North Bay, the total 34.96% of ascidian settlement was recorded on all four panels at the depth of 20 m at North Bay during May to August 2015 while no settlement was recorded at the depth of 10 m at North Bay during September to December 2015 (Fig. 4). While in Pongibalu, the maximum (12.63%) of ascidian settlement was recorded at the depth of 20m during May to August 2015 whereas minimum (0.70%) coverage was documented at the depth of 10m during January to April 2015 (Fig. 5). In North Bay, highest percentage of cover of 90.20% was observed on concrete panel with a composition of 3 species during May to August 2015 at the depth of 20m while lowest (0.02%) was found on ceramic panel with a colony of a single species during January to April, 2015 at 10m depth (Fig. 4).

Among the four types of substrate panels, concrete and ceramic panels showed significant cover of ascidian larval settlement at both the study sites. In Pongibalu, the highest settlement coverage of 37.14% was recorded with 8 species at a depth of 20m during May to August 2015 on glass panel. The lowest (0.25%) settlement with 4 species was found on ceramic panel during January to April 2015 at a depth of 10m (Fig. 5).

The four panels viz. concrete, glass, ceramic and tin were selected to conduct the settlement study and observe the difference between the settlement patterns on each panel. Concrete materials are used for the construction of jetties and other permanent structures. Andaman and Nicobar Islands is a tourist destination where glass bottom boats are used to show the magnified coral reef areas of Andaman and Nicobar Islands and they also can be prone to fouling. Hence, glass panels are used as substratum of ascidian settlement. Ceramic panels were used to compare the settlement worldwide as several researchers generally use ceramic panels to study settlement pattern. Tin panel is used as a metallic sheet which can be comparable to the metallic structures like ship hulls etc. Earlier studies also used acrylic panels (Swami and Chhapgar, 2002; Bowden *et al.*, 2006), recycled PVC (Perkol-Finkel and Benayahu, 2007) and wood (Sahu *et al.*, 2011) materials for settlement.

In comparison with the artificial reef at North Bay, the species richness was higher on the settlement panels in natural reef area of Pongibalu, as the low species diversity was observed at the experimental site of the North Bay and higher species diversity was observed at the natural reef area. Due to this phenomenon, the release of ascidian larvae of several reef associated species were abundant in Pongibalu and they also preferred all panels to settle on it. The species composition was very low in North Bay, and species dominance was higher on the settlement panels. The similar trend of settlement was observed on the shipwreck. Although the species assemblage was higher in Pongibalu in comparison with North Bay, the percentage of settlement was lesser in Pongibalu than in North Bay. In Pongibalu, due to the natural reef area, the settlement panels contained other reef associated faunal communities such as sponges, soft corals, sea anemones, hydrozoans, bryozoans, polychaetes, bivalves, barnacles along with less sediments and algae. However, in North Bay settlement panels contained few bivalves with enormous quantity of sediments and algae. In Pongibalu, *Rhopalaea bilobata* was observed during every season from both depths. *Herdmania pallida* was observed during a single season from both depths of North Bay. Among the documented species from the settlement panels, 6 species namely, *Ascidia sydneiensis*, *Phallusia Arabica*, *Styela canopus*, *Didemnum psammatodes*, *Herdmania momus* and *Herdmania pallida* were reported as non-indigenous to Indian waters. Among these, *H. pallida* showed settlement on the concrete panels from North Bay and 7 individuals were found from the same panel. However, the *Symplegma viride*, *Symplegma rubra* and *Didemnum* sp.3 made maximum settlement cover but their status regarding indigenous or non-indigenous were not evaluated till now from Indian waters. Ascidian cover on the panels at Pongibalu was maintained almost a stable value during two seasons except during May to August 2015; whereas, the settlement on glass panel was high at the depth of 20m. However, no settlement was observed during January to April 2015 and September to December 2015 on the glass panels at the depth of 10m. While in North Bay, settlement cover was not stable and varied seasonally and no settlement was observed during several seasons on several panels from both depths although mostly no settlements were observed at the depth of 10m. while, at the depth of 20m in North Bay, concrete panels always showed massive settlement of ascidians, although the cover was always made by a single species only. During September to December 2015 ceramic panels displayed the higher settlement than the concrete panel.

Irrespective of the depth, season and locality, settlement of ascidians is found to be more on average on the concrete panel. During present study, the settlement or percentage of cover was found same on average in most of the seasons from most of the panels at Pongibalu, while ascidian settlement was displayed by a maximum percentage of the panels at North Bay at the depth of 20m. Only a few small crabs were noticed on the settlement panels when the ascidian settlement was not observed on those panels. The present study reported maximum ascidians density during the month of June with two species only. The study made by Swami and Chhapgar (2002) revealed settlement of 12 species of ascidians and documented the highest settlement during September from Tidal basin. Ascidian diversity was found highest by Sahu *et al.* (2011) during March-April on weekly panels at Kalpakkam coastal waters. They also recorded maximum species richness from South break waters during February and March and the highest settlement was recorded during the month of February. As Andaman and Nicobar Islands have prolonged rainy season it may not affect the settlement of ascidians throughout the year unlike other researchers have documented (Swami and Chhapgar, 2002; Sahu *et al.*, 2011) form the mainland, India.

Conclusion

The present study pioneers the species-specific settlement pattern of ascidians in the Andaman and Nicobar Islands. The study also observes the settlement of the reef associated ascidians along with the non-indigenous species based on season, different substratum, and depth of natural reef and artificial reef habitat. There was significant difference in settlement found between 10m depth and 20m depth of Pongibalu (natural reef), and North Bay (artificial reef). A great variation among the species composition was also recorded depending on the seasons and the depth between natural reef and artificial reef habitat. Beside the natural reef environments, settlement of ascidian was diverse and dominant on concrete substrate along with non-indigenous/cryptic species from both areas. In comparison with Pongibalu (natural reef), North Bay (artificial reef) is prone for fouling by non-indigenous/cryptic species as it serves as a navigational channel.

Table 1: Ascidian species recorded from the settlement panels area and depth-wise

Sl. No.	Taxa	Pongibalu		North Bay	
		10m	20m	10m	20m
	Phylum CHORDATA Haeckel, 1874				
	Subphylum TUNICATA Lamarck, 1816				
	Class ASCIDIACEA Blainville, 1824				
	Order APLOSOBRANCHIA Lahille, 1886				
	Family DIDEMNIDAE Giard, 1872				
1	*Didemnum* sp.1		•		
2	*Didemnum* sp.2	•			
3	*Didemnum* sp.3	•	•		•
4	*Didemnum* sp.4	•			
5	*Didemnum psammatodes* (Sluiter, 1895)		•		
6	*Didemnum cuculliferum* (Sluiter, 1909)	•			
7	*Trididemnum* sp.	•			
8	*Lissoclinum* sp.1		•		
9	*Lissoclinum* sp.2	•			
10	*Diplosoma* sp.1		•		
11	*Diplosoma* sp.2	•			
12	*Leptoclinides* sp.	•	•		
	Family POLYCITORIDAE Michaelsen, 1904				
13	*Eudistoma* sp.	•			
	Family CLAVELINIDAE Forbes and Hanley, 1848				
14	*Clavelina robusta* Kott, 1990		•		
	Family DIAZONIDAE Seeliger, 1906				
15	*Rhopalaea bilobata* Mondal *et al.*, 2017	•	•		
	Order PHLEBOBRANCHIA Lahille, 1886				
	Family ASCIDIIDAE Herdman, 1882				
16	*Ascidia sydneiensis* Stimpson, 1855			•	
17	*Phallusia arabica* Savigny, 1816		•		
	Order STOLIDOBRANCHIA Lahille, 1887				
	Family STYELIDAE Sluiter, 1895				

Sl. No.	Taxa	Pongibalu		North Bay	
		10m	20m	10m	20m
18	*Polycarpa aurita* (Sluiter, 1890)	•			
19	*Polycarpa* sp.			•	
20	*Styela canopus* Savigny, 1816	•		•	
21	*Cnemidocarpa areolata* (Heller, 1878)	•			
22	*Botrylloides violaceus* Oka, 1927	•	•		
23	*Eusynstyela latericius* (Sluiter, 1904)	•			
24	*Symplegma rubra* Monniot, 1972				•
25	*Symplegma viride* Herdman, 1886				•
26	*Polyandrocapa* sp.		•		
	Family PYURIDAE Hartmeyer, 1908				
27	*Pyura vittata* (Stimpson, 1852)			•	•
28	*Pyura sacciformis* (Drasche, 1884)	•	•		
29	*Pyura lanka* Herdman, 1906	•			
30	*Pyura* sp.		•		
31	*Microcosmus exasperatus* Heller, 1878	•		•	
32	*Microcosmus* sp.	•			
33	*Herdmania momus* (Savigny, 1816)	•			
34	*Herdmania pallida* (Heller,1978)	•		•	•
35	*Halocynthia spinosa* Sluiter, 1905	•			
	Total number of species	22	13	6	5
	Total number of genera	16	10	6	4
	Total number of families	8	7	3	3

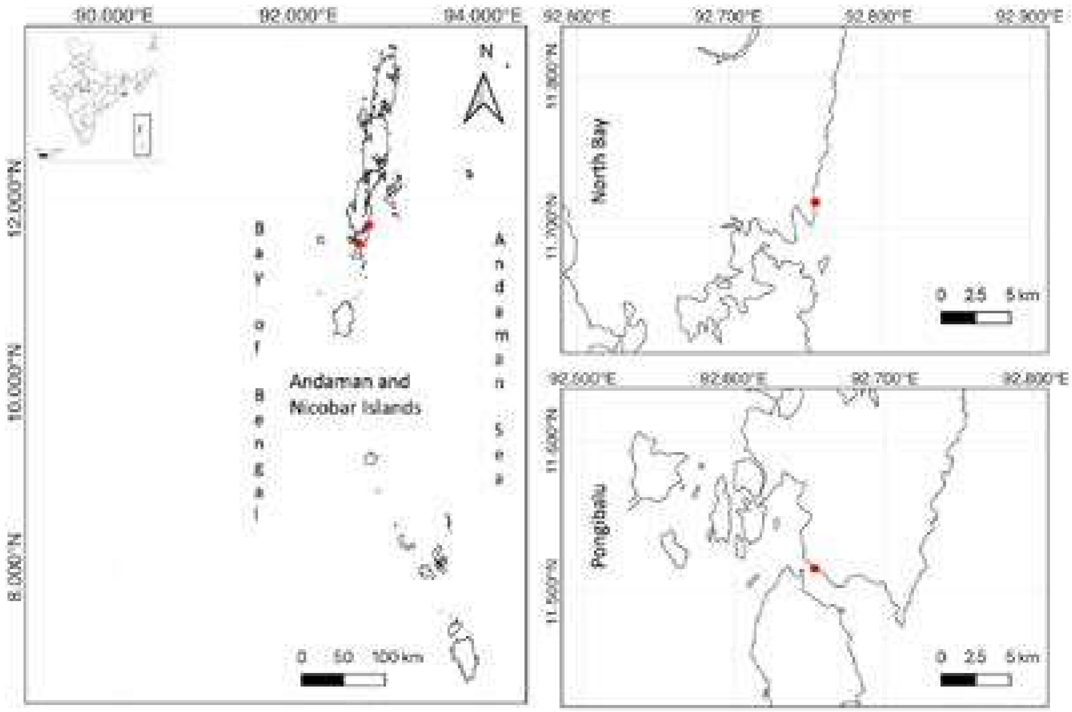

Fig.1: Study Area of Andaman and Nicobar Islands

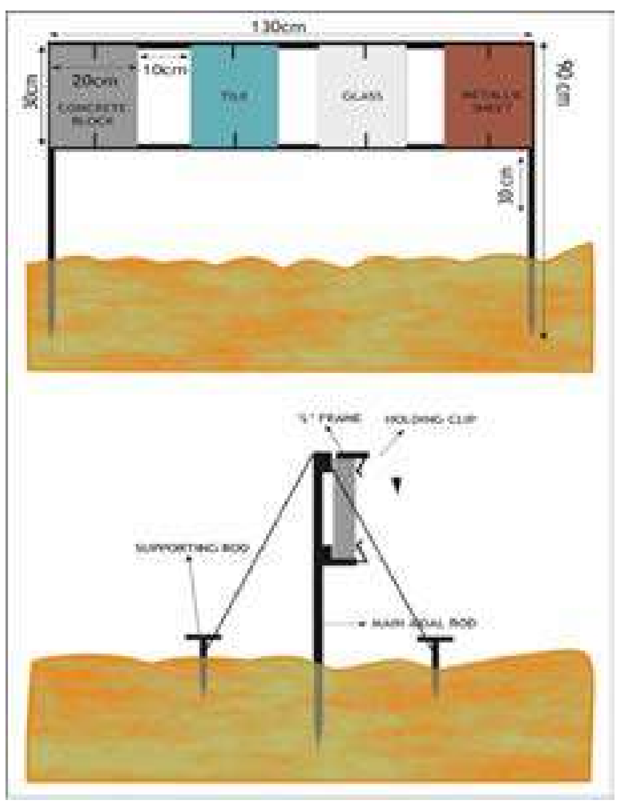

Fig. 2: Schematic diagram of experimental set up

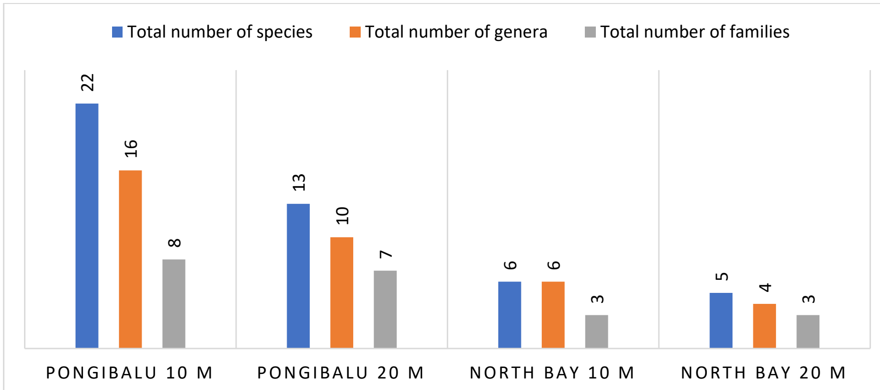

Fig. 3: Species composition at the 10m and 20m Depth at Pongibalu and North Bay

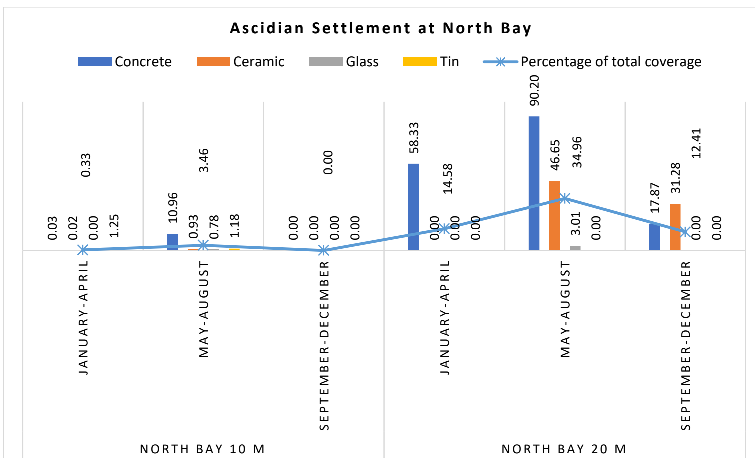

Fig. 4: Depth, season and panel wise percentage cover of ascidians at North Bay

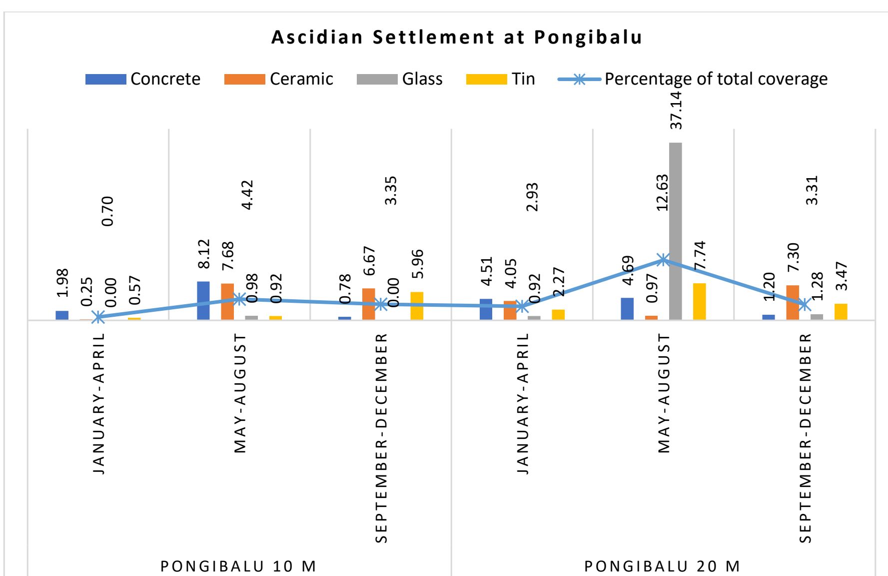

Fig. 5: Depth, season and panel wise percentage cover of ascidians at Pongibalu

Acknowledgements

Authors are grateful to the Director, Zoological Survey of India, Kolkata for providing necessary facilities and permission to carry out the work. The supports extended by Department of Environment and Forests, Andaman and Nicobar Administration during field trips are duly acknowledged.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Faunal diversity of zooplankton in the selected wetlands of Nagaland, North-East India

[1]Kensibo Pamai*, [2]B. K. Sharma

[1]Department of Zoology, Patkai Christian College (Autonomous), Chümoukedima-Seithekema Chümoukedima, Pin- 797103, Nagaland, India
Email ID: kensibo971@gmail.com
[2]Department of Zoology, North-Eastern Hill University Shillong-793022, Meghalaya, India
Email ID: profbksharma@gmail.com

Abstract

The study aims to assess the faunal diversity of zooplankton importance base on our plankton collections from three selected wetland of Nagaland (North East-India). Our collection from Madladijam, Bolfangdisa and Noune wetlands revealed biodiverse zooplankton assemblage with a report of 181 species spread over 79 genera and 34 families, belonging to five groups of zooplankton. Rotifera followed by Cladocera largely contribute to zooplankton richness while Rhizopoda, Copepoda and Ostracoda are other components. Our study reveals 32 species new records from Nagaland State and 2 species from North East-India, besides, 50 species of rotifers has been recently added as new records from the State. Total zooplankton richness ranged between 109-160 (138±22) species and percentage similarity between wetlands shows high similarities, Noune and Madladijam is 71.1%; Noune and Bolfangdisa is 73.6% and similarity between Madladijam and Bolfangdisa wetland is 83.4%. The study revealed several biogeographically interesting elements. The biodiversity and biogeographically importance as recorded is attributed to ecological heterogeneity of the sampled wetlands.

Keywords: Zooplankton, Diversity, Wetlands, Nagaland, North-East India.

Introduction:

Zooplankton is an essential constituent of aquatic ecosystems and plays a significant role in the transfer of energy and nutrients through the food web (Steinberg & Robert, 2009). Zooplankton invariably forms an integral component of freshwater communities and contributes significantly to biological productivity. These fish-food organisms have been studied from various inland ecosystems of this country but information on their ecology in the Indian floodplain lakes in particular is yet limited (Sharma & Sharma, 2008). Floodplain lakes are important features of landscapes in major river systems all around the world. These shallow wetlands are considered ecotones, as they have diverse environmental conditions due to changes in water levels and the presence of macrophytes and are well-known for their rich biodiversity and ecological significance (Funk et al. 2009, Górski et al. 2013, Dembowska & Napiórkowski 2015, Napiórkowski et al. 2019). The floodplain lakes, an important component of inland aquatic resources of India, are hypothesized to be rich habitats for zooplankton diversity (Sharma & Sharma 2008). The small water bodies (ponds and wetlands) are considered as keystone systems for analyses of biodiversity (Vad et. al. 2017; Oertli 2018). The present study is the continuation of our earlier reports on biodiversity of rotifers in Nagaland (Sharma and Kensibo, 2017; Sharma et. al., 2017).

*Author for correspondence :
Article Received on: 02.04.2023
Accepted on: 24.04.2023

Material and Methods

Plankton samples were collected from Bolfangdisa, Madladijam and Noune wetlands at regular monthly intervals during the study period i.e., from December 2014-November 2016 at three sampling station each. The monthly qualitative plankton samples were collected by towing nylobolt plankton net (#50 µm) from the littoral and limnetic regions of three wetlands and were preserved in 5% formalin. All plankton samples were screened with Wild Stereoscopic Binocular Microscope for isolation of various taxa which in turn were observed with Leica (DM 1000) stereoscopic phase contrast microscope fitted with an image analyser. A polyvinyl alcohol-lactophenol mixture was used to mount zooplankton. Micro-photographs were taken with a Leica DM 1000 image analyser. The measurements were given in micrometres (µm). Different groups of zooplankton, Rotifera were identified following Kutikova (1970), Koste (1978), Koste and Shiel (1987, 1989, 1990), Shiel and Koste (1992, 1993), Segers (1995), De Smet (1997), Sharma (1983, 1987a, 1987b, 1998), Nogrady and Pourriot (1995), Sharma and Sharma (1997, 1999a, 1999b, 2000, 2008) and, Nogrady and Segers (2002). Cladocera were identified following Smirnov (1971, 1974, 1996), Michael and Sharma (1988), Korovchinsky (1992), Sharma and Sharma (2008, 2013), Orlova-Bienkowskaja (2001) and Korinek (2002). Rhizopoda were identified following the works of Deflandre (1959), Chattopadhyay and Das (2003) and, Sharma and Sharma (2008). Copepoda were identified following Ranga (1994, 2001), Alekseev (2002) and, Ueda and Reid (2004). Ostracoda were identified following Victor and Fernando (1982) and Victor (2002).

Various macrophytes were recorded from the sampled wetlands. In Bolfangdisa wetland it comprises of *Alternanthera* sp., *Azolla* sp., *Centella* sp., *Ceratophyllum* sp., *Chara* sp., *Commelina bengalensis, Elodea* sp., *Hydrilla verticillata, Juncus* sp., *Nelumbo* sp., *Nymphaea* sp. *and Scirpus* sp. The different macrophytes of Madladijam wetland were *Alternanthera* sp., *Azolla* sp., *Centella* sp., *Ceratophyllum* sp., *Chara* sp., *Commelina bengalensis, Elodea* sp., *Hydrilla verticillata, Juncus* sp., *Nymphaea* sp. and *Scirpus* sp. *Nymphaea* sp. is the main macrophyte in Noune wetland.

Systematic Accounts

Systematic list of zooplankton recorded of Nagaland wetlands

(In the Tables and figures file)

Results and Discussion

The present report of 181 species belonging to 81 genera, 33 families and five groups from the three wetlands of Nagaland state of NEI affirms species-rich and diverse zooplankton. The reported taxa deserve biodiversity importance as the highest richness of fish-food organisms and one of the richest zooplankton diversity known till date from small lentic environs of any state of northeast India (NEI) and from India (BKS, unpublished), respectively. The results endorse the hypothesis (Sharma and Kensibo, 2017) on small lentic ecosystems to be one of the rich habitats for metazoan diversity. The documented zooplankton heterogeneity is hypothesized to habitat diversity and ecological heterogeneity of the sampled wetlands and it is also attributed (Sharma and Sharma, 2004, 2008) to biodiverse nature of 'slightly acidic-circum neutral-slightly alkaline' and 'soft-moderately hard' waters characterized by 'low ionic concentrations'.

A total of 34 species (18.78% of S) of zooplankton are new records with 32 new records from Nagaland and 2 species are new records from northeast India (NEI); the former includes 13, 4, 11 and 4 species of new records of Cladocera, Copepoda, Rhizopoda and Ostracoda, respectively while two of Copepoda are new records from NEI. This study marks an important contribution to faunal diversity and biogeography of zooplankton in NEI in general and Nagaland in particular in light of limited earlier works on the rotifer species (Sharma and Sharma, 2014a; Sharma and Kensibo, 2017; Sharma et. al. 2017).

Total zooplankton of Nagaland wetlands reported richness outnumbered distinctly the reports of 148 species from sub-tropical small urban wetland of Meghalaya (Sharma & Sharma, 2021); 141 species from three Floodplain Lakes (Beels) of the Majuli River Island, Assam (Sharma & Hatimuria, 2017); 121 species from two floodplain lakes of Manipur (Sharma, 2011); 76 species (Khan, 2002) and 89 species (Khan, 2003) from the floodplains lakes of Southeastern West Bengal; 76 species from two floodplain wetlands (Datta, 2011) of north Bengal; and 51 species from two Himalayan wetlands (Khan, 1987). The stated comparisons asserted biodiversity importance of the present study *vis-à-vis* ecosystem diversity of the small lentic ecosystems of Nagaland.

The present study indicated higher rotifer richness of 109-160 (139±22) species of individual wetlands. Bolfangdisa wetland recorded a total of 160 species with richness of 149 and 111 species during two years, respectively. Madladijam wetland recorded 147 species with 133 and 109 species during two years of the study, respectively. Noune wetlands recorded a total 109 species and it indicated 96 and 83 species during first and second year, respectively. Community similarities of 71.1-83.4% (*vide Sørenson index*) during this study as well as 62.9-77.6% and 62.5-82.2% during two years, respectively, the present results characterized overall homogeneity in zooplankton species composition amongst the wetlands. Maximum similarity is observed between Bolfangdisa and Madladijam while Noune and Madladijam recorded the lowest similarity both during the study as well as during two years individually. The Maximum community similarity observed between Bolfangdisa and Madladijam while Noune and Madladijam recorded the lowest similarity maybe attributed to diversity in aquatic macrophytes (Ahmad & Parveen, 2013).

Rotifera, the most species-richness group of zooplankton, recorded a total of (S) of 110 species (S) belonging to 31 genera and 17 families; the results thus indicate rich and diverse Rotifera assemblage (Sharma and Kensibo, 2017) which merit biodiversity interest as ~39.0 and ~26.0% of species known from NEI and India, respectively (Sharma and Sharma, 2017a). The rotifer richness provides a significant update to 66 species, 23 genera and 14 families of the rotifers reported earlier from Nagaland (Sharma and Sharma, 2014a) while it is higher than a recent high report of 90 species from a small urban sub-tropical wetland of Meghalaya state of NEI (Sharma *et al*., 2016). Rotifera recorded reasonable richness variations (82±12 species) amongst three Nagaland wetlands with higher richness in Bolfangdisa (95 species) > Madladijam (84 species) wetlands while Noune wetlands with the semi-limnetic habitat is characterized by relatively lower richness (66 species). Besides, high rotifer richness in the three wetlands individually is hypothesized to their habitat diversity and environmental heterogeneity.

The globally interesting elements formed a notable fraction (11.0% of S) of Rotifer diversity of the Nagaland wetlands (Sharma and Kensibo, 2017). These are represented by the Australasian *Brachionus dichotomus reductus*; three Oriental endemics *i.e.*, *Lecane blachei*, *Lecane bulla diabolica*, *Lecane latissima*; and eight palaeotropical species *viz., Lepadella discoidea, Lepadella vandenbrandei*, *Lecane lateralis, Lecane simonneae, Lecane unguitata*, *Testudinella brevicaudata*, *Testudinella greeni* and *Trichocerca hollaerti*. Besides, *Lecane doryssa, Lecane elegans, Lecane haliclysta, Lecane hastata, Lecane rhenana, Lecane thienemanni, Lecane undulata, Lepadella benjamini, Lepadella costatoides, Lepadella dactyliseta, Testudinella amphora, Testudinella dendradena*, *Testudinella tridentata, Trichocerca insignis* and *Trichocerca maior* are species of regional distribution interest in the Indian-sub region. Amongst these, 12 species *viz., Lepadella benjamini, Lepadella vandenbrandei*, *Lecane elegans, Lecane latissima, Lecane rhenana, Lecane undulata, Testudinella amphora, Testudinella brevicaudata*, *Testudinella dendradena*, *Testudinella greeni*, *Trichocerca hollaerti* and *Trichocerca maior* are characterized by their distribution in India till date exclusively restricted to NEI (Sharma and Sharma, 2015, 2017a). *Lecane latissima,* an interesting lecanid noticed in Nagaland collections, deserved attention. It was originally reported from India from Meghalaya state of NEI (Sharma, 2004) as *Lecane thailandensis* which was subsequently assigned (Sharma and Sharma, 2014b) to *Lecane latissima* following its recent synonymy (Segers and Savatenalinton, 2010).

Lecanidae > Lepadellidae together comprise major component (~49.0% of S) of the rotifer diversity. In addition, Brachionidae > Trichocercidae > Testudinellidae deserved attention (~29.0% of S). *Lecane* > *Lepadella* (45.4% of S) are more diverse genera and *Trichocerca* > *Brachionus* > *Testudinella* together form a notable fraction (~23% of S). The richness importance of the stated taxa endorsed the littoral-periphytic character of the rotifer assemblages concurrent with general habitat of the two wetlands. This generalization endorsed the remarks the wetlands of Manipur (Sharma *et al*., 2016) of the Brahmaputra river basin floodplains of NEI (Sharma and Sharma, 2014a, 2014c). Nevertheless, the richness of Brachionidae (14 species) and *Brachionus* (8 species) is attributed to certain semi-limnetic conditions in these water bodies. This in contrast to the relative paucity of these taxa known from Meghalaya wetland (Sharma *et al*., 2016) in spite of open water conditions. The speciose nature of the \`tropic-centred' *Lecane* and *Brachionus* to certain extent; high richness of cosmopolitan species (~62.0% of S); and the reports of several tropicopolitan and pantropical species (~25% of S) impart a 'tropical character' to the rotifer fauna in conformity with the composition of the tropical faunas from different parts of the globe (Green, 1972; Pejler, 1977; Fernando, 1980; Dussart *et al*., 1984; Segers, 1996, 2001; Sharma and Sharma, 2014a, 2017a).

Forty-four species (S), belonging to 34 genera and seven families, recorded from the sampled Nagaland wetlands reveal a fairly rich and diverse **Cladocera** assemblage; these comprise ~37.0% of the species of this group known from India (Sharma and Sharma, 2017b). Total cladoceran richness (S) assumes particular biodiversity value *vis-à-vis* a conservative estimate of up to 60–65 cladoceran species from tropical and subtropical parts of the Indian subcontinent (Fernando and Kanduru, 1984; Sharma and Michael, 1987; Sharma and Sharma, 2017b). Thirteen species are new records to Nagaland; these include *Alona kotovi, Anthalona harti, Chydorus angustirostris, Chydorus eurynotus, Disparalona caudata, Graptoleberis testudinaria, Grimaldina brazzai, Guernella raphaelis, Kurzia latissima, Leydigiopsis pulchera, Macrothrix odiosa, Ovalona cambouei* and *Picripleuroxus quasidenticulatus.* In general, the present study marked a significant contribution to the ecosystem diversity of Cladocera of the small lentic ecosystems of India in general and Nagaland wetlands in particular.

The biogeographically interesting **Cladocera** include the Australasian *Disparalona caudata*; the Indo-Chinese *Alona cheni, Alona kotovi* and *Picripleuroxus quasidenticulatus*; the Oriental *Celsinotum macronyx*; and the Palaearctic *Kurzia latissima*. Of these, *Disparalona caudata* is an important link between the Cladocera faunas of northeast India, Southeast Asia and Australia (Sharma and Sharma, 2007, 2017b). The Indo-Chinese *Alona cheni* was originally described by Sinev (1999); it is known elsewhere in India from Kerala while Sharma and Sharma (2013) extended its distribution to NEI. *Alona kotovi,* another member of this category, is recent addition (Sharma and Sharma, 2014d) to the cladoceran faunas of India from the wetlands of the Majuli River Island. This conger of the old world *Alona quadrangularis* is considered as a notable example of connection between South American and Australasian faunas of Chydoridae (Sinev, 2012). The Oriental *Celsinotum macronyx* reported from NEI from Meghalaya (Sharma, 2008) and Assam (Sharma and Sharma, 2012, 2015). The Palaearctic *Kurzia latissima* deserved attention: this species is reported from India from the Brahmaputra basin, Assam (Sharma and Sharma, 2012, 2014d).

Total **Cladocera** richness (S) reported from Nagaland (40 species) is higher than the reports of 11 species from two floodplain lakes (Khan, 1987) of Kashmir; 9 species from 65 wetlands of 24-Parganas district (Nandi *et al.*, 1993) of West Bengal; 4 species (Sinha *et al.*, 1994) and 12 species (Sanjer and Sharma, 1995) from the floodplains of Bihar; 36 species from 20 wetlands from the floodplains of south-eastern West Bengal (Khan, 2003) and 30 species from 30 wetlands of Keoladeo National Park (Venkataraman, 1992).

Cladocera exhibited richness variations in this study (33±8 species) in conformity with habitats variations of the three wetlands; Bolfangdisa and Madladijam indicated high diversity of 40 and 36 species, respectively while the semi-limnetic waters of Noune wetland recorded only 22 species. The results also indicated inter-annual richness variations in individual wetlands. The richness reports during the study and annually coupled with community similarities asserted habitat variations amongst three wetlands but with high homogeneity of Cladocera species composition. Cladocera are also more biodiverse than the reports of 13 species (Sharma and Bhattarai, 2005) from peat bog in Bumdeling wildlife sanctuary of Bhutan; 7 species (Sharma and Lyngskor, 2003) from a subtropical reservoir of Meghalaya; 6 species (Sharma and Wanswett, 2006) from fish pond of high rainfall region of Meghalaya.

Chydoridae, the most diverse family, formed a dominant component (59.1% of S) of the richness of Cladocera with Aloninae and Chydorinae represented by 7 and 19 species, respectively. In general, the chydorid importance concurred with the reports of Khan (2003), Sharma and Sharma, (2008, 2014d). This generalization highlighted the littoral-periphytic character of Cladocera which, in turn, is supported by certain semi-planktonic taxa *viz., Chydorus sphaericus, Disparalona caudata, Ephemeroporus barroisi, Graptoleberis testudinaria, Karualona karua* and *Notoalona globulosa*; and paucity of planktonic *elements*. The lack of any species of *Daphnia* as well as *Acroperus harpae* and *Dadaya macrops* in the sampled water bodies is notable and required analysis of factors limiting the distribution of these taxa. In general, Cladocera assemblages of Nagaland wetlands are characterized by their 'tropical character' following the generalizations of Sharma and Sharma (2008, 2014d, 2017b); Sharma and Sharma (2013).

Rhizopoda included 14 species belonging to seven genera and five families in the sampled Nagaland wetlands with Lobosea: Filosea ratio = 2.5. High richness in individual wetlands (12±1 species) affirmed high homogeneity of the testate amoebae composition amongst the wetlands. The richness is higher than the report of 8 species (Sharma and Bhattarai, 2005) from peat bog of Bhutan, 4 species (Sharma and Lyngskor, 2003) from a reservoir of Meghalaya and 3 species (Sharma and Wanswett, 2006) from fish pond of Meghalaya. Eleven species of Rhizopods are new records from Nagaland state. *Arcella hemispherica, Centropyxis aculeata, Centropyxis ecornis, Difflugia corona, Difflugia oblonga, Difflugia pyriformis, Difflugia urceolata, Euglypha* *acanthophora, Trinema lineare, Lesquereusia spiralis* and *Nebela caudata* are new records of rhizopods from Nagaland.

Copepoda is represented by 8 species spread over four genera and two families; cyclopoid and calanoid Copepoda included four species each. *Mesocyclops isabellae* and *Mesocyclops parentium* are new records from northeast India (NEI) while *Heliodiaptomus cinctus, Heliodiaptomus contortus, Neodiaptomus schmackeri* and *Thermocyclops crassus* are new records from Nagaland. Of these, the palaeotropical *Mesocyclops isabellae* is known from India (Madhya Pradesh) and Sri Lanka (Holynska, 1997) and *Mesocyclops parentium* originally reported from Kerala and from swamps of Sri Lanka (Holynska, 1997; Ueda and Reid, 2003), is a rare cyclopoid species (Resmi and Jayachandran, 2014). *Heliodiaptomus contortus,* described by Gurney (1907) from the Indian Museum tank, Calcutta, is an Indian endemic and *Heliodiaptomus viduus* is reported to be most common in South India and decreased gradually in North (Hossain, 1985). *Heliodiaptomus cinctus*, described by Gurney (1907) from Chakradharpur (Bihar), is a eurytopic species which is fairly widely distributed in India except subtropical Kashmir. It is a Southeast Asian element with reports from India, Sri Lanka and Myanmar while *Neodiaptomus schmackeri* is an Oriental element. Copepoda richness in individual ponds varied 8±1 species; it is lower than the reports of 12 species (Kumar *et al.,* 2011) from a pond of Bihar but higher than 3 species (Sharma and Bhattarai, 2005) from peat bog of Bhutan; 5 species (Devi *et al*., 2013) from temple pond of Jammu and Kashmir; and 4 species (Sharma *et al*., 2015) from two ponds of Jammu region.

Ostracoda is represented by five species belonging to five genera and two families; all the recorded species *viz., Cypris subglobulosa, Hemicypris anomala, Stenocypris major* and *Pseudocypretta maculata* are new records from Nagaland except *Cypretta* sp. Of these, *Cypris subglobulosa* is a widely distributed in the Oriental region and *Hemicypris anomala* distributional range is recently extended to northeast India (Sharma and Sharma, 2013).

Conclusion

The species-rich and diverse assemblage, hypothesized to result from the micro-habitat diversity and environmental heterogeneity of wetlands. The rich and diverse zooplankton of the 'slightly acidic-circum neutral-slightly alkaline' and 'soft-moderately hard' waters characterized by 'low ionic concentrations' Nagaland wetlands reveal sizeable fractions of species of global and regional biogeography interest (Sharma and Sharma, 2021). Total richness variations and heterogeneity of species composition are attributed to habitat heterogeneity amongst the wetlands. This study provides the first baseline data on the faunal diversity of zooplankton in the small wetlands of Nagaland, North-East India. The findings reveal that these wetlands have a relatively high diversity of zooplankton, with rotifers being the dominant group. More research is needed to understand the factors affecting zooplankton diversity and abundance in these wetlands, as well as their role in the food web and ecosystem functioning. The findings of this study have important implications for the conservation and management of these wetlands, which are facing increasing threats from anthropogenic activities.

Table-1: The sampled wetlands of Nagaland

SAMPLED WETLANDS	LATITUDE	LONGITUDE	ALTITUDE	AREA (ha)
Noune wetland	25°50'54.6” N	093°50'05.6” E	172 m ASL	7.2
Madladijam wetland	25°46'36.39” N;	093°38'07.58” E	175 m ASL	4.7
Bolfangdisa wetland	25°46'23.86” N	093°38'03.49” E	178 m ASL	5.2

Table-2: Species richness of zooplankton of three wetlands of Nagaland (Study Period)

Group↓ Wetland→	Noune	Madladijam	Bolfangdisa
Rotifera	66	84	95
Cladocera	22	36	40
Rhizopoda	11	14	12
Copepoda	7	8	8
Ostracoda	3	5	5
Total species	**109**	**147**	**160**

Systematic Accounts

Systematic list of zooplankton recorded of Nagaland wetlands

Table-3: Species composition of zooplankton of three wetlands of Nagaland

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
Family BRACHIONIDAE			
1. *Anuraeopsis fissa* Gosse	+	-	+
2. *Brachionus angularis* Gosse	+	-	-
3. *Brachionus caudatus* Barrois & Daday	+	+	-
4. *Brachionus dichotomus reductus* Koste & Shiel	-	+	+
5. *Brachionus diversicornis* (Daday)	+	-	-
6. *Brachionus falcatus* Zacharias	+	+	+
7. *Brachionus forficula* Wierzejski	+	+	-
8. *Brachionus mirabilis* Daday	-	+	+
9. *Brachionus quadridentatus* Hermann	+	+	+
10. *Keratella cochlearis* (Gosse)	+	+	+
11. *Keratella lenzi* Hauer	+	-	+
12. *Keratella tropica* (Apstein)	+	-	+

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
13. Plationus patulus (O.F. Müller)	+	+	+
14. Platyias quadricornis (Ehrenberg)	+	+	+
Family EUCHLANIDAE			
15. Beauchampiella eudactylota (Gosse)	-	+	+
16. Dipleuchlanis propatula (Gosse)	+	+	+
17. Euchlanis dilatata Ehrenberg	+	+	+
18. Euchlanis incisa Carlin	+	-	+
19. Tripleuchlanis plicata (Levander)	-	-	+
Family MYTILINIDAE			
20. Mytilina acanthophora Hauer	+	-	+
21. Mytilina bisulcata (Lucks)	+	-	+
22. Mytilina ventralis (Ehrenberg)	+	+	+
Family TRICHOTRIIDAE			
23. Macrochaetus sericus (Thorpe)	-	+	+
24. Trichotria tetractis (Ehrenberg)	+	+	+
Family LEPADELLIDAE			
25. Colurella obtusa (Gosse)	+	+	+
26. Colurella sulcata (Stenroos)	+	+	-
27. Colurella uncinata (O.F. Müller)	+	+	+
28. Lepadella acuminata(Ehrenberg)	+	+	+
29. Lepadella apsida Harring	+	-	+
30. Lepadella benjamini Harring	-	+	+
31. Lepadella biloba Hauer	+	+	-
32. Lepadella costatoides Segers	-	+	+
33. Lepadella dactyliseta (Stenroos)	-	+	+
34. Lepadella discoidea Segers	+	+	+
35. Lepadella ovalis (O.F. Müller)	+	+	+
36. Lepadella patella (O.F. Müller)	+	+	+
37. Lepadella rhomboides (Gosse)	-	+	+
38. Lepadella triba Myers	+	-	+
39. Lepadella triptera Ehrenberg	-	+	-
40. Lepadella vandenbrandei Gillard	-	+	+

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
41. *Lepadella (H.) apsicora* Myers	+	-	+
42. *Lepadella (H.) ehrenbergi* Perty	+	+	+
43. *Lepadella (H.) heterostyla* (Murray)	-	-	+
44. *Squatinella lamellaris* (O.F. Müller)	-	+	-
Family LECANIDAE			
45. *Lecane aculeata* (Jakubski)	+	+	+
46. *Lecane blachei* Berzins	-	-	+
47. *Lecane bulla* (Gosse)	+	+	+
Lecane bulla diabolica (Hauer)	-	-	+
48. *Lecane closterocerca* (Schmarda)	+	+	+
49. *Lecane crepida* Harring	+	+	+
50. *Lecane curvicornis* (Murray)	-	+	+
51. *Lecane doryssa* Harring	-	+	+
52. *Lecane elegans* Harring	-	+	+
53. *Lecane furcata* (Murray)	+	+	+
54. *Lecane haliclysta* Harring & Myers	+	+	+
55. *Lecane hamata* (Stokes)	+	+	+
56. *Lecane hastata* (Murray)	-	+	-
57. *Lecane hornemanni* (Ehrenberg)	+	+	+
58. *Lecane lateralis* Sharma	+	+	+
59. *Lecane latissima* Yamamoto	-	+	+
60. *Lecane leontina* (Turner)	+	+	+
61. *Lecane ludwigii* (Eckstein)	-	+	+
62. *Lecane luna* (O.F. Müller)	+	+	+
63. *Lecane lunaris* (Ehrenberg)	+	+	+
64. *Lecane monostyla* (Daday)	-	-	+
65. *Lecane nitida* (Murray)	-	+	+
66. *Lecane obtusa* (Murray)	-	+	+
67. *Lecane papuana* (Murray)	+	+	+
68. *Lecane ploenensis* (Voigt)	-	+	-
69. *Lecane pyriformis* (Daday)	+	+	+
70. *Lecane quadridentata* (Ehrenberg)	+	+	+

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
71. *Lecane rhenana* Hauer	-	+	+
72. *Lecane signifera* (Jennings)	+	+	+
73. *Lecane simonneae* Segers	-	-	+
74. *Lecane stenroosi* (Meissner)	+	+	+
75. *Lecane thienemanni* (Hauer)	-	-	+
76. *Lecane undulata* Hauer	+	+	+
77. *Lecane unguitata* (Fadeev)	+	+	+
78. *Lecane ungulata* (Gosse)	+	+	+
Family NOTOMMATIDAE			
79. *Cephalodella gibba* (Ehrenberg)	+	+	+
80. *Monommata longiseta* (O.F. Müller)	-	+	+
81. *Monommata maculata* Harring & Myers	+	-	+
82. *Notommata copeus* Ehrenberg	-	+	+
Family SCARIDIIDAE			
83. *Scaridium longicaudum* (Müller)	-	+	+
Family GASTROPODIDAE			
84. *Ascomorpha ovalis* (Bergendal)	+	+	+
Family TRICHOCERCIDAE			
85. *Trichocerca bicristata* (Gosse)	-	-	+
86. *Trichocerca bidens* (Lucks)	-	+	+
87. *Trichocerca flagellata* Hauer	+	+	+
88. *Trichocerca hollaerti* De Smet	-	+	-
89. *Trichocerca insignis* (Herrick)	+	-	+
90. *Trichocerca maior* (Hauer)	-	-	+
91. *Trichocerca pusilla* (Jennings)	-	+	-
92. *Trichocerca rattus* (O.F. Müller)	-	+	+
93. *Trichocerca similis* (Wierzejski)	+	+	+
94. *Trichocerca tigris* (O.F. Müller)	-	-	+
Family ASPLANCHNIDAE			
95. *Asplanchna priodonta* Gosse	+	+	-
Family SYNCHAETIDAE			
96. *Polyarthra vulgaris* Carlin	+	+	+

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
97. *Synchaeta* sp.	-	-	+
Family DICRANOPHORIDAE			
98. *Dicranophorus epicharis* Harring & Myers	-	+	+
Family FILINIIDAE			
99. *Filinia longiseta* (Ehrenberg)	+	+	-
Family FLOSCULARIIDAE			
100. *Sinantherina spinosa* (Thorpe)	+	-	+
Family TESTUDINELLIDAE			
101. *Pompholyx sulcata* Hudson	+	-	-
102. *Testudinella amphora* Hauer	-	+	+
103. *Testudinella brevicaudata* Yamamoto	-	+	+
104. *Testudinella dendradena* de Beauchamp	-	-	+
105. *Testudinella emarginula* Stenroos	-	+	+
106. *Testudinella greeni* Koste	-	+	+
107. *Testudinella patina* (Hermann)	+	+	+
108. *Testudinella tridentata* Smirnov	+	+	-
Family PHILODINIDAE			
109. *Dissotrocha aculeata* (Ehrenberg)	+	+	+
110. *Rotaria neptunia* (Ehrenberg)	+	+	+
CLADOCERA			
Family SIDIDAE			
111. *Diaphanosoma excisum* Sars	-	-	+
112. *Diaphanosoma sarsi* Richard	+	+	+
113. *Pseudosida szalayi* (Daday)	-	+	+
114. *Sida crystallina* (O. F. Muller)	+	+	+
Family DAPHNIIDAE			
115. *Ceriodaphnia cornuta* Sars	-	+	+
116. *Scapholeberis kingi* Sars	+	+	+
117. *Simocephalus acutirostratus* (King)	-	+	+
118. *Simocephalus mixtus* Sars	+	+	+
119. *Simocephalus serrulatus* (Koch)	+	+	+
Family BOSMINIDAE			

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
120. Bosmina longirostris (O. F. Muller) s.lat.	+	+	+
Family MOINIDAE			
121. Moina micrura Kurz	-	+	-
122. Moinodaphnia macleayi (King)	-	+	+
Family MACROTHRICIDAE			
123. Grimaldina brazzai Richard*	+	+	+
124. Guernella raphaelis Richard*	+	-	+
125. Macrothrix odiosa Gurney*	-	-	+
126. Macrothrix spinosa King	-	-	+
127. Macrothrix triserialis (Brady)	+	+	+
Family ILYOCRYPTIDAE			
128. Ilyocryptus spinifer Herrick	-	+	+
Family CHYDORIDAE			
Subfamily ALONINAE			
129. Alona affinis (Leydig) s.lat	+	+	+
130. Alona cheni Sinev*	+	+	+
131. Alona kotovi Sinev*	+	+	+
132. Anthalona harti Van Damme et al.	-	+	+
133. Camptocercus uncinatus Smirnov*	+	+	+
134. Celsinotum macronyx (Daday)	-	-	+
135. Coronatella rectangula (Sars)	+	+	+
136. Euryalona orientalis (Daday)*	-	-	+
137. Karualona karua (King)*	-	+	+
138. Kurzia latissima (Kurz)	-	+	-
139. Kurzia longirostris (Daday)	-	+	+
140. Leberis diaphanus (King)*	-	+	+
141. Leydigia ciliata (Gauthier)*	-	+	-
142. Leydigiopsis pulchera	+	-	+
143. Notoalona globulosa (Daday)	+	+	+
144. Ovalona cambouei (Guerne & Richard)	-	+	+
145. Oxyurella singalensis (Daday)	+	+	+
Subfamily CHYDORINAE			

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
146. *Alonella excisa* (Fischer)	+	+	+
147. *Chydorus angustirostris* Frey	-	+	+
148. *Chydorus eurynotus* Sars*	-	+	+
149. *Chydorus sphaericus* (O. F. Muller)	+	+	+
150. *Disperalona caudata* Smirnov	+	+	+
151. *Dunhevedia crassa* King*	+	-	+
152. *Ephemeroporus barroisi* (Richard)	-	+	+
153. *Graptoleberis testudinaria* (Fischer)*	-	+	-
154. *Pleuroxus quasidenticulatus* (Smirnov)	+	+	+
RHIZOPODA			
Family ARCELLIDAE			
155. *Arcella discoides* Ehrenberg	+	+	+
156. *Arcella hemispherica* Perty*	+	+	+
157. *Arcella vulgaris* Ehrenberg	+	+	+
Family CENTROPYXIDAE			
158. *Centropyxis aculeata* (Ehrenberg)*	+	+	+
159. *Centropyxis ecornis* (Ehrenberg)*	+	+	+
Family DIFFLUGIDAE			
160. *Difflugia acuminata* Ehrenberg	+	+	+
161. *Difflugia corona* Wallich*	+	+	+
162. *Difflugia oblonga* Ehrenberg*	+	+	+
163. *Difflugia pyriformis* Perty*	-	+	-
164. *Difflugia urceolata* Carter*	-	+	+
Family NEBELIDAE			
165. *Lesquereusia spiralis* (Ehrenberg)*	+	+	+
166. *Nebela caudata* Leidy*	+	+	+
Family EUGLYPHIDAE			
167. *Euglypha acanthophora* Dujardin*	+	+	+
168. *Trinema lineare* Penard*	-	+	-
COPEPODA			
Family DIAPTOMIDAE			
169. *Heliodiaptomus cinctus* (Gurney)*	+	+	+

Taxa↓ Wetland→	Noune	Madladijam	Bolfangdisa
170. Heliodiaptomus contortus (Gurney)*	+	+	+
171. Heliodiaptomus viduus (Gurney)	-	+	+
172. Neodiaptomus schmackeri (Poppe & Richard)*	+	+	+
Family CYCLOPIDAE			
173. Mesocyclops hyalinus (Rehberg)**	+	+	+
174. Mesocyclops isabellae Dussart & Fernando**	+	+	+
175. Mesocyclops parentium Holynska*	+	+	+
176. Thermocyclops crassus (Fischer)	+	+	+
OSTRACODA			
Family CYPRIDIDAE			
Subfamily CYPRIDINAE			
177. Cypris subglobulosa Sowerby*	+	+	+
Subfamily CYPRINOTINAE			
178. Hemicypris anomala (Klie)*	+	+	+
Subfamily HERPETOCYPRIDINAE			
179. Stenocypris major (Baird)*	-	+	+
Family CYPRIDOPSIDAE			
Subfamily CYPRIDOPSINAE			
180. Pseudocypretta maculata Klie*	-	+	+
Subfamily CYPRETTINAE			
181. Cypretta sp.	+	+	+
Total Number of Species	**109**	**147**	**160**

** New records from northeast India; * New record from Nagaland

Table-4: Zooplankton similarities (study period)

Wetland	Noune	Madladijam	Bolfangdisa
Noune	-	**71.1**	73.6
Madladijam	-	-	**83.4**
Bolfangdisa	-	-	-

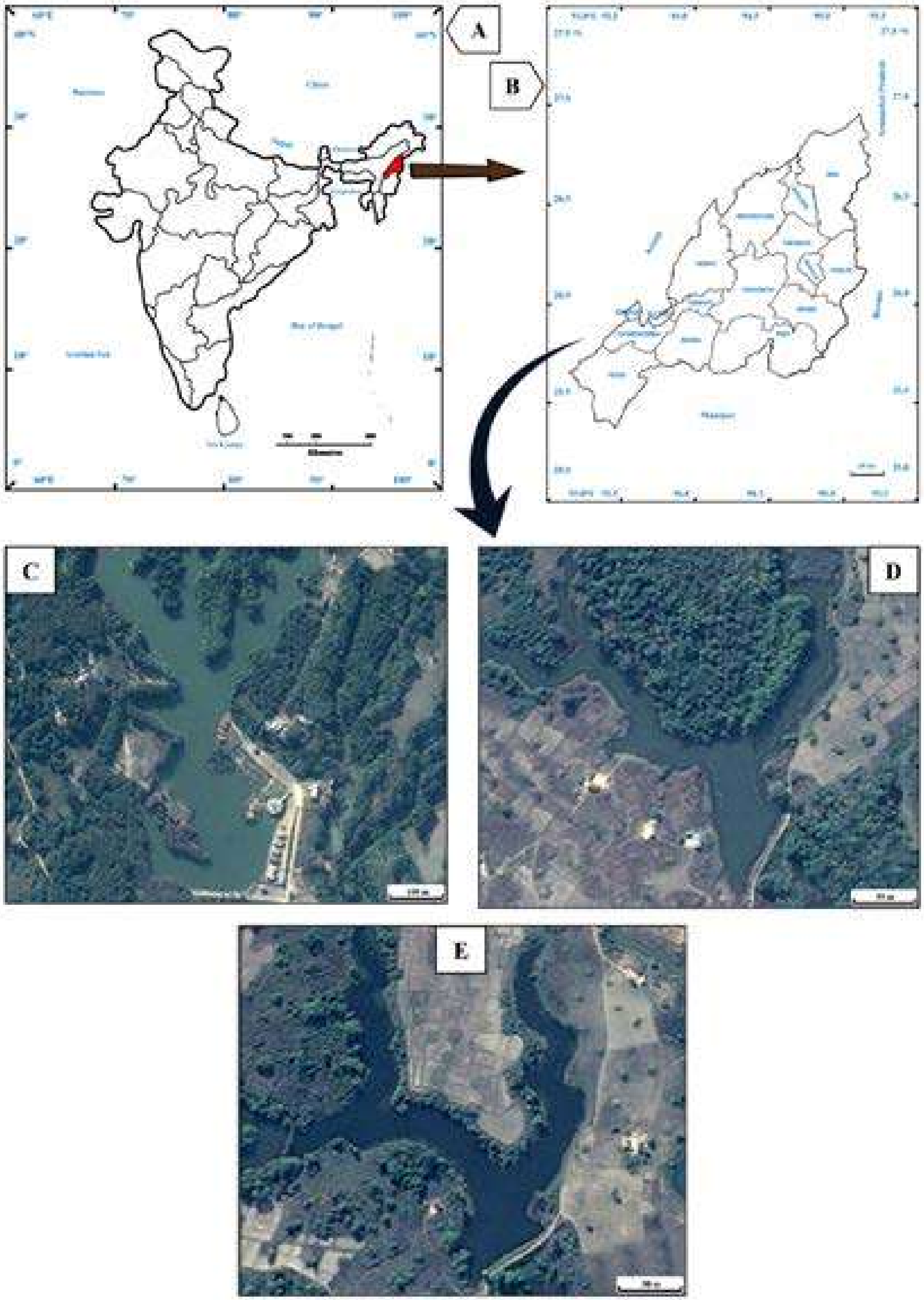

Figure-1: (A) Map of India indicating Nagaland state; (B) Map of Nagaland indicating different districts; (C) Noune wetland (Google image); (D) Madladijam wetland (Google image); (E) Bolfangdisa wetland (Google image)

Figure-2: View of Noune wetland from sampling site

Figure-3: View of Madladijam wetland from sampling site

Figure-4: View of Bolfangdisa wetland from sampling site

Acknowledgments

Thanks are due to the Head, Department of Zoology, North-Eastern Hill University, Shillong for providing all the necessary laboratory facilities. Most of the species identification been done by BKS and the present study sampling was undertaken by KP with the support of the Rajiv Gandhi National Fellowship awarded by UGC, New Delhi. Thanks due to Dr. Y. Ranga Reddy, Professor Emeritus, Department of Zoology, Acharya Nagarjuna University, Andhra Pradesh for his help in identifying copepods. The authors have no conflict of interests.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Habitat selection in Orb weaving spider *Nephila pilipes* Fabricius,1793 (Araneae: Araneidae): niche complexity determines site selection and distribution of kleptoparasites

Minakshi Dash and C. Sivaperuman
Zoological Survey of India- Andaman Nicobar Regional Center
Port Blair-744101

Abstract

It is believed that slight variations in the physical parameters within the microhabitat can lead to significant differences in the populations of both the host and parasite. The golden orb weaver spider, *Nephila pilipes* Fabricius, 1793, serves as a host for various kleptoparasites in its web. This study focuses on examining the abundance of Argyrodinae spiders and their presence in relation to the positioning of the web on roadside vegetation in Kamorta, Nancowry Group of Islands, Andaman and Nicobar Islands, India. We analyzed species abundance using presence or absence data and employed NMDS and PCoA to calculate niche overlap. The total number of specimens collected was assessed using individual rare fractions.

Keywords: Zooplankton, Diversity, Wetlands, Nagaland, North-East India.

Introduction

Orb-web spiders employ a sit-and-wait predation strategy, but there are unanswered questions regarding the key factors influencing prey capture in their circular webs, such as web location and structure. Web location can be influenced by sunlight, wind orientation, and proximity to other webs. Sunlight attracts insects, potentially increasing prey capture success. Wind can blow insects towards the web, impacting prey capture. Proximity to other webs can lead to high competition, although some species mitigate this through the "ricochet effect" (Uetz, 1989; Rao, 2009) This effect occurs when webs are built close together, allowing prey to bounce through multiple webs before being caught, reducing competition costs. Web structure, including size, also affects prey capture efficiency. Larger webs have a higher likelihood of intercepting prey, and spider size may influence capture success due to the correlation with web size (Herberstein and Heiling, 1999; Vasconcellos-Neto *et al*., 2007).

Studies have demonstrated that aggregation in web-building spiders leads to increased prey capture (Lubin, 1974), even when controlling for prey availability (Uetz, 1988). In such aggregations, individuals reduce their food intake due to higher kleptoparasitic intensity The evolution of kleptoparasitism in spiders and other invertebrates is influenced by factors such as resource competition, predation risk, and ecological interactions. The study of kleptoparasitism sheds light on animal behaviour evolution and predator-prey dynamics. Brockmann and Barnard (1979) examined kleptoparasitism in birds, encompassing various forms and its evolutionary aspects. Furness (1987) studied kleptoparasitism in seabirds, emphasizing the importance of understanding the ecology and behaviour of kleptoparasites and their prey for comprehending this behaviour's dynamics.

Kleptoparasitism, the behaviour of stealing resources from other individuals, has been the subject of various studies

*Author for correspondence : minakshidash97@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

across different animal species. Hamilton (2002) found that the likelihood of kleptoparasitism is higher when the victim is weaker and when food is abundant. This suggests that unequal competitors are more prone to kleptoparasitic interactions. Vollrath (1979) studied the kleptoparasitic spider *Argyrodes elevatus* and discovered that it actively seeks out the webs of other spider species to steal prey. The study also highlighted the tactics employed by *A. elevatus* to avoid detection by the host spider during the theft. Rypstra (1981) investigated the impact of kleptoparasitism on prey consumption and web relocation in the spider *Nephila clavipes*. The study revealed that kleptoparasitic spiders can significantly reduce the prey consumption of the host spider and induce it to relocate its web. Agnarsson (2002) examined the relationship between sociality and kleptoparasitism in theridiid spiders. The study found that social spiders are less likely to engage in kleptoparasitic behaviour compared to solitary spiders. This suggests that sociality may act as a defense mechanism against kleptoparasites. Su and Smith (2014) investigated the evolution of host use, group-living, and foraging behaviours in kleptoparasitic spiders by constructing a molecular phylogeny. Their findings shed light on the evolutionary relationships within the Argyrodinae subfamily of the Theridiidae family. Cangialosi (1990) examined the defence mechanisms of social spiders against kleptoparasites. The study revealed that social spiders exhibit more aggression towards kleptoparasites than towards other spiders. Sociality may enhance the spiders' ability to defend against kleptoparasites. These studies contribute to our understanding of the dynamics, evolutionary consequences, and defence strategies associated with kleptoparasitism in various animal species.

Methods

Study Area

The webs analysed for the sampling of microhabitat association between kleptoparasites and orb-web weavers were selected through a random strategy between February 2018 and February 2020 at Kamorta, Nancowry group of Islands, Andaman and Nicobar Islands, India (Figure 1; Table 1). Each web was studied for its microhabitat stratification dynamics and the number of kleptoparasites in each niche category. A single count method was used for the web study while collecting kleptoparasites.

Table 1. Survey locality details

SI No.	Survey Location	GPS Data
	Point 1	8°13'0.87"N 93°32'6.40"E
	Point 2	8°12'0.17"N 93°30'23.25"E
	Point 3	8°11'12.27"N 93°29'17.86"E
	Point 4	8°10'25.55"N 93°28'48.80"E
	Point 5	8°10'29.28"N 93°30'17.53"E
	Point 6	8°11'29.52"N 93°31'26.22"E
	Point 7	8° 6'11.27"N 93°29'43.11"E
	Point 8	8° 5'33.26"N 93°29'42.76"E

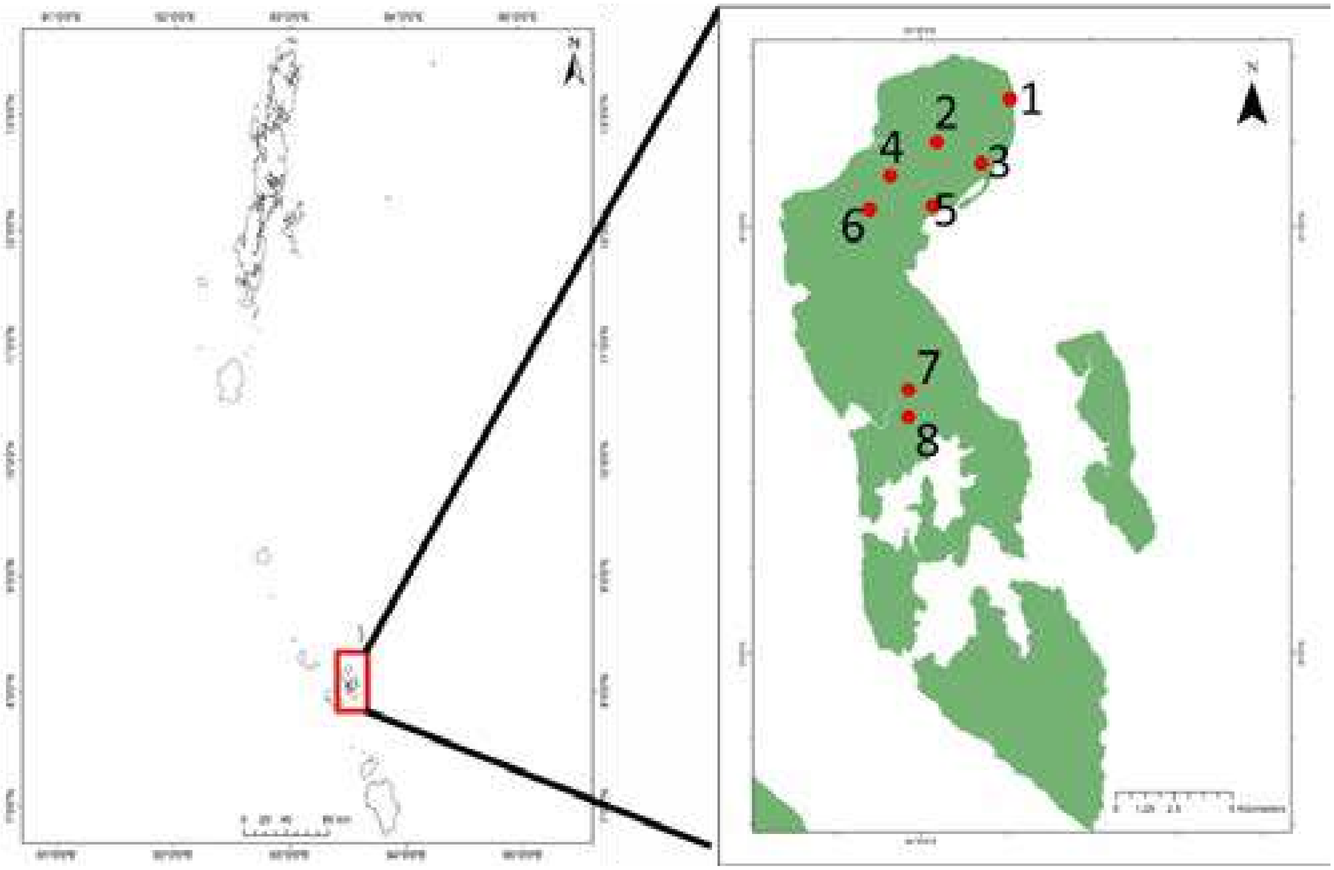


Figure 1. An outline of the survey locality

Collection and analysis of data

The study included active searching for *Nephila pilipes* webs at each visit. (Study period: March and April 2018–2020) Web diameter was measured as the horizontal diameter of the capture spiral. All the webs we found were between 40 and 200 cm from the ground and each was sampled once. For each web, the number of prey items adhered to the webs was counted as the dependent variable. Multiple linear and logit regression analyses to analyse the interplay between web size, isolation, and the presence and number of kleptoparasites. We used non-parametric tests to understand the interplay between habitat patch size, isolation, and the likelihood of patch occupancy by the prey community.

Results

We found 864 kleptoparasites in 119 *Nephila* webs encountered along the transect. When the spider webs were intact the observations showed that 90% of the webs were inhabited by both *Faiditus xiphius* (Thorell, 1887) and *Argyrodes* sp. These species occurred in about similar frequencies. Occupancy in small webs was lower than expected given non-parametric correlation between web size and kleptoparasite number, which predicted between two to four kleptoparasites for each unoccupied web. The orbs of solitary webs were larger (radius: 1.5 m for *Nephila*), while the orbs of webs that were part of a cluster ranged from 0.15–0.47 m (Table 1). In either case, we found kleptoparasites only in webs larger than 0.04 m^2. The largest web encountered (90x80 cm, located in the center of a cluster) had the highest number of kleptoparasites (18) (Table 2). Two *Argyrodes* species were identified. The number of kleptoparasites increased with web size ($r^2 = 0.61$, $F = 109.2$, $df = 68$, $P < 001$, $n = 70$) (Table 3). Looking at clustered and solitary webs separately, web size explained nearly all the variance in clustered webs ($r^2 = 0.94$, $F = 310.2$, $df = 20$, $P > .001$, $n = 22$) but much less so in solitary webs ($r^2 = 0.29$, $F = 19.8$, $df = 46$, $P > .001$, $n = 48$). The homogeneity of the regression line slopes is rejected ($S^2 = 42.506$, $F = 5.861$, $df = 1$, $P = 0.018$). The difference in variance in kleptoparasitic load in clustered ($S^2 = 2.1$) and solitary ($S^2 = 9.5$) webs is significant ($P > 0.01$). There was no difference in the mean number (Table 4) of kleptoparasites per web area between clustered (18.5 kleptoparasites/m, SD = 13.3) and solitary (23.1 kleptoparasites/m, SD = 26.4) webs ($t = 0.77$, $df = 68$, $P = 0.443$).

Table 2. Number of *Nephila pilipes* webs present in response to different habitat structure

Habitat	Number of *Nephila* Webs	Number of Kleptoparasite	% of Web Intact
Open Forest	22	99	69
Grass Land	24	93	57
Understorey Vegetation	16	184	92.5
Roadside Vegetation	19	122	76.54
Mangrove	5	54	89.6
Agricultural Land	13	109	45
Plantation	37	266	74.8

Table 3. Regression analysis for kleptopararasite occupancy and abundance in host webs for *Argyrodes*

	Multiple		Simple	
	Linear	Logit	Web Size	Distance
Occupancy	$R^2 = 0.36$*		$R^2 = 0.21$*	$R^2 = 0.01$
Abundance	$R^2 = 0.28$*	$R^2 = 0.32$*	$R^2 = 0.27$*	$R^2 = 0.00$

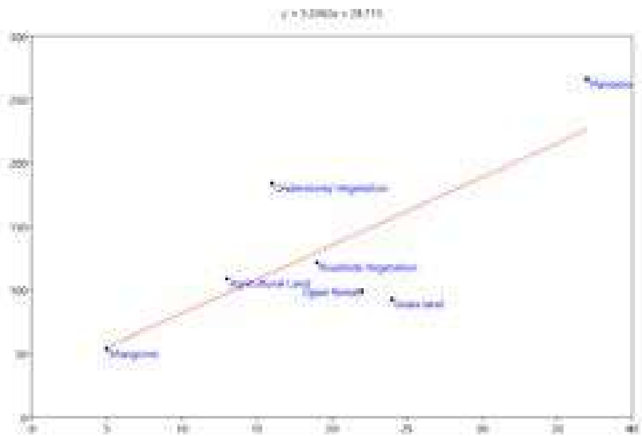
*Indicates significance at $P < 0.001$ level

Table 4. Non-parametric tests for understanding the interplay among habitat patch size and isolation on one hand and likelihood of patch occupancy by prey community

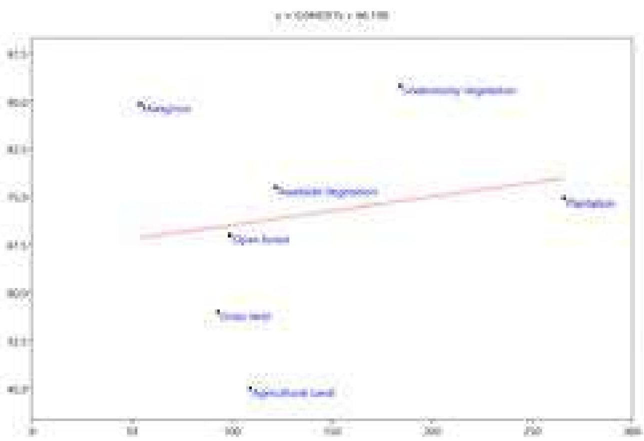
Correlations

			abundance value	relative prey size
Kendall's tau_b	abundance value	Correlation Coefficient	1.000	.786**
		Sig. (2-tailed)	.	.000
		N	20	20
	relative prey size	Correlation Coefficient	.786**	1.000
		Sig. (2-tailed)	.000	.
		N	20	20

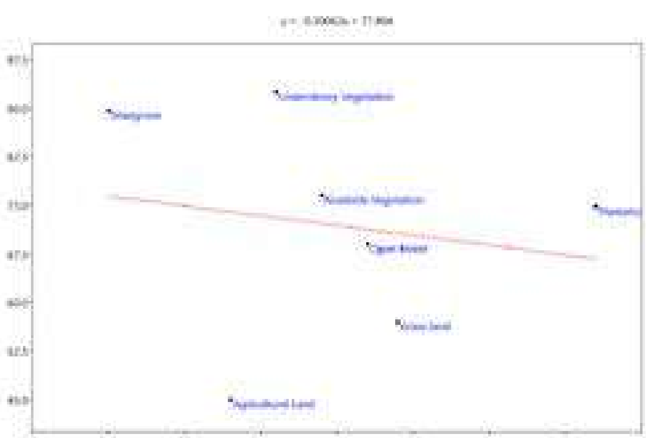
**. Correlation is significant at the 0.01 level (2-tailed).



a. Number of Kleptoparsaite~%web intact



b. Number of *Nephila* web~number of kleptoparasite



c. Number of *Nephila pilipes* web~% of web intact

Fig. 2 Showing 3 linear models for a. Number of Kleptoparsaite~%web intact; b. Number of *Nephila* web~number of kleptoparasite; c. Number of *Nephila pilipes* web~% of web

(2:0.51)

Table 4 PCoA summary for mean prey at 128 sites

Axis	Eigenvalue	Percent
mean prey	1.63E+05	99.964
mean prey sp. abundance	58.606	0.035863

Discussion

The distribution of kleptoparasites among Nephila webs appears to be strongly influenced by patch connectivity. A cluster of webs within a web cluster does not simply function as a single large web; rather, it represents a community of individual webs that may experience multiple extinctions and colonization events by kleptoparasites. Contrary to Elgar's (1989) conclusions, Grostal and Walter (1999) found results that conflicted with previous findings, suggesting a more random distribution of kleptoparasites. While this study agrees with Elgar (1989) regarding the difference in kleptoparasitic load between clustered and solitary webs, it emphasizes that the distinction lies in stability rather than simply the mean number of kleptoparasites.

Seasonal fluctuations in the population sizes of kleptoparasitic Argyrodes and their Nephila hosts have been observed by Vollrath (1987) and Higgins and Buskirk (1998). Pooling data from different seasons could mask correlations between kleptoparasite load and web site at smaller time scales. Moreover, if the majority of webs considered were large, Elgar's (1989) study may have been biased toward larger webs, resulting in a low percentage of webs without kleptoparasites and a high mean number of kleptoparasites per web. Therefore, reanalyzing the data from these previous studies may reveal more general and consistent patterns, with the apparent conflict being more superficial than real.

The structural complexity and longevity of *Nephila* web clusters may partially account for the greater stability of kleptoparasite populations in them compared to shorter-lived solitary webs. Accumulating evidence suggests that kleptoparasites strongly prefer complex, long-lived webs over simpler webs that are frequently dismantled. This preference is observed not only in Nephila webs but also in other spider species such as *Anelosimus, Argiope, Cyrtophora, Diplura, Stegodyphus*, and *Tengella* (Elgar, 1993; Miyashita, 2002). Considering the detrimental effects kleptoparasitic *Argyrodes* can have on their hosts, it is tempting to speculate that frequent web renewal may serve as an adaptation against kleptoparasitism. However, determining cause and effect in this context can be challenging due to the influence of various factors on web duration, such as predation by sphecid wasps. Previous studies have demonstrated a correlation between patch (web) size and population size, and the current study reveals an increase in population stability with patch connectivity. These characteristics align with general ecological models, including island biogeography (MacArthur and Wilson, 2016) and metapopulation biology (Hanski, 1999). To further test these models, future studies should incorporate additional factors such as the absolute distances between webs, the number of webs per cluster, the size of barrier webs, the phenology of both hosts and kleptoparasites, and the patterns of migration between host webs. Nephila webs are ideal for such investigations due to their relative longevity and the extensive mesh-like structure of their barrier webs, which may facilitate kleptoparasitism (Grostal and Walter, 1999; Miyashita, 2002). Kleptoparasites primarily reside in the host barrier web, providing a safe space beyond the host's monitoring range when they are not actively foraging. In observed cases of Nephila orb reconstruction, the kleptoparasites maintained their association with the specific host. During the rebuilding process, the kleptoparasites stayed in the unchanged barrier web, and no migration was observed. The new orb was connected to the existing barrier web, and once completed, the kleptoparasites rebuilt their association lines. The barrier web provides a secure substrate for kleptoparasites to monitor the host web, adds a three-dimensional aspect to the orb, potentially facilitating group living, and enables kleptoparasites to remain associated with the host during web reconstruction. The major significances of the study are investments in retreats for the subsequent movement of web-building spiders, a factor that has been overlooked for a long time. This discovery has broader implications for any species that constructs retreats, particularly those engineering species that modify their environment to enhance their fitness.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

The Diversity and Distribution of The Order Charadriiformes Along The Kerala Coast and Selected Islands of Lakshadweep, India

Nisanth HP* and Biju Kumar A

Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram - 695581

Abstract

The birds belonging to the order Charadriiformes are widely distributed along the coastal regions and coastal waters of Kerala and Lakshadweep. Most species in this region are migratory and use the coastal habitats and coastal waters as their feeding grounds or stopover sites. In this study, we documented the diversity and distribution of Charadriiformes along the Kerala coast and Lakshadweep, and recorded 47 species of birds. Among this, 22 species were recorded from both the Kerala coast and the Lakshadweep islands. The abundance and distribution of the Charadriiformes have been examined, and the results show the distribution pattern between the mainland and the islands. On the Kerala coast, the population of three gull species and three sand plover species and in Lakshadweep islands, the population of three tern species and brown noddy determines the Charadriiformes abundance. The breeding colonies of *Anous stolidus* and *Onychoprion fuscatus* were observed during the study from the Pashi Pitti, Lakshadweep archipelago. While the distribution and diversity of birds will be used to measure the ecosystem's health, the results obtained from the current study will provide insight into coastal management and conservation of the avian fauna.

Keywords: Seabirds, Shorebirds, Laridae, Breeding, Bird sanctuary

Introduction

Charadriiformes are one of the widely distributed non-passerines, which consist of the alliance of the shorebird and seabird families (Brooke and Birkhead, 1991). This order consists of 15 Families with three suborders: Alcae, Charadrii, and Lari. (McCain, 2015). Charadriiformes have a wide range of habitat preferences, including coastal, freshwater wetlands, and agricultural fields (Gokulakrishnan *et al.,* 2014). Most of the Charadriiformes are long distance migrants, and the species migrate along the Central Asian, South Asian Flyways, East Asian-Australian and Western Pacific Flyways use the Indian subcontinent as their primary wintering grounds and stopover sites (Aarif *et al*., 2020; Rashia *et al.,* 2022). Many avian species are considered sentinel of the aquatic ecosystems and show rapid changes to ecological responses and climate change (Thompson and Ollason, 2001; Piersma and Lindstrom 2004; Frederiksen *et al*., 2006). So, these are considered as monitors and indicators of the ecosystem and ecological evaluations (Furness and Camphuysen, 1997; Canterbury *et al.,* 2000; Mallory *et al.,* 2010). In the Indian scenario, the studies on avian diversity are limited to seasonal monitoring, and detailed studies are limited. According to Gourley *et al.* (2010), studies on the abundance and distribution of birds are crucial in managing ecosystems and conserving Charadriiformes. The present study aims to assess the diversity, abundance and distribution of the birds belonging to the order Charadriiformes across the Kerala coast and the Lakshadweep to study the distribution among the mainland and islands.

*Author for correspondence : nisanthhp@gmail.com

Article Received on: 02.04.2023

Accepted on: 24.04.2023

Materials and Methods

Study Area

In Kerala, the surveys for the assessment of birds were conducted along the coastal line around the 570 km stretch, which is part of 9 districts of Kerala. In Kerala, the surveys undertaken mainly in the coastal stretch with sandy beaches are seen, and the pelagic surveys were conducted from Vizhinjam, , Azheekal (Kollam), Kochi, Ponnani, and Neeleshwaram. The survey excluded areas where the seashore is absent and the coastal regions with granite or tetrapod walls. Lakshadweep archipelago (8°–12°13" N 71°–74°E) consists of 27 islands 12 atolls, and 3 reefs from about 220–440 km from the west coast of Kerala. The present study was conducted along seven of ten inhabited islands, excluding Chethlat, Kiltan and Amini, and seven uninhabited islands of the Lakshadweep archipelago.

Survey method

The survey was conducted during 2021 – 2022 along Kerala and Lakshadweep. The single day pelagic surveys in Kerala were carried out from September to April in Kerala coast from 5 stations and coastline surveys were conducted from 25 sites (Figure 1). The surveys in the Lakshadweep islands were carried out from January to March (Figure 2). The team visited the Pitti islands and Perumal Par in March.2022. Direct observation of the birds was followed. Point count methods were employed to get the total count and species identification. In the point count or point transact method, we count the birds from fixed locations for a fixed time (Buckland *et al.,* 2001). The survey was conducted during the day, from 0700 to 1100 h, when the birds were active. We employed the line transect method for the opportunistic pelagic surveys, where the vessel moves offshore in a prefixed route and counts the birds (Gregory *et al.,* 2004). In the present study, for the pelagic surveys three-member team is constituted for counting birds. The pelagic survey was carried out from 0500 to 1830 h. The direct observation was done using binoculars (Olympus 10x50 DPI), and the photo documentation was carried out using a DSLR camera (Nikon d500 with Nikkor 200-500mm f 5.6 lens, Nikon d5200 with Nikkor 70-300mm f 3.6: 4 ED lens, and GoPro Hero 9). The species were identified using field guides (Hayman *et al*., 2011; Rasmussen and Anderton, 2012; Vinicombe *et al*., 2014). During the survey, the team maintained the distance between the bird flocks to minimise the disturbance.

Statistical Analysis

The Dominance index, Shannon diversity index, Margalef index and Fisher alpha index were assessed and the Whittaker beta diversity index was calculated to compare the diversity across Kerala and Lakshadweep using PAST 4.3 software (Hammer *et al.,* 2001).

Results and Discussion

Charadriiformes are considered a diverse order in the non-passerine group (Lovette, 2016). According to the checklist of the birds of India and Kerala, 120 species of Charadriiformes were recorded from India and 91 species from the state of Kerala (Praveen, 2015; Praveen *et al.,* 2016; Chandran and Praveen, 2019). In the present study, in total 47 species belonging to Charadriiformes were recorded from the Kerala coast (44 species) and seven inhabited and seven uninhabited islands of Lakshadweep islands (25 species) (Table 1; Figure 3). These species were distributed into eight families and 26 genera. According to the recent checklists, 38 species from the order Charadriiformes were reported from the Lakshadweep islands (Aju *et al.,* 2021). The reports of Mathew *et al.* (1991) and Kurup and Zacharias (1994) also recorded 35 species, and the expeditions conducted by Pande *et al.* (2007) reported 20 species of Charadriiformes.

Out of 47 species reported, 22 species were common to both the Kerala coast and Lakshadweep islands and 22 species were recorded only from the Kerala coast. Three species, *Sternula albifrons, Anous tenuirostris* and *Anous stolidus* were recorded only from the Lakshadweep islands. Three species, *Haematopus ostralegus*, *Numenius arquata* and *Limosa lapponica*, listed as Near Threatened by IUCN, were also documented from the study areas.

Considering family-wise composition, Scolopacidae and Laridae shared the highest number of species (Figure 4). During the survey, species belonging to the Haematopodidae Dromadidae and Stercorariidae was represented only from Kerala. In the case of the abundance of species in Kerala, four species from *Laridae* (*Chroicocephalus brunnicephalus, Chroicocephalus ridibundus*, *Larus fuscus* and *Chlidonias hybrida,)* three species from *Charadriidae* (*Charadrius mongolus Charadrius leschenaultia*, and *Charadrius alexandrines*) and one species from Scolopacidae (*Calidris alba*) contributes the highest count. Considering the population of charadriiforms in Lakshadweep islands, five species from Laridae (*Anous stolidus, Onychoprion fuscatus, Sternula albifrons Thalasseus bengalensis* and *Thalasseus bergii*) contributes the highest numbers. Compared to the checklists, the number of species is comparatively less primarily because the species entries of the checklists are either made by the observers or updated lists based on the compilation of historical records and earlier works, and no seasonal-wise data is available. (KovaČiĆ *et al*., 2020) In Charadriiformes, many species are long distant migrants and in between the migration from breeding sites to foraging sites, these species use the coastal regions as its halting stations (stopover sites) for a short period of time (Butler *et al*., 2001). It will also affect the estimation of species diversity and distribution.

Regarding the breeding population, the nesting colonies of three species, Sooty Terns *Onychoprion fuscatus*, Brown Noddies *Anous stolidus*, and Greater Crested Terns *Thalasseus bergii* have been reported on the Lakshadweep islands (Hume, 1876; Betts, 1939; Kurup and Zacharias, 1994; Mathew *et al.,* 1996). During the present survey, the breeding colonies the Sooty Tern *Onychoprion fuscatus* and Brown Noddy *Anous stolidus* were observed from the Pitti islands, and 167 eggs were counted from the Pitti islet. The number of eggs counted was comparatively less than the previous records of Pande *et al*., (2007) and Mondreti *et al.,* (2018). According to Pande *et al.* (2007), the islet Pitti and Cheriyapani are considered as the breeding grounds for the tern species and Kurup and Zacharias (1994) observed the breeding activities of terns from Suheli island.

The biodiversity can be expressed by the number of species, relative abundance, variability and complementarity between the habitats (Whittaker, 1972). For assessing the status of the avian diversity of the Kerala coast and Lakshadweep islands, various diversity indices were calculated (Table 2). From the results, the Shannon diversity index (2.66), Fisher alpha index (6.99), and Margalef index (5.22) values were highest in Kerala compared to Lakshadweep. In the case of dominance index along the Kerala coast it was estimated as 0.099 but the dominance index value of Lakshadweep was 0.185 and this could be due to the high abundance of species such as *Anous stolidus, Onychoprion fuscatus, Sternula albifrons.* For beta diversity, the Whittaker beta diversity index was calculated and observed at a value of 0.362 between the Kerala coast and the Lakshadweep islands. The overall diversity indices value of the Charadriiformes of the Kerala coast was higher when compared to that of the Lakshadweep islands.

The species abundance and distribution of birds in a location were influenced by migrant species, especially the birds which use the sites as a halting station (stopover site). Their site selection may be influenced by local habitat structure, community patterns, food availability and other ecological parameters., (Cunningham *et al.,* 2016; Taft *et al.,* 2006; Fairbairn *et al.,* 2001). This may reflex in the changes in distribution and abundance estimation of the Charadriiformes across the location and during the survey. According to Rashiba *et al.* (2022) the distribution of Charadriiformes, especially the shorebirds, depends on the distinctive ecological and biotic and abiotic factors along the Indian coast.

The west coast of India has been considered an important wintering ground and stopover site for Charadriiformes, and most of the migratory species in the region show a population decline (Aarif *et al.,* 2018; Hua *et al.,* 2015; Balachandran *et al.,* 2012). So, the documentation of the diversity and distribution of these groups will give an insight into the health of the local ecosystem, and the documentation will be instrumental in coastal and island management and the conservation of the avian fauna.

Table 1: List of sea/shore birds (Order: Charadriiformes) recorded from Kerala coast and Lakshadweep islands during the present study.

Family	Species	Common Name	Kerala	Lakshadweep
Haematopodidae	*Haematopus ostralegus* Linnaeus, 1758	Eurasian Oystercatcher	+	-
Recurvirostridae	*Himantopus himantopus* (Linnaeus, 1758)	Black-winged Stilt	+	+
Charadriidae	*Pluvialis squatarola* (Linnaeus, 1758)	Grey Plover	+	+
	Pluvialis fulva (Gmelin, JF, 1789)	Pacific Golden Plover	+	+
	Charadrius alexandrinus Linnaeus, 1758	Kentish Plover	+	-
	Charadrius mongolus Pallas, 1776	Lesser Sand Plover	+	+
	Charadrius leschenaultii Lesson, 1826	Greater Sand Plover	+	+
Scolopacidae	*Numenius phaeopus* (Linnaeus, 1758)	Whimbrel	+	+
	Numenius arquata (Linnaeus, 1758)	Eurasian Curlew	+	+
	Limosa lapponica (Linnaeus, 1758)	Bar-tailed Godwit	+	+
	Arenaria interpres (Linnaeus, 1758)	Ruddy Turnstone	+	+
	Calidris temminckii (Leisler, 1812)	Temminck's Stint	+	-
	Calidris subminuta (Middendorff, 1853)	Long-toed Stint	+	-
	Calidris alba (Pallas, 1764)	Sanderling	+	+
	Calidris alpina (Linnaeus, 1758)	Dunlin	+	+
	Calidris minuta (Leisler, 1812)	Little Stint	+	+
	Gallinago stenura (Bonaparte, 1831)	Pintail Snipe	+	+
	Xenus cinereus (Güldenstädt, 1775)	Terek Sandpiper	+	-
	Actitis hypoleucos (Linnaeus, 1758)	Common Sandpiper	+	+
	Tringa ochropus Linnaeus, 1758	Green Sandpiper	+	-
	Tringa nebularia (Gunnerus, 1767)	Common Greenshank	+	+
	Tringa totanus (Linnaeus, 1758)	Common Redshank	+	+
	Tringa glareola Linnaeus, 1758	Wood Sandpiper	+	-
	Tringa stagnatilis (Bechstein, 1803)	Marsh Sandpiper	+	-
Dromadidae	*Dromas ardeola* Paykull, 1805	Crab-plover	+	-
Glareolidae	*Glareola maldivarum* Forster, JR, 1795	Oriental Pranticole	+	+
Stercorariidae	*Stercorarius longicaudus* Vieillot, 1819	Long-tailed Skua (vagrant)	+	-
	Stercorarius parasiticus (Linnaeus, 1758)	Arctic Skua	+	-
	Stercorarius pomarinus (Temminck, 1815)	Pomarine Skua	+	-

Family	Species	Common Name	Kerala	Lakshadweep
Laridae	*Anous stolidus* (Linnaeus, 1758)	Brown Noddy	-	+
	Anous tenuirostris (Temminck, 1823)	Lesser Noddy	-	+
	Chroicocephalus genei (Brème, 1839)	Slender-billed Gull	+	-
	Chroicocephalus brunnicephalus (Jerdon, 1840)	Brown-headed Gull	+	-
	Chroicocephalus ridibundus (Linnaeus, 1766)	Black-headed Gull	+	-
	Ichthyaetus ichthyaetus (Pallas, 1773)	Pallas's Gull	+	-
	Larus fuscus Linnaeus, 1758	Lesser Black-backed Gull	+	-
	Onychoprion fuscatus (Linnaeus, 1766)	Sooty Tern	+	+
	Onychoprion anaethetus (Scopoli, 1786)	Bridled Tern	+	-
	Sternula albifrons (Pallas, 1764)	Little Tern	-	+
	Gelochelidon nilotica (Gmelin, JF, 1789)	Gull-billed Tern	+	-
	Hydroprogne caspia (Pallas, 1770)	Caspian Tern	+	--
	Chlidonias hybrida (Pallas, 1811)	Whiskered Tern	+	+
	Sterna hirundo Linnaeus, 1758	Common Tern	+	+
	Sterna repressa Hartert, 1916	White-cheeked Tern	+	-
	Thalasseus bengalensis (Lesson, 1831)	Lesser Crested Tern	+	+
	Thalasseus sandvicensis (Latham, 1787)	Sandwich Tern	+	-
	*Thalasseus bergi*i (Lichtenstein, MHK, 1823)	Greater Crested Tern	+	+

+ - Presence of the species. 0 – Absence of the species

Table 2: Diversity indices of Charadriiformes along Kerala coast and Lakshadweep

	Kerala coast	Lakshadweep
Taxa_S	44	25
Dominance_D	0.09962	0.1855
Shannon_H	2.66	2.055
Margalef	5.222	2.824
Fisher_alpha	6.993	3.442
Whittaker beta diversity	0.362	

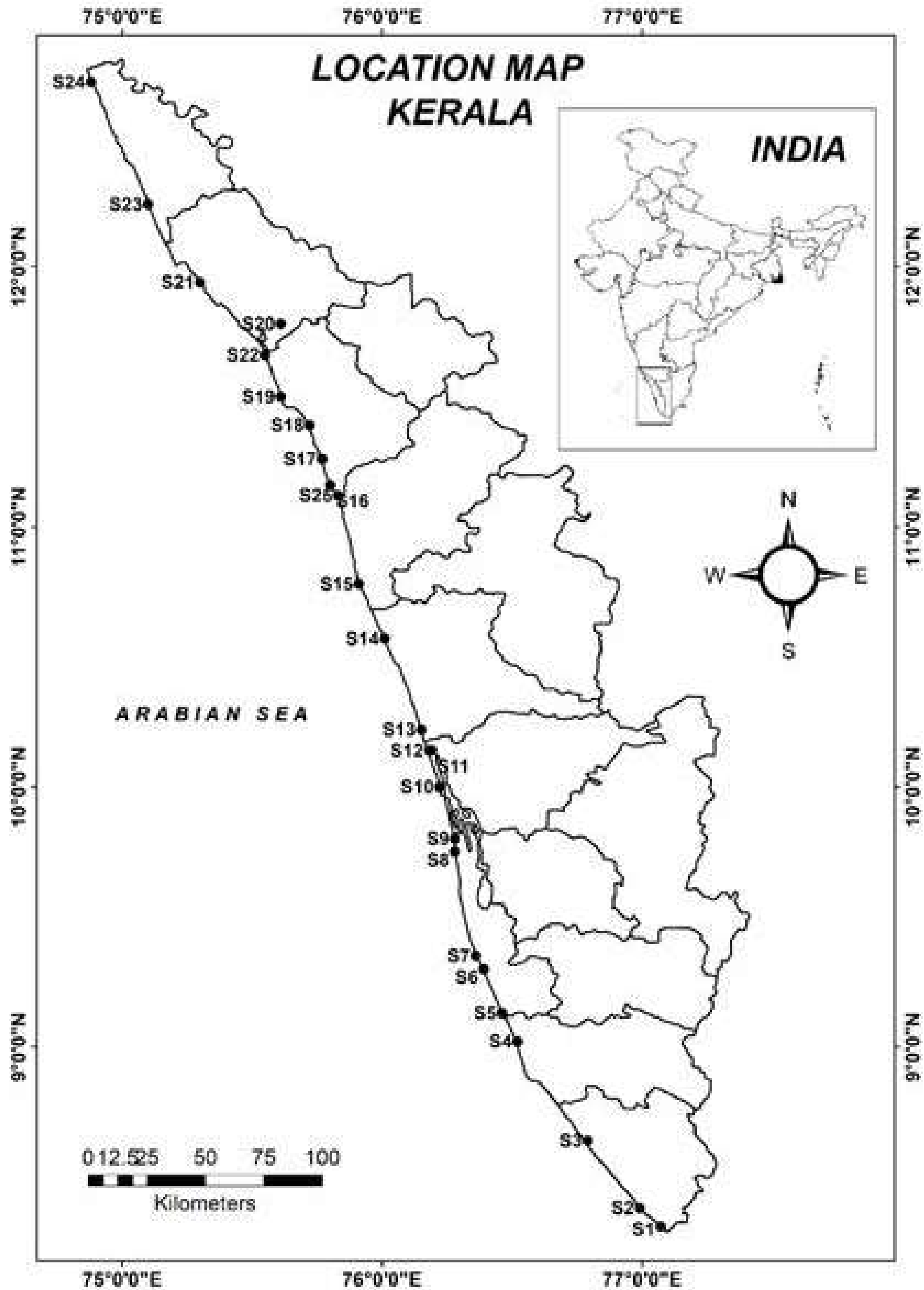


Figure 1: Location map showing the study areas in Kerala with coastline survey locations

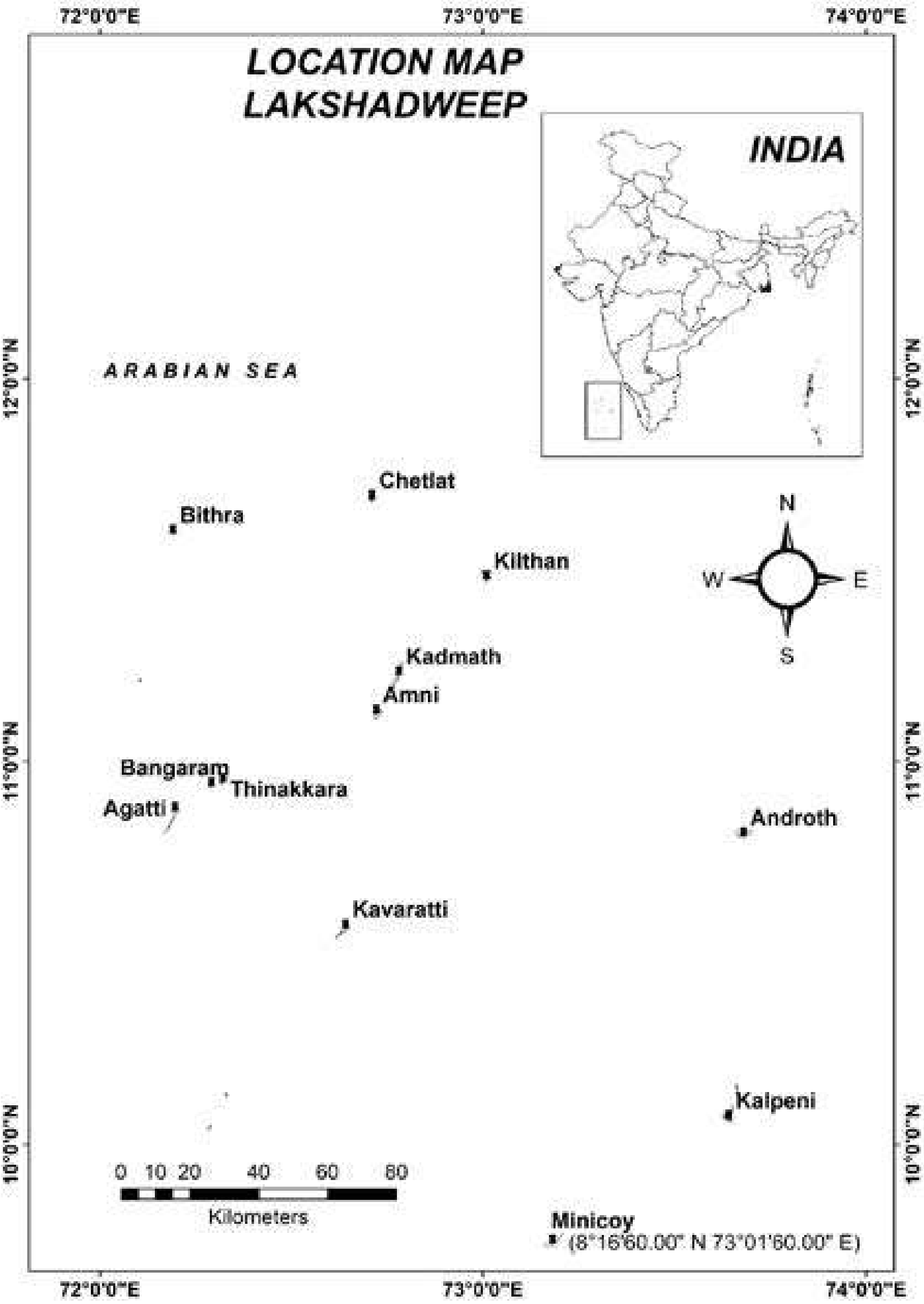


Figure 2: Location map of Lakshadweep islands


Ichthyaetus ichthyaetus


Larus fuscus


Chroicocephalus genei


Chroicocephalus brunnicephalus


Chroicocephalus ridibundus


Hydroprogne caspia


Sterna hirundo

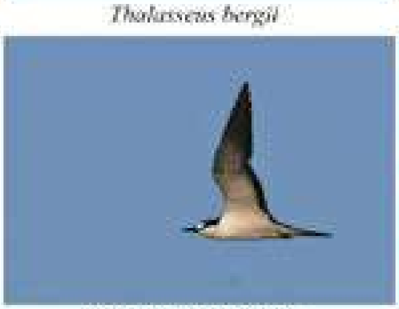

Gelochelidon nilotica


Chlidonias hybrida

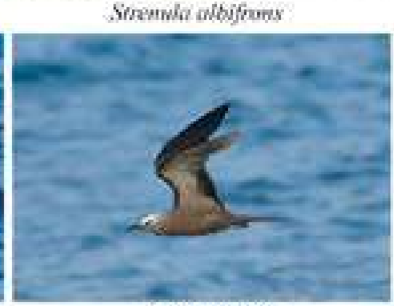

Thalasseus bergii


Thalasseus bengalensis


Sternula albifrons


Onychoprion fuscatus


Onychoprion anaethetus


Anous stolidus

Stercorarius parasiticus

Stercorarius pomarinus

Stercorarius longicaudus

Numenius arquata

Numenius phaeopus

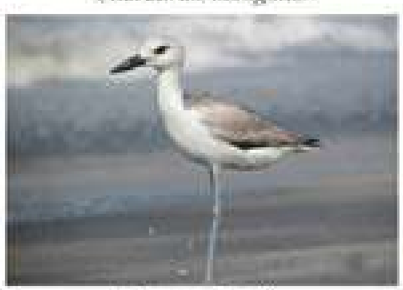
Actitis hypoleucos

Charadrius leschenaultii

Charadrius mongolus

Charadrius alexandrinus

Haematopus ostralegus



Dromas ardeola

Arenaria interpres

Calidris alba

Pluvialis fulva

Pluvialis squatarola

Figure 3: Species of Charadriiformes reported along the Kerala coast and Lakshadweep islands

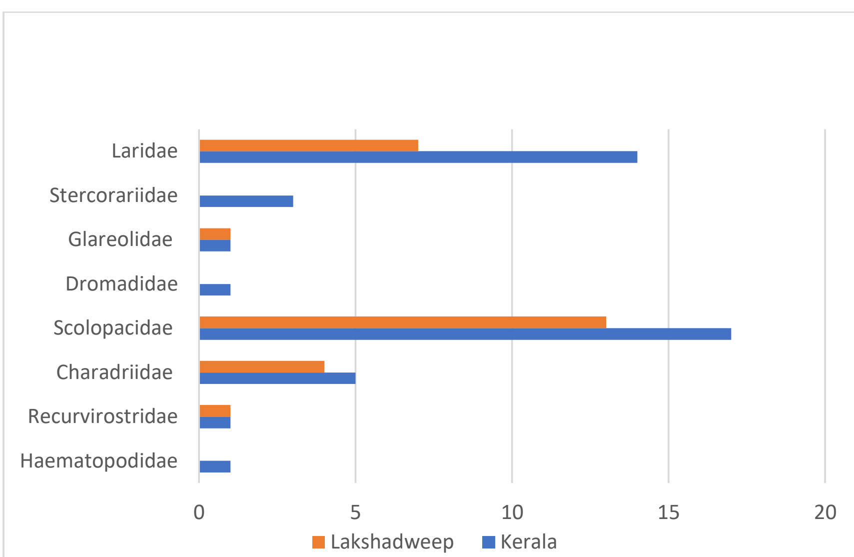


Figure 4: Distribution of families along Kerala coast and Lakshadweep islands

Acknowledgement

NHP thanks DST for providing DST-INSPIRE fellowship for carrying out the study. The authors also thank the Forest and Wildlife Department of Kerala (FWLD-D2/199/2019-FWLD) and the Environment and Forest Department of U.T of Lakshadweep (1/10/2018-E& F/534) for permitting the surveys.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Ant (Family: Formicidae) diversity in two urban landscapes of Kolkata

Priyanka, Das*[a], Arijit Chatterjee[b], Sheela Saroj[a]

[a] *Zoological survey of India, M-Block, New Alipore, Kolkata-700 053, India.*
[b] *Department of Environmental Science, Asutosh College, Kolkata, India*

Abstract

Ants are one of the most diverse and abundant organisms of terrestrial ecosystem. This study was carried out between September 2020 to August 2021 in two urban localities of Kolkata i.e., Subhas Sarovar (SS) and Salt-Lake (SL). This study aims to understand how diversity and distribution of ant species vary in different habitat types in an urban set up. Ants were collected along a transect followed by hand picking throughout the year. During the study, a total of 45 ant species under 6-subfamilies were collected which is approximately 11.7% ant diversity of West Bengal; subfamily Myrmicinae contains maximum species. SS consists 36 ant species while SL having 33 species. SS is more species rich and diverse and species dominance is less in this area than SL. SS, having a huge water body and diverse vegetation including plenty of trees, is well maintained in comparison to SL where dominance is more and diversity is less. Dominance of *Camponotus compressus*, presence of *Tapinoma melanocephalum*, *Paratrechina longicornis* indicate human interference and disturbance. This study emphasises the capacity of ants to adapt themselves and flourish in disturbed habitats especially urban areas. Rapid urbanization and climate change put enormous challenge on the ecosystem's functioning and human wellbeing. This kind of diversity studies help making strategies for maintaining balance between human needs and ecological stability in urban areas.

Keywords: Ant, Formicidae, Kolkata, Diversity, Urban

Introduction

Ants belong to holometabolous insect group under the order Hymenoptera. They are classified under the family Formicidae and from India 864 species/subspecies has been reported so far (Antwiki India, 2023). They along with termites, bees and wasps consists approximately 75% insect biomass (Fittkau and Klinge, 1973). Ease of collection, stationary nesting behaviour, and their many roles in ecosystem as predators, scavengers, seed dispersers, pollinators make them suitable for ecological and behavioural studies. But their immense impact on the ecosystem and environment is yet to be properly explored, especially in urban localities. Bharti et al. (2016) reported 382 species and 65 genera of ants from the state of West Bengal. Ghosh et al. (2007) studied the roadside soil inhabiting ants of Kolkata, from Rabindra Sarovar 29 species of ants were reported (Ghosh et al., 2005), 20 species were documented by Purkait (2017) from south Kolkata. Two study areas have been selected for conducting the present work- one is a manmade lake (Subhas Sarovar) situated at eastern part of Kolkata and another is a roadside area (Salt Lake) located at Sukanta Nagar, Salt Lake, Kolkata. Both the areas are exposed to immense anthropogenic activities and pollution. This study focusses on the primary documentation of ants from the selected areas.

Materials and Methods

Study areas:

Subhas Sarovar (SS): This area (22° 34′-22° 34′ 30′′ N, and 88° 24′-88° 24′ 30′′ E), is situated at the eastern part of Kolkata, West Bengal and maintained by Kolkata Improvement Trust (KIT), acts as the lung of north eastern

*Author for correspondence : priyankazsi10@gmail.com
Article Received on: 02.04.2023

Accepted on: 24.04.2023

Kolkata with massive environmental fillip. It is a manmade lake which spreads in an area of about 98 acres (both land and water body) (Saha et al., 2001) The water body alone consists of 16 ha. and the length and width of the lake are 617m and 352m respectively and maximum depth is 10m (Samal et al., 2008). The lake ecosystem is playing a key role in maintaining the oxygen balance and is also being used for sports, recreational and cultural activities. The vast water body and its two islands have also got potential for attracting the tourists. Moreover, this ecosystem is acting as a natural sink for the removal of pollutants from the surrounding environments. A wide variety of floral collection has been found here like- *Bahunia*, Mango, Neem, Sacred fig, Banyan tree, Arjun, Banana plant, Indian plum, Pomegranate, Ashok, *Eucalyptus* etc. Flowers like *Ixora*, Crepe jasmine, *Hibiscus*, Yellow elder, Bottle brush, *Lantana* are also found here. Along with well-maintained gardens, different types of weeds, bushes are also present. This area is exposed to different kinds of anthropogenic activities like morning and evening walk, playing, fishing, bathing, washing clothes.

Salt Lake (SL): This area is located at Sukanta Nagar, Sector-IV Salt Lake (22°33´75´´N, 88°24´946´´E), along Biswa Bangla Sarani, Kolkata, West Bengal, spreads over approximately 20 acres and it is surrounded by a canal on one side and a very busy road on the other side. A few birds, butterflies, squirrels, different groups of insects are found here along with vegetations like Coconut, Neem, Guava, Papaya, Jackfruit, Mango, flowering plants like Kamini, *Hibiscus*, Yellow elder etc. This area is exposed to heavy vehicular pollution due to heavy traffic and highly disturbed due to construction work for metro railways. Frequently pesticides are used to maintain the plants. People use the area for different recreational activities

Study period: Sampling was done between September 2020 to August 2021.

Collection method: The areas were divided into different transect lines. Ants were collected along those lines from belt shaped quadrats by hand picking method. Ants were picked up from different habitats like vegetations, soil surface, concrete structure with the help of soft brush (soaked in alcohol) and forceps. After collection identification was done by using standard literature: Bolton (1994) and Bingham (1903). Leica S8AP0 microscope was used for identification of ants and field photographs were taken by using Nikon D5600 camera.

Result

A total of 45 ant species (Table-1) under 27 genera belonging to six subfamilies (Fig 2) (Dolichoderinae, Dorylinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae) were collected from the study areas. Subfamily Myrmicinae is the most species rich and consists 18 species, followed by Formicinae (13 species), Ponerinae (6 species), Dolichoderinae (3 species), Dorylinae (3 species) and Pseudomyrmecinae (2 species). Genera *Camponotus* and *Monomorium* both the most species rich and consists 4 species i.e., *Camponotus compressus* (Fabricius, 1787), *Camponotus dolendus* Forel, 1892, *Camponotus oblongus* (Smith, 1858), *Camponotus parius* Emery, 1889 and *Monomorium floricola*, *M. orientale*, *M. latinode*, *Monomorium* sp. respectively. *Camponotus compressus* is the most abundant species (Fig 1) in both the study areas. Among the 24 exotic species found in India (Bharti, 2016), three exotic species i.e., *Anoplolepis gracilipes* (Smith, 1857), *Paratrechina longicornis* (Latreille, 1802) and *Solenopsis geminata* (Fabricius, 1804) have been found in this study. Subhas Sarovar (SS) consists 36 ant species while Salt Lake (SL) possess 33 species of ants. Diversity indices for SS and SL are 2.415 and 2.299 (Shannon_H), 0.872 and 0.846 (Simpson_1-D), 0.311 and 0.302 (Evenness_e^H/S), 0.128 and 0.154 (Dominance_D) respectively (Fig 3). 53% ant species are common in both the study areas while 12 species of ants were exclusively found in Subhas Sarovar and 9 in Salt Lake. A few rare species of ants i.e., *Tapinoma himalaica* Bharti, Kumar & Dubovikoff, 2013 is only from Salt Lake, *while Lioponera longitarsus* (Mayr, 1879) and *Recurvidris recurvispinosa* (Forel, 1890) are found from both the study areas.

Discussion

Approximately 11.7% ant species of West Bengal (Bharti, 2016) has been found from these two urban areas. In the global scenario the three most species rich subfamilies of extant ants are Myrmicinae (48%), Formicinae (23%) and Ponerinae (10%) (Kasseney et al., 2019), in the present study a similar kind of trend is seen where Subfamily Myrmicinae represents 40%, Formicinae 29% and Ponerinae represents 13%. Species of the subfamily Myrmicinae maintains diverse food choice, some are seed harvesters (*Carebara affinis* (Jerdon, 1851), *Trichomyrmex scrabiceps* (Mayr, 1879)), nectar feeders (*Myrmicaria brunnea* Saunders, 1842, *Monomorium floricola* (Jerdon, 1851)) scavengers (*Lophomyrmex birmanus* Emery, 1893, *Meranoplus* *bicolor* (Guerin-Meneville, 1844)), predators (*Carebara affinis*, *Myrmicaria brunnea, Solenopsis geminata*); some maintain mutualistic association (*Lophomyrmex birmanus, Meranoplus bicolor, Myrmicaria brunnea*) and they also build their nest in ground soil, under leaf litter, concrete structure, nest on trees. Due to their varied food choice and nesting methods, they adapt, adjust and spread in various habitats which make them the more dominant group.

Camponotus compressus ants are generally known as carpenter ants due to their dwelling habits (Chavhan et al. 2011). In the study areas *Camponotus compressus* alone were seen with different food habits and nesting habits as they found to make their nest at the bases of different trees like Yellow elder, Guava, Ashok, Kamini; sometimes make their nest in the grass covered ground. They are a generalist predator (Khot et al. 2013) and found to bring different kinds of insects, dead ants to their nests. They were also seen to consume nectar of flowers, honeydew secreted by Aphids and Treehoppers. Due to their diverse range of feeding habit, nesting behaviour and capability to adjust in urban disturbed areas, they are the most dominant and well spread ant species in both the study areas. They alone occupied 26% specimens of all the collected ants. Arboreal species like *Tetraponera rufonigra* (Jerdon, 1851), *T. binghami* (Forel, 1902), *Polyrhachis rastellata* (Latreille, 1802) are collected from the areas. Out of 0.62% species of *Tetraponera*, only 0.04% are collected from Salt Lake where tall trees were very less in number and 0.58% were collected from Subhas Sarovar consisting plenty of larger trees and this signifies diverse range of habitats for different ants. Still, it is interesting to see that these arboreal species are surviving depending on the minimum number of trees which shows their tolerance in such highly disturbed areas.

Study done by Ghosh et al., 2007 revealed that the species *Solenopsis geminata* is dominant in the road side soil heavily polluted by lead, in this study also abundance of *S. geminata* is more in the Salt Lake which is exposed to more vehicular activities in comparison to Subhas Sarovar. Apart from *S. geminata*, *Paratrechina longicornis*, *Monomorium floricola*, *Meranoplus bicolor* are more abundant at Salt Lake in comparison to Subhas Sarovar which reflects that these ants are more adaptive in nature to survive in such disturbed conditions. The second dominant species in this study is *Tapinoma melanocephalum* (Fabricius, 1793) (26.77%) which is an indication of human interference (Viswanathan and Narendra, 2000), so monitoring these areas on a regular basis could reveal further impact of these kind of species in urban localities. According to Begum et al., 2018 small representation of the species belonging to the Subfamilies Ponerinae and Pseudomyrmecinae reflect fragmented habitat; in this study also Salt Lake which is more disturbed and less diverse possess three species of Ponerinae group while Subhas Sarovar consists six species. *Meranoplus bicolor*, *Recurvidris recurvispinosa*, *Solenopsis geminata* make their nest in ground soil while *Paratrechina longicornis*, *Lepisiota sericea* (Forel, 1892), *Trichomyrmex mayri* often seen to make their nest in concrete wall. Among the three exotic species collected, two (*Anoplolepis gracillipes* and *P. longicornis*) are known for their invasive nature.

According to the United Nations, Department of Economic and Social Affairs (Kabisch et al., 2017) approximately half of the global population lives in urban areas and this number is gradually increasing with the passing time. The need for spaces and other requirements of these large populations contribute to land degradation, unplanned construction, destruction and disturbance of natural areas and water bodies. It is the need of the hour to find out solutions that balance human needs as well as maintain ecological stability.

Green patches in urban areas are extremely important as they act as the lungs in urban localities. Insects like ants which are contributing to the ecosystem health in many ways is vital to the maintenance of these greeneries too.

Table and Figures

Table 1. Number of ant species recorded from the study locations

Subfamily	Species of Ants	Subhas Sarovar	Salt Lake
Dolichoderinae	*Tapinoma himalaica* Bharti, Kumar & Dubovikoff, 2013	-	+
	Tapinoma indicum Forel, 1895	+	+
	Tapinoma melanocephalum (Fabricius, 1793)	+	+
Dorylinae	*Aenictus ceylonicus* (Mayr, 1866)	-	+
	Aenictus pachycerus (Smith, 1858)	+	-
	Lioponera longitarsus (Mayr, 1879)	+	+
Formicinae	*Anoplolepis gracilipes* (Smith, 1857)	+	-
	Camponotus compressus (Fabricius, 1787)	+	+
	Camponotus dolendus Forel, 1892	+	+
	Camponotus oblongus (Smith, 1858)	+	-
	Camponotus parius Emery, 1889	+	+
	Lepisiota bipartita (Smith, 1861)	-	+
	Lepisiota sericea (Forel, 1892)	+	+
	Nylanderia bourbonica (Forel, 1886)	+	+
	Paratrechina longicornis (Latreille, 1802)	+	+
	Plagiolepis dichroa Forel, 1902	-	+
	Plagiolepis sp1	-	+
	Plagiolepis sp2	-	+
	Polyrhachis rastellata (Latreille, 1802)	+	-

Subfamily	Species of Ants	Subhas Sarovar	Salt Lake
Myrmicinae	*Cardiocondyla wroughtonii* (Forel, 1890)	+	+
	Carebara affinis (Jerdon, 1851)	+	-
	Carebara diversa (Jerdon, 1851)	+	-
	Crematogaster flava Forel, 1886	+	+
	Crematogaster sp.	+	+
	Crematogaster travancorensis Forel, 1902	+	+
	Lophomyrmex birmanus Emery, 1893	-	+
	Meranoplus bicolor (Guerin-Meneville, 1844)	+	+
	Monomorium floricola (Jerdon, 1851)	-	+
	Monomorium latinode Mayr, 1872	+	-
	Monomorium orientale Mayr, 1879	-	+
	Monomorium sp.	+	+
	Pheidole sp1	+	+
	Pheidole sp2	+	+
	*Recurvidris recurvispinos*a (Forel, 1890)	+	+
	Solenopsis geminata (Fabricius, 1804)	+	+
	Tetramorium sp.	+	+
	Trichomyrmex mayri (Forel, 1902)	+	-
Ponerinae	*Bothroponera sulcata* (Mayr, 1867)	+	-
	Brachyponera jerdonii (Forel, 1900)	+	-
	Brachyponera luteipes (Mayr, 1862)	+	-
	Diacamma indicum Santschi, 1920	+	+
	Leptogenys chinensis (Mayr, 1870)	+	+
	Pseudoneoponera rufipes (Jerdon, 1851)	+	+
Pseudomyrmecinae	*Tetraponera binghami* (Forel, 1902)	+	-
	Tetraponera rufonigra (Jerdon, 1851)	+	+

‘+’ = Presence, ‘-’ = absence

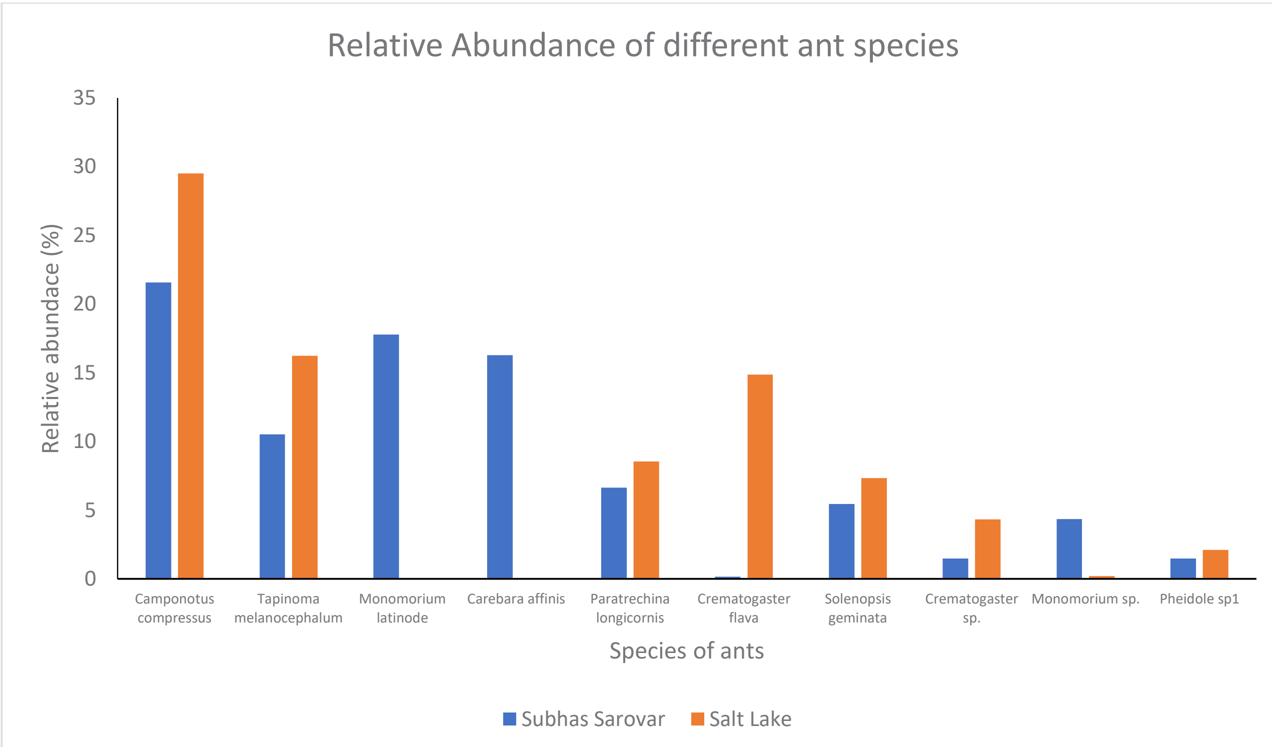


Fig. 1- Relative abundance of ten most abundant ant species in this study.

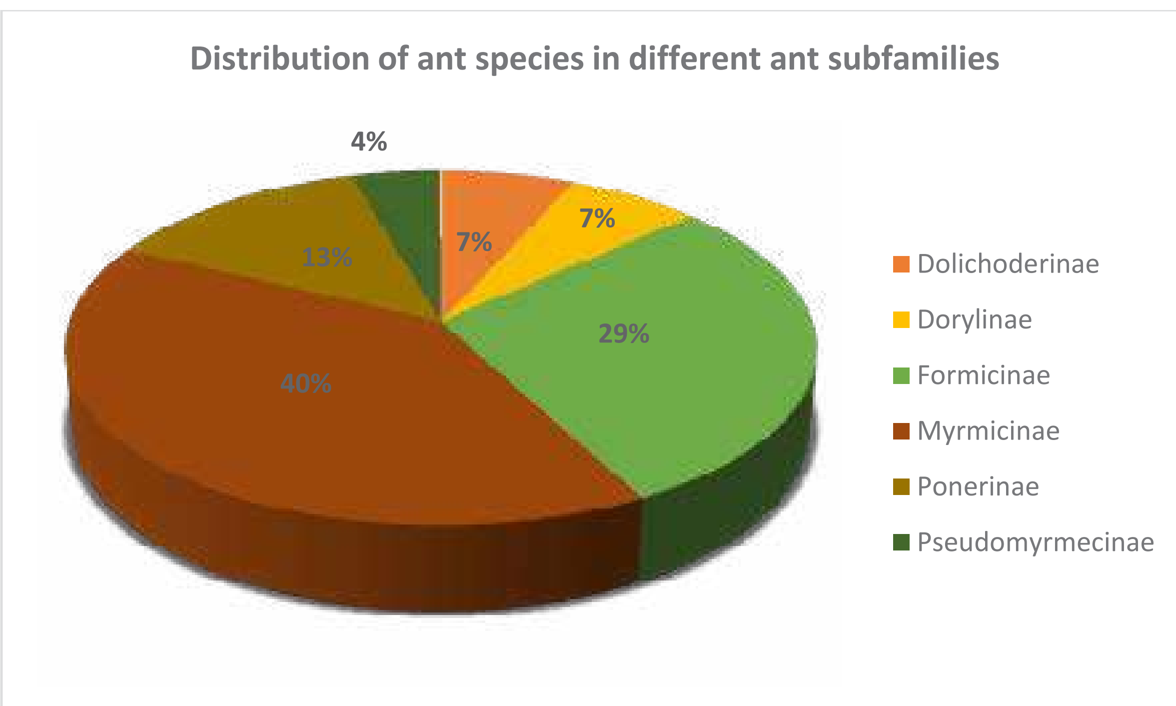


Fig. 2- Species distribution from different subfamilies found in the study locations.

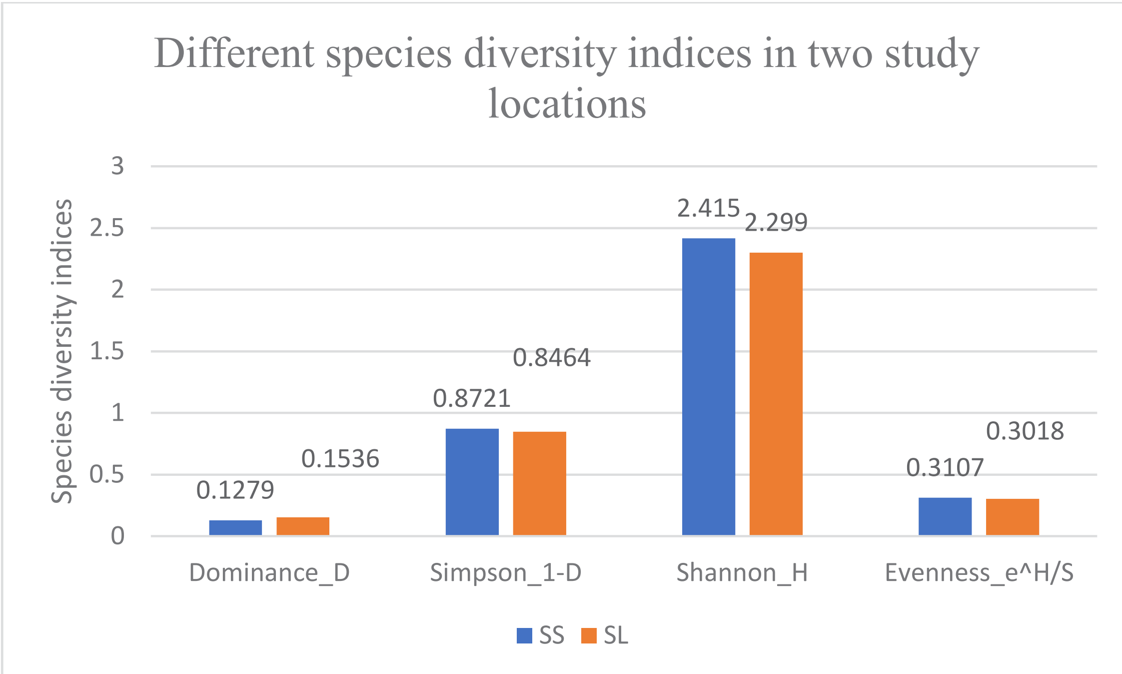
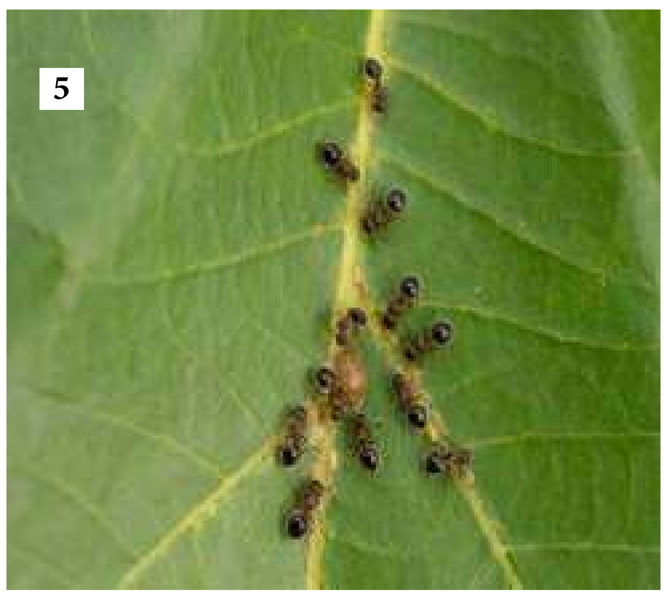


Fig. 3- Different species diversity indices in two study locations

Solenopsis geminata



Meranoplus bicolor

Camponotus compressus

Carebara affinis

Paratrechina longicornis

Tetraponera binghami

Figs 4-9. Different species of ants

Acknowledgement

The authors are thankful to the Director, Zoological Survey of India, Kolkata for providing all necessary help and support. They are immensely grateful to the authority and staff members of Subhas Sarovar for permitting the study and all co-operation extended for this study. The help and support by the members of Central Entomology Laboratory, Zoological Survey of India, Kolkata especially to Mr. Arnab Mandi, MTS for his help during identification and Dr Longjam Roni Kumar Singh, Post-Doctoral Research Fellow for his guidance are greatly acknowledged here. The first author is thankful to Dr. Swarnali Mukherjee, Assistant Professor of Raghunathpur college for her guidance. She is indebted to the Council of Scientific & Industrial Research for providing financial assistance for conducting research as a part of NET-SRF fellowship programme.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Genetic diversity and phylogenetic analysis of Indian Rhesus macaque (*Macaca mulatta*) using Mitochondrial D-loop

E. Agnita Sharon and Ranjana Bhaskar*

DNA Barcoding Lab, Zoological Survey of India, Southern Regional Centre, 130, Santhome high road, Chennai-600028.

Abstract

Indian Rhesus macaques (*Macaca mulatta*) are non-human primates having a wide range of distribution in India. Rhesus macaques are distributed throughout Northern India and Northeast India up to some extent part of South India. In this study, we investigated the genetic diversity and phylogenetic relationship of Indian rhesus macaques in comparison with macaques from other countries using the mitochondrial D-loop region. A total of 61 DNA sequences were generated from five Indian states and compared with 46 sequences from China, Thailand, Japan, and Bangladesh from GenBank. A total of 40 haplotypes were identified in studied samples. The median-joining network showed clustering based on different geographic locations. The Phylogenetic analysis shows two major clades in which the Indian rhesus macaques formed a single clade. There was no geographical cluster found in studied samples. The mismatch and Bayesian skyline plot show recent expansion in the Indian rhesus macaque population. Our results show that the Indian rhesus macaque is undergoing expansion in the population.

Keywords: Macaques; Populations; Expansion; D-loop; Clade

1. Introduction

Rhesus macaques (*Macaca mulatta*) are widely distributed non-human primates (Fooden, 2000). Its distribution range covers a vast variety of ecologies such as tropical, subtropical, temperate forests, and even rural and urban areas, which could be due to its rich behavioral and genetic features (Zhou *et al.*, 2022). The origin and diversification of Indian rhesus macaques began about 2.5 million years ago when the fascicularis species originated and diversified upon reaching the mainland Indo-China region (Fooden, 2006; Stevison and Kohn, 2009). The range and distribution of rhesus macaque are unique. Rhesus macaques have the largest distribution spanning Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, China, Burma, Laos, Thailand, and Vietnam (Brandon Jones *et al.*, 2004; Fooden, 2000). In India, the Rhesus macaque occurs in a wide range of habitats from the Himalayas, deserts, tropics, and temperate forests except in southern India where two native species namely the Bonnet macaque (*Macaca radiata*) and lion-tailed macaque (*Macaca Silenus*) (Chaudhuri*et al.*, 2006) occur. Rhesus macaques are widely distributed across southern and south-eastern Asia, whereas bonnet macaques are restricted to peninsular India (Kumar *et al.*, 2011). Rhesus macaques are common commensals with maximum ecological adaptability (Southwick and Siddiqi, 1988). In India, Rhesus macaques signify historical and cultural aspects of the country. Rhesus macaques have been listed in CITES Appendix II, Schedule I of Part I of the Indian Wildlife (Protection) Act (amended up to 2002). The Indian people view them in terms of food and habitat preferences based on their experiences and religious belief systems. Around 90% considered the macaques to be an incarnation of Lord Hanuman, a Hindu deity. Temple structures also represent Lord Hanuman which is used for worship purposes. Such

*Author for correspondence : ranjana.bhaskar@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

religious beliefs help in the conservation and management of macaques in India (Southwick and Siddiqi, 1988; Pirta*et al*., 1997).

Rhesus macaques are the primary animal model used for research (Smith and McDonough, 2005) and were used extensively for studying human diseases mainly to understand HIV and develop vaccines (Vandeberg and Willams Blangero, 1997). Most of the rhesus macaques were transported from India and China but after 1978 India ceased to supply and China became the main supplier of rhesus macaques to the biomedical research centers in the United States. However, phenotypic differences and significant genetic differences between the Chinese and Indian rhesus macaques have also been noted. Thus, it is necessary to have a detailed understanding of genetic variation within different populations of Rhesus macaques as a part of biomedical research. Regional genetic differences among rhesus macaques may justify the maintenance of separate breeding groups suitable for different animal models. Therefore, it is necessary to characterize rhesus macaques with their geographic distribution (Smith and McDonough, 2005) and understand the distributionand patterns of genetic diversity at the intraspecies level for planning effective conservation management strategies. Although there have been several genetic studies of rhesus macaques in Bangladesh, China, and Nepal which primarily focused on wild populations. There have been no molecular studies on the genetic diversity of rhesus macaques belonging to the Indian subcontinent. Numerous primate habitats have been destroyed due to the increasing human population pressure, industrialization, and urbanization (Feeroz*et al*., 2011), and many rhesus macaque populations have been confined inside human settlements (Hasan *et al*., 2013) causing human monkey conflicts. For this study, non-invasive sampling techniques were performed which provided a new approach in classical taxonomyfor the identification of species and the determination of theirgenetic diversity. This technique includes a collection of naturally shed materials such as hair,faecal pellets, etc., which don'tcause harm or disturb the animals in the wild during sampling (Bhaskar *et al*., 2021).

Phylogeny, evolutionary history, and gene variations in connection to adaptations to local environments will help us understand the biology and evolution of Rhesus macaques. Molecular studies based on mitochondrial DNA genes help in establishing the phylogenetic position and help in understanding divergence and gene flow among the different groups of macaques (Tosi *et al*., 2002; Tosi *et al*., 2003). Mitochondrial DNA is maternally inherited (Giles, 1980) and the control region (CR) evolves at a magnitude more rapidly than nuclear DNA (Brown *et al*., 1979). This region must characterize the intra specific genetic differences in species that are related to geographic distribution (Takahata and Slakin, 1984). The population retrieval of Rhesus macaques in India would help with research and conservation. The data provide in present study will help in genetic resource conservation and management of Indian Rhesus macaques (*Macaca mulatta*). We will discuss the genetic diversity and population differentiation in the collected samples with the overall distribution of mitochondrial D-loop in other country.

2. Materials and Methods

2.1 Sample collection

Faecal materials of Rhesus macaque (*Macaca mulatta*) were collected using a non-invasive technique from five north Indian states namely Uttar Pradesh, Bihar, Assam, Punjab, and Himachal Pradesh during field surveys from the year 2019 to 2022 (Fig.1 and Table 1). Sterile forceps were used to place the fecal pellets in sterile containers which contained ethanol or silica gel depending on whether the fecal sample was fresh or dried, respectively, and preserved at room temperature in the laboratory and stored at -80˚C until DNA isolation is done. The Indian rhesus macaque sequences were also compared with China (JF746823-JF746842), Bangladesh (AB275633-AB275639), Thailand (EF208877-EF208892), and Japan (LC585815-LC585818) sequences. The sequences were aligned using the 'CLUSTALW' alignment (Thompson *et al*., 1994).

Fig. 1. The dots indicate the various sampling sites of Rhesus macaque in India

Table 1. Samples of Rhesus macaque collected for phylogeographic analysis.

Indian states/ Location ID	Location	Latitude and longitude	No of samples
Uttar Pradesh	Lucknow	26.832 N 80.919 E	20
Himachal Pradesh	Shimla	31.105 N 77.172 E	20
Punjab	Chandigarh	30.759 N 76.771 E	20
Bihar	Kaimur wildlife sanctuary, Kaimur	24.704 N 83.174 E	14
Assam	Guwahati	26.806 N 82.777 E	20

2.2 DNA Isolation and PCR amplification of faecal samples

The QiagenQIAmp fast DNA stool kit (QIAGEN, Germany) was used for fecal DNA extraction using the manufacturer's protocol with slight modifications. Samples were processed separately to avoid contamination. The PCR amplification was carried out using DLoop F1 (5′-GCCATAACAATCAAGATCGC-3) and DLoop R1 (5′-TGTTGCGGGTTGGTGTAGAG-3) primers (Zhu and Evans, 2023). PCR amplification was performed using a 3 µl DNA template for a 30 µl PCR reaction using 15 µl master mix, 0.4 µl forward and reverse primer and 12.8 µl nuclease-free water. The PCR wascarried out with an initial denaturation at 94°C for 5 min, 35 cycleseach with denaturation at 94°C for 30 s, annealing at 60°C for 35 s, and extension at72°C for 60 s followed by a final extension at 72 °C for 10 min. After checking the amplification in 1% agarosegel, the successful amplicons were sequencedbidirectionally using BigDyechemistry on an ABI 377 automated sequencer.

2.3 Molecular data analysis

The sequences were confirmed throughBLASTn (Basic Local Alignment Search Tool) (https://blast.ncbi.nlm.nih.gov). The obtained sequences were checked andedited manually for ambiguous bases usingBioEdit V7.0 (Hall, 1999) software.

2.4 Genetic Variability Analysis

The estimates of genetic polymorphism ie. haplotype numbers (H) and haplotype diversity (Hd) were generated in DNASP V6 (Rozas*et al*., 2017). Pairwise genetic differences were calculated using DNASP V6. Mismatch distribution neutrality tests like the Tajima's D (Tajima, 1989) and Fu's Fs (Fu, 1997) values were performed in Arlequin v3.5 (Excoffier and Lischer 2010) software for within and between the populations.

2.5. Phylogenetic analysis and haplotype network

Phylogenetic analysis was carried out in MEGA v10.2.2 software using the Maximum Likelihood tree method with 1000 bootstrap replicates. We first tested the most suitable model which was found to bethe HYK+G model. The maximum likelihood (ML) was constructed using the best fit substitution model which was selected in MEGAX software accordingly. Branch specific rates and lengths were visualized with Figtree v1.4 (Rambaut, 2009). PopART 1.7software was used in constructing a median-joining (MJ) haplotype network (Leigh and Bryant 2015). We also estimated population genetic differentiation (Fst) between the five different populations of rhesus macaques using Arlequin v3.5 (Excoffier and Lischer 2010).

2.6. Population demographic analysis

Mismatch distribution graphs were plotted using the DnaSP Ver. 6.12.03 (Rozas*et al*., 2017) for each geographic sample to infer whether the Indian rhesus macaques had experienced demographic expansion. We evaluated the effective population size over time using the Bayesian skyline plot (BSP) (Ho and Shapiro, 2011) which was implemented in BEAST v2.0 (Bouckaert*et al*., 2014) to understand the historical demographic with the mtDNA. We used the HKY model, empirical base frequencies, and ran the MCMC algorithm for 10,00,000 generations, sampling trees and parameters every 3000 generations. Tracer 1.7.2 (Rambaut*et al*., 2018) was used to visualize the plots to evaluate the convergence of all parameters.

3. Results

3.1 Genetic polymorphism using mitochondrial Dloop

We obtained DNA from 75 fecal samples, out of 94 fecal samples processed and got 61 good quality sequences after the amplification. It showed 64% successful amplification for the mitochondrial D-loop amplification. The final dataset consisted of 595bp of sequences. Generated sequences were submitted in NCBI database (OQ674824- OQ674849, OQ674904- OQ674924, OQ674928- OQ674932). A total of 40 haplotypes (h) were found in the dataset. The total haplotype diversity (Hd) was 0.730. The number of variable sites (S) was 70 and the total number of mutations was (Eta) 72. The nucleotide diversity (Pi) was 0.030 and the average number of nucleotide differences (k) was 16.133. Low haplotype diversity was observed for Assam (0.167) and high haplotype diversity was observed for Bihar (0.833) samples (Table 2).

Table 2. DNA polymorphism data of Indian rhesus macaque samples: sample size (n), haplotype (H), haplotype diversity (h), nucleotide diversity (π).

	n	H	h	π	Tajima D	FuFs
Uttar Pradesh	27	10	0.752	0.002	-1.598 (0.034)	-4.314 (0.003)
Bihar	4	3	0.833	0.019	-0.705 (0.282)	3.504 (0.90)
Assam	12	2	0.167	0.0006	-1.451 (0.067)	0.431 (0.378)
Himachal Pradesh	9	3	0.667	0.001	-0.359 (0.39)	3.040 (0.924)
Punjab	9	5	0.722	0.003	-1.477 (0.076)	-1.185 (0.138)
Total	61	18	0.730	0.003	-2.43** (0.01)	-5.48** (0.02)

3.2 Distribution of Haplotypes and phylogenetic relationships

The median joining network was constructed using mitochondrial Dloop sequences. No cluster was found in the study sample. When, we compared our sequences with other countries we found that the Indian rhesus macaque formed a separate cluster (Fig. 2). The mtDNA haplotypes of India, China, Bangladesh, Japan, and Thailand formed four distinct haplogroups in the haplotype network shown in Fig. 3. Haplogroup1 consisted of haplotypes belonging predominately to China. Haplogroup 2 is consisted of Bangladesh and haplotype 3 is Thailand. Haplogroup4 consisted of haplotypes of India. The phylogenetic tree (ML) of all the haplotypes from these populations showed two major clades. Clade 1 showed the Indian samples whereas Clade 2 showed four subclades consist of Chinese, Bangladesh, Japan, and Thailand samples (Fig. 3).

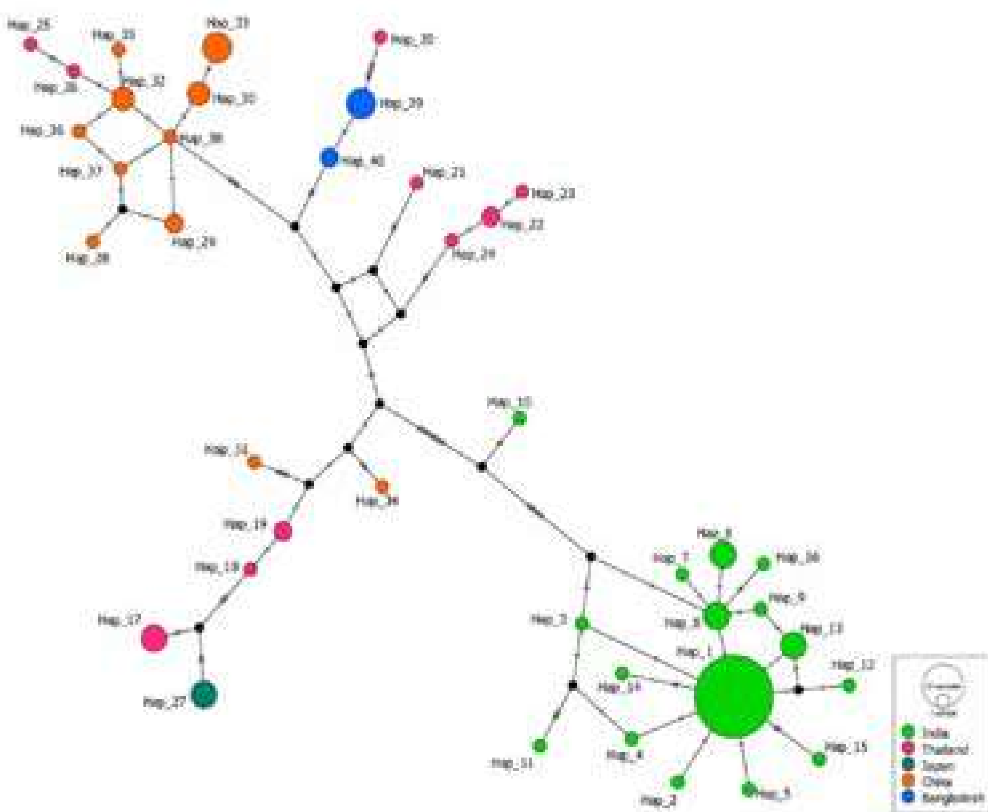

Fig. 2. Median-joining network showing separate clusters based on geographic locations of Rhesus macaque.

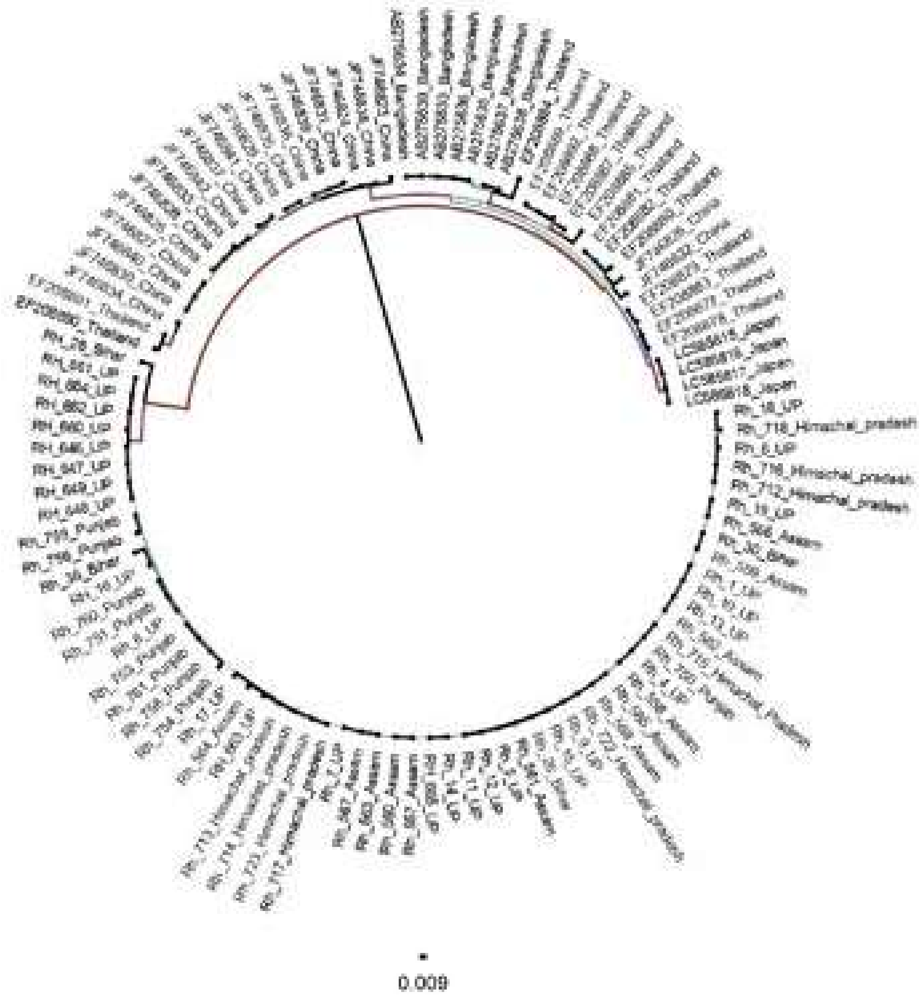

Fig. 3. Maximum likelihood (ML) tree of rhesus macaques showing the separate clades between the Indian Rhesus macaque population and the rhesus macaque from other populations.

3.3 Genetic distances and population structure

The pairwise genetic distance and FST were calculated in studied samples (Tables 3). Genetic distance and genetic differentiation (Fst) was detected between all the population pair was very low ranged from 0.00 to 0.003 and 0.001 to 0.011 respectively. The pairwise FST and genetic distance were also calculated with other country (Table 4). Low Fst valoue was observed between china and Japan (0.07) and highest in Bangladesh and Japan (0.974) while genetic distance is low between two pair China and Bangladesh and Thailand and Bangladesh (0.026) and high between India and Bangladesh (Table 4).

Pairwise genetic differences were calculated for the Indian rhesus macaque populations which signify demographic expansion in the population. Mismatch distribution analysis shows unimodal ragged distribution (Fig. 4). Neutrality test of Tajima's D and Fu's Fs were also performed within the Indian population and between different populations (Tables5 and 6). Among the Indian samples, the Uttar Pradesh samples showed significant Tajima D and Fs values. When comparing different populations, the Indian population showed significant Tajima D and Fu's Fs values when compared to the Chinese. The Japanese populations did not show any values due to the low sample size. The negative value of Tajima's D for Indian haplotypes was statistically significant indicating a recent population expansion in rhesus macaques. The Bayesian skyline plot was constructed for Indian rhesus macaque samples to show the population is recent expansion expansion (Fig. 4).

Table 3 Genetic differentiation among the Rhesus macaque populations. The pairwise *FST* values (Below diagonal) and genetic distance (above diagonal) based on D-loop.

	Uttar Pradesh	Bihar	Assam	Himachal Pradesh	Punjab
Uttar Pradesh	**0.000**	0.002	0.000	0.001	0.001
Bihar	0.011	**0.000**	0.002	0.002	0.003
Assam	0.001	0.010	**0.000**	0.000	0.001
Himachal Pradesh	0.002	0.011	0.001	**0.000**	0.001
Punjab	0.004	0.013	0.003	0.004	**0.000**

Table 4. Genetic differentiation among the Rhesus macaque populations with different country. The pairwise *FST* values (Below diagonal) and genetic distance (above diagonal) based on D-loop.

	India	Thailand	Japan	China	Bangladesh
India	**0.000**	0.054	0.059	0.055	0.060
Thailand	0.800	**0.000**	0.027	0.028	0.026
Japan	0.932	0.251	**0.000**	0.034	0.035
China	0.882	0.229	0.070	**0.000**	0.026
Bangladesh	0.936	0.351	0.974	0.611	**0.000**

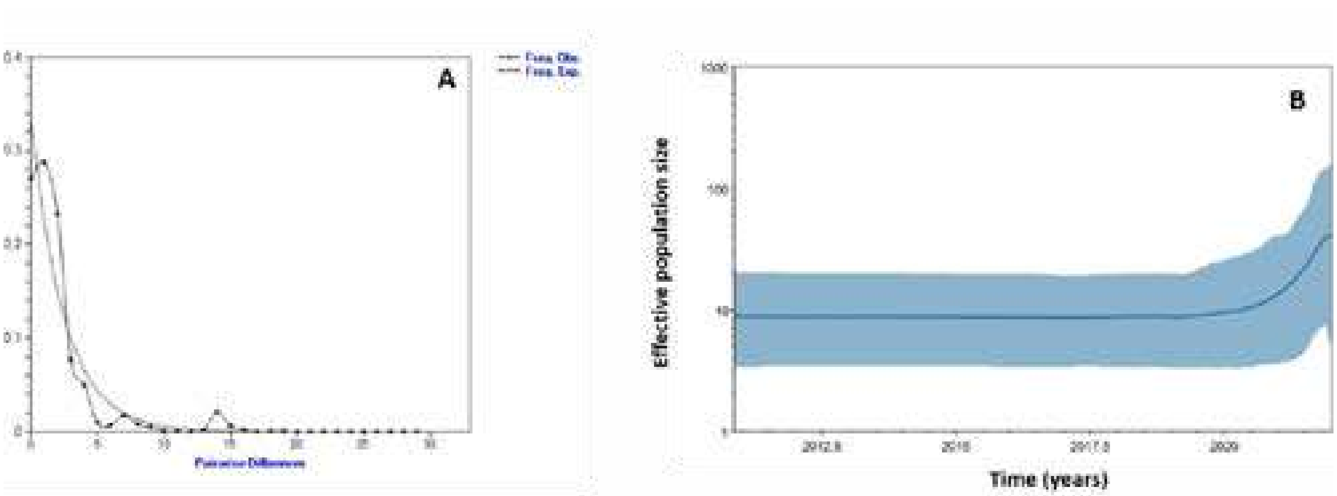

Fig. 4. (A) Mismatch distribution analysis based on mtDNA (CR) sequences of Indian rhesus macaques. The black lines denote observed frequencies and the dotted lines show expected frequencies; (B) Bayesian Skyline plots showing the historical population size for the Indian Rhesus macaque populations.

4. Discussion

Primate populations in Asia face intense ecological pressure which is known throughout the world. The major reasons are habitat, destruction, competition for food and space, pet trade, etc. (Southwick and Siddiqi, 1994). The present study demonstrates the genetic diversity and population structure of Rhesus macaque (*Macaca mulatta*) from the five states of the country. The study was done by the mitochondrial D-loop. We processed 94 samples and generated 61 good quality sequences for analysis. Clustering patterns pattern of the haplotype network and phylogenetic analysis show no population structure in the studied samples. The median joining network with other country was formed four clusters. It shows that Indian cluster is closer to Thailand as compare to Bangladesh. This shows that the Bangladesh haplotypes were not similar to Indian haplotype samples but rather clusters with Chinese rhesus macaques. Smith & McDonough, 2005, studied that Indian haplogroup formed separate cluster that included none of the Bangladesh. This might be due to the occurrence of subspecies. The analysis of phylogenetic tree shows that Punjab and Himachal Pradesh a separate group. The sampling locations of rhesus macaques in India are separated by each other by geographic isolated distances of 30 to 300km (Hasan et al 2013). In some locations, the populations are separated by human settlements or natural barriers such as rivers which contribute to differences in gene flow. Hence the Chinese and the Indian rhesus macaques form two separate haplotypes due to significant genetic differences.

In the case of rhesus macaques (*Macaca mulatta*), it exhibits female philopatry and male dispersal from natal groups (Pusey and Packer, 1987), and the mtDNA contains the genetic differences among the regional populations (Smith *et al*., 2007). Previous studies have shown that the Indian and Chinese rhesus macaques were reproductively isolated during the Pleistocene, during which the Indian rhesus macaques experienced a severe genetic bottleneck, and that some gene flow westward into India was subsequently re-established. Bayesian skyline plot shows that the Indian rhesus macaques are undergoing population expansion from 2019 onwards in recent years. From our data, the phylogenetic analysis shows that the Indian rhesus forms a separate clade from other countries. The median joining network shows the Indian and the Chinese rhesus macaques form separate haplogroups. The genetic distance and the FST values also signify that they are separate populations. Groves (2001) assigned rhesus from Kashmir/Punjab region to subspecies *M. m. villosus.* The geographic range of rhesus macaques is sufficiently extensive, and the antiquity of their dispersal throughout that range is sufficiently great, that major genetic differences might have evolved in regional populations of Macaca mulatta. Smith and McDonough (2005) argued that the current geographic distribution of rhesus macaques in India resulted from a westward dispersal or redispersal, that the species dispersal took place through mainland Southeast Asia and China. Melnick and Kidd (1985) suggested that genetic similarity between Chinese rhesus macaques and cynomolgus macaques in Thailand results from the divergence of rhesus from cynomolgus macaques in Thailand during a glacial maximum, followed by the dispersal of cynomolgus macaques to the south.

The outcome of this study shows a stark difference in the rhesus macaque populations of India and China in terms of their origin and diversity. This is consistent with the phenotypic differences between the two regional populations as Chinese rhesus males tend to beheavier, longer, and taller than Indian rhesus males (Peng *et al*., 1993).The significance of both negative Tajima's D and Fu Fs, as well as the presence of low nucleotide but high haplotype diversity, shows recent expansion in the Indian population. This is because the male macaques tend to leave their natal groups and improve the gene flow. The mitochondrial haplotype network showed geographical clustering which had unique haplotypes. The mismatch distribution shows the unimodal and ragged distribution. The Bayesian skyline plot shows that the Indian rhesus macaques are undergoing population expansion from 2019 onwards in recent years. This might be due to anthropogenic factors contributing towards the expansion. It is necessary to closely monitor the wild populations of rhesus macaques to in order to maintain constant population.

5. Conclusion

We discussed the genetic diversity and haplogroups of various rhesus macaque (*Macaca mulatta*) populations from the five states of India and with other country. There is no much difference obtained in five states population but due to geographic barrier Punjab and Himachal population formed separate group. The Indian and Chinese rhesus macaques tend to exhibit significant differences in their mitochondrial D-loop. However, the Indian rhesus macaque populations showed expansion in population which needs to be ascertained using more sampling. The Bangladeshi macaques were not similar to the Indian macaques but showed more similarity with the macaques from Thailand.

6. Acknowledgements

We are thankful to the Director, Zoological Survey of India, Kolkata, Ministry of Environment, Forest and Climate Change (MoEF&CC) for providing the necessary facilities. We are also thankful to the Officer-in-Charge and the staff members of the Zoological Survey of India, Southern Regional Centre, Chennai, for their encouragement and support during the study. The authors are thankful to the funding agency DST SERB for funding this work.

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ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Rec. zool. Surv. India: Vol. 123(iS2)/01-15, 2023
DOI: 10.26515/rzsi/v123/i1S/2023/172458

Ecological Interactions Based on Shell Selection in Hermit Crabs (Decapoda: Anomura): A Case Study from Kerala Coast

Reshmi, R.[1], Preetha Karnaver[2] and A. Bijukumar[3]

[1]Department of Zoology, NSS College, Pandalam, Pathanamthittah 689501, Kerala, India
**Email: reshmiaqb@gmail.com*
[2]Department of Zoology, Christian College Chengannur, Alappuzha 689122, Kerala, India
[3]Department of Aquatic Biology & Fisheries,University of Kerala, Thiruvananthapuram 695581, Kerala, India

Abstract

Hermit crab extensively distributed along tropics and subtropics, forms a perfect example for ecological interaction. Mobile habitat selection by hermit crabs is very complex phenomenon extremely important for their survival. Hermit crabsare engaged in shell fights for choosing suitable shells andexhibit mutualism with sea anemone. Sea anemone attached to shell provides additional protection to the hermit crab, while both are mutually benefited by their food gathering activity.Inorder to understand the shell selection behaviour of hermit crabs in natural conditions 35 species of hermit crabs along with their shells were collected from the Kerala coast, and regression analysis of seven species was done to understand the shell selection pattern. In nature, hermit crab exhibits a greater plasticity in shell selection and it varies with species.

Keywords: Crustacea, Ecology, Gastropoda, Paguroidea

Introduction

The superfamily Paguroidea of the infraorder Anomura comprises hermit crabs and their relatives in the families Coenobitidae (17 species in 2 genera), Diogenidae (428 species in 20 genera), Paguridae (542 species in 75 genera), Parapaguridae (76 species in 10 genera), Pylochelidae (52 species in 10 genera), and Pylojacquesidae (2 species in 2 genera)(McLaughlin, 2003).Hermit crabs represent an important portion of the intertidal, sublittoral and moderately deep benthic marine communities worldwide (McDermott, 1999; Shives and Dunbar, 2010),although some species have physiological and behavioural adaptations for living in almost all habitats such as estuarine, semi-terrestrial and terrestrial (Mantelatto and Sousa, 2000).They have high diversity in tropical and subtropical regions (McLaughlin *et al*., 2007), where they play an important role in food web (Balkıs and Kurun, 2008). They are ecologically important scavengers, feeding on organic deposits and are also good predators (Whitman *et al*., 2001).

Hermit crabs have a soft abdomen, and they keep the abdomen tucked away in a discarded gastropod shell or cavities of appropriate size for safety from predation, desiccation and mechanical damage (Khan, 1992;Gherardi, 1996; Balkıs and Kurun, 2008).Few hermit crabs are found inhabiting shelters other than shells, which includesbivalve and scaphopod shells, hollowed cylinders of wood (McLaughlin and Lemaitre, 1997);stones, calcareous tubes of polychaetes, or vermetid gastropods which are immobile (Gherardi and Cassidy, 1994; Rodrigues *et al*., 2000);corals (McLaughlin and Lemaitre, 1993);and sponges (Sandford, 2003). Terrestrial hermit crab, popularly known as “coconut crab” [*Birguslatro* (Linnaeus, 1767)], is fully calcified andexist without a shell, although megalopae and young crabs of this species require shells (Greenaway, 2003).

*Author for correspondence : ranjana.bhaskar@gmail.com
Article Received on: 02.04.2023 Accepted on: 24.04.2023

Survival and reproductive fitness of hermit crab critically depend on the gastropod shellsmaking it alimiting factor(Mantelatto and Meireles, 2004;Laidre, 2011). Hermit crabsselect the most suitable shell, perfect for their size and shapeby exchanging or sharing shells among individuals of same or different species (Gherardi and Nardone, 1997), seeking empty shells or migrating to areas where gastropod shells are abundant (Mantelatto and Garcia, 2000; Halpern, 2004; Mantelatto*et al.*, 2004). Shell abundance may regulate their fecundity (Bertness, 1981a), growth rate (Fotheringham, 1976; Bertness, 1981b; Blackstone, 1985), survival (Vance, 1972; Bertness, 1981c), copulatory success (Hazlett andBaron, 1989), intra- and interspecific interactions among them (Bach *et al.*, 1976),and the resource partitioning (Mantelatto*et al.*,2010).Gastropod shells thus form an indispensable resource for hermit crabs.

Shell exchanges take place by agonistic interactions called 'shell fights' between intraspecific and interspecific populations (Barron and Hazlett, 1989) in order to obtain better-quality shell. Those hermit crabs are aware of the information about the shells, opponent and their own physiological condition (Briffa and Elwood, 2004). Hermit crabs choose suitable shells after a lengthy process of shell investigation (Elwood and Stewart, 1985).Hermit crabs are ideal model organisms showing vacancy chain process (Mclean, 1974).

Relationship between hermit crabs and gastropod shells is an excellent example of decision-making during habitat selection (Hazlett, 1981), which requires good cognitive abilities (Elwood and Appel, 2009). The intrinsic relationship between crab and shell, their shell use pattern, shell preferences, etc., can be understood only by experimental analysis (Dominciano *et al.*, 2009). Hermit crabs are good example of 'ecosystem engineers' as they influence the abundance and distribution of diverse variety of invertebrates through use of gastropod shells (Jones *et al.*, 1994, 1997). As such they bring dead gastropod shells back to life (Gutiérrez *et al.*, 2003) that would have been otherwise degraded.

The previous studies on the shell selection and utilization by hermit crabs in context to the Indian subcontinent were mainly those of Trivedi and Vachhrajani (2014), Reshmi *et al.*(2018), Sardar *et al.* (2019), Nirmal *et al.* (2020), and Patel *et al.* (2020).The present study explains the shell selection done by 35 species of hermit crabs from the southwest coast of India in their natural environment.

Material and Methods

Study sites

Hermit crabs were collected during November 2021 to October 2022 from major fishing harbours, landing centers, intertidal areas, mangrove swamps and sandy beaches along seven coastal districts of Kerala coast (Fig.1).

Collection and Preservation

The collected animals were transported to the laboratory in plastic containers. The date, time andlocality of collection and the live colourationof the specimens were recorded. The specimens collected were cleaned, washed and photographed in the field. The dead specimens with shells were preserved in 10% formaldehyde after noting necessary morphometric measurements of the host and shell. The shells of each species of hermit crabs were dried and identified for studying the shell selection in hermit crabs.

Identification and Morphometry

Each hermit crab and its shell were identified up to species level using standard literature and online databases. The identification keys of McLaughlin *et al.* (2007) were the primary source for identification. Shells were identified followingApte (1998), Subba Rao (2003), Robin (2008) and other molluscan databases.Shell morphometric characters like Shell Length (SHL), Shell Width (SW), Aperture Length (AL), Aperture Width (AW), Shell Weight (W), Internal Volume (IV), External Volume (EV) and Aperture Perimeter (AP) were recorded. Hermit crab measurements like Shield Length (SL), Carapace Length (CL), Thoracic Length (TL), Abdominal Length (AL), Carapace Width (W) and Wet weight were also taken(Fig.2).

Statistical Analysis

Regression analysis (Zar, 1996) of seven species of hermit crabs wasdone. Shell-size preference was analyzed using multiple linear regression log$Y$= a + b log$X$,where Y = shell measurements and X = hermit crab measurements. The level of significance was 5%.

Results and Discussion

Thirty-five species of hermit crabs were chosen, and they showed different patterns of shell selection.Hermit crabs and their preferred shell in nature are shown inTable 1. Diogenidae was the most diverse family obtained throughout the study, and the shell selection was most abundantly found among the species in this family (Fig.3). The species of *Diogenes* Dana, 1851 occupied the most diverse variety of shells; among them, *Diogenes alias*, *Diogenes canaliculatus* and *Diogenes mannarensis* occupied the most diverse varieties of shells. Great diversity of shell occupied by a hermit crab species in nature depends on the availability of different shell species, the relative abundance of the gastropods, and their mortality rate in an area (Meireles *et al*., 2008). *Coenobita rugosus*, the semi-terrestrial species, was found occupying a great variety of shells; they, however, preferred shells lacking columella. Kinosita and Okeyima (1968) studied *Coenobita rugosus* occupying shells of *Nerita striata* from Japan and found that the shells occupied by this species had missing columella. Majority of shells occupied by *Coenobita* lack columella (Ball, 1972), and this may be due to the reason that land hermit crab tend to inhabit shells that are modified by previous hermit crab use (Wolcott, 1988). A well-fitting shell is essential for semiterrestrial hermit crab for preventing evaporation and to carry ample water (Sallam*et al*., 2008).

From the study, it is clear that morphometry of shells plays a significant role in its selection by the host hermit crabs. According to Sallam *et al*. (2008), shell dimensions are the main determinant of shell utilization in hermit crabs. *Ciliopagurus grandis* and *Clibanarius longitarsus* were found occupying certain shells with larger aperture length. This was due to the shape and size of the hermit crab carapace which allows it to completely fit into the preferred shell. In the case of *Diogenes miles* and *Ciliopagurus krempfi*, the carapace was much flattened so they choose shells which had large shell length and aperture length. *Clibanarius longitarsus* has a rounded carapace and was collected mainly from the mangrove ecosystems, and the species preferred the shells of *Telescopium telescopium* that has a rounded aperture. Hermit crabs in nature have a greater choice of shell selection, and the selection depends upon certain shell characters, which vary among one another and is not based on previous experiences (Conover, 1978). The morphometric characters of hermit crabs and the shells associated with it have morphometric relation and were independent of shell species (Mantellato *et al*., 2010). According to Meireles *et al.* (2008), the morphometric relationships between shell aperture length and hermit crab shield length best describes the selected shells. Single shell species preference showed by certain hermit crab indicates active selection behaviour. There is a close relationship between the shell use and availability of resources (Volker, 1967).

The results of the regression analysis showing morphometric relationships of seven species of hermit crabs collected from sea and their host gastropod shells are given in Table 2. The study showed positive correlations between morphometry of hermit crab and shell morphometry. *Coenobita rugosus* showed a positive correlation to all shell parameters of *Euchelus asper.* Shield length of *Diogenes alias* showed a positive correlation to shell parameters of*Babylonia spirata* and *Babylonia zeylanica* ($p<0.01$). With shells of *Cantharus tranquebaricus, Diogenes alias* showed a positive correlation to all shell parameters except AW×SL. Parameters of *Bufonaria crumena* and *Diogenes alias* showed significant value, $p<0.05$. *Murex ternispina* showed a high significant relation with parameters like shield length and shield width of *D. alias* ($p<0.01$).*Diogenes dubius* mainly occupied three species of shells, viz., *Babylonia spirata*, *Babylonia zeylanica* and *Bufonaria crumena*. High significance of 'p' value ($p<0.01$) was shown by shell length, shell width and aperture length versus shield width in the case of *Bufonaria crumena* and shell width versus shield length with shells of *Babylonia spirata. Clibanarius longitarsus* occupied the shell of *Telescopium telescopium* and showed a positive correlation between all morphometric parameters except aperture width versus shield length and shield width. *Ciliopagurus grandis* was most abundantly found hermit crab, occupying the shells of *Conus inscriptus*. Significant correlations were observed for the parameters like shell length × shield length, shell width × shield length and aperture length × shield length. *Ciliopagurus krempfi* possesses much flattened carapace than rest of the species and were found occupying the shells of *Conus inscriptus* that has a narrow shell aperture. Significant relationships were recorded for parameters such as shell length × shield length, aperture length × shield width and aperture width × shield width. *Diogenes miles* were found occupying shells of *Agaronia gibbosa* and showed correlation for all morphometric shell and hermit crab parameters. High significance was obtained for parameters like shell length, shell width and aperture length verses shield width ($p<0.01$).

Shell utilization pattern varies between hermit crab and are greatly influenced by the available shell's size and type, hermit crabs shell preferences and by area of occurrence of hermit crab (Mantelatto and Garcia, 2000;Meireles*et al*., 2003; Mantelatto and Meireles, 2004). A great variety of shells werefound occupiedby the hermit crabs, and this indicates resource partitioning between hermit crabs.In general, hermit crabs always select optimal shells based on shell characters like shell length, shell width, aperture length, aperture width and aperture perimeter in addition to certain other characters like shell type, weight, internal volume, shell availability, current shell quality and shell experience (Fig.4). Hermit crab are good 'ecosystem engineers' as they help in distribution of diverse variety of invertebrates through use of gastropod shells and are the key species because the degree of healthiness of a shore is determined by the rarity or abundance of hermit crabs.

Table 1. Systematic list of hermit crabs and their preferred shell species along the Kerala coast.

Sl.No.	Hermit crab species	Preferred shell species
1.	**Class: Malacostraca** **Order: Decapoda** **Family: Coenobitidae** Genus: *Coenobita* Latreille, 1829 *Coenobita brevimanus* Dana, 1852	*Turbo intercostalis, Nerita albicilla* and *Nerita polita*
2.	*Coenobita rugosus*H. Milne Edwards, 1837	*Purpura panama, Turbo brunneus, Purpura bufo, Neritapolita, Euchelus asper, Babylonia zeylanica*and *Babylonia spirata.*
3.	**Family: Diogenidae** Genus: *Paguristes*Dana, 1851 *Paguristesmiyakei* Forest & McLaughlin, 1998	*Xenophora pollidula, Biplexperca*and *Polinices mamilla.*
4.	*Paguristesluculentus*Komai, Reshmi and Bijukumar, 2015	*Fusinuscolus*
5.	Genus: *Ciliopagurus*Forest, 1995 *Ciliopagurusgrandis*Komai, Reshmi and Bijukumar, 2012	*Ficusgracilis*, *Conus textile,Fusinuscolus*and *Turris javana*.
6.	*Ciliopaguruskrempfi*Forest, 1995	*Conus inscriptus*.
7.	*Ciliopagurusliui* Forest, 1995	*Conus inscriptus*.
8.	Genus: *Dardanus*Paul'son, 1875 *Dardanus pedunculatus* (Herbst, 1804)	*Chicoreus chicoreusramosus*and*Phaliumglaucum*.
9.	*Dardanus hessi* (Miers, 1884)	*Phaliumglaucum,Bufonariacrumena, Bufonaria echinata, Natica vitellus* and*Vokesimurexmalabaricus.*
10.	*Dardanus megistos* (Herbst, 1804)	*Lambis lambis*and *Tibia curta*.
11.	*Dardanus setifer*(H. Milne Edwards, 1836)	*Rapanarapiformis, Bufonaria echinata, Tibia curta, Tutufa bufo, Harpulina loroisi*and *Phaliumglaucum*.
12.	Genus: *Clibanarius* Dana, 1852 *Clibanarius Clibanarius*	*Rapanarapiformis*and*Phaliumglaucum*
13.	*Clibanarius longitarsus* (De Haan, 1849)	*Bufonaria echinata*, *Telescopium telescopium, Tibia curta*, *Phaliumglaucum, Pugilina cochlidium* and *Murex trapa*

Sl.No.	Hermit crab species	Preferred shell species
14.	*Clibanarius merguiensis* De Man, 1888	*Turbo intercoastalis*
15.	*Clibanarius arethusa* De Man, 1888	*Purpura bufo, Indothais lecera,Thiasmancinella*and *Tibia curta*
16.	*Clibanarius padavensis* de Man 1888	*Babylonia zeylanica*, *Bufonaria echinata, Bufonaria crumena, Babylonia spirata* and *Tibia curta*.
17.	Genus: *Diogenes*Dana, 1851 *Diogenes alias* McLaughlin & Holthuis 2001	*Babylonia zeylanica, Babylonia spirata, Phaliumglaucum, Phaliumbandatum, Natica vitellus, Natica lineata, Polinix*sp., *Purpura bufo, Harpa major, Rapanarapiformis, Bufonaria echinata, Bufonaria crumena, Turbinella pyrum, Ficusvariegata, Chicoreus ramosus, Murex trapa, Vokesimurexmalabaricus, Pugilina cochlidium, Tibia curta, Indothais lecera, Conus inscriptus, Cantharus melanostomus, Cantharus tranquebaricus, Euchelus asper, Gyrinium natator, Colus*sp., *Turrisamicta, Fusinuscolus, Fusinuslaticostatus, Turritella duplicate* and *Turritella banksi.*
18.	*Diogenes avarus* Heller 1865	*Clypeomorus batillariaeformis,Turricula javana* and *Euchelus asper*.
19.	*Diogenes canaliculatus* Komai, Reshmi and Bijukumar, 2013	*Distorsio reticularis*, *Nassarius distortus*, *Agaronia gibbosa*, *Margistrombusmarginatus*, *Euchelus asper*, *Gyrinium natator*, *Polinices mammilla*, *Natica vitellus, Umbonium vestiarium*, *Thias*sp., *Cantharus tranquibaricus, Dolomena sibbaldi*, *Turrisamicta*, *Turris tornata*, *Turrisamicta, Turritella duplicata, Ranularia obesa* and *Dentalium* sp.
20.	*Diogenes custos* (Fabricius, 1798)	*Tonna dolium,Pugilina cochlidium, Bufonaria echinata, Purpura bufo, Turritella duplicata, Babylonia zeylanica,Babylonia spirata, Natica vitellus* and *Natica lineate*
21.	*Diogenes dubius* (Herbst 1804)	*Turbo intercoastalis, Purpura bufo, Babylonia zyelanica, Babylonia spirata* and *Natica vitellus.*
22.	*Diogenes klaasi* Rahayu and Forest, 1995	*Bufonaria crumena* and*Cerithiacea cingulata.*
23.	*Diogenes mannarensis* Henderson, 1893	*Fusinuslaticostatus, Tibia curta, Murex trapa, Bufonaria echinata, Tonna dolium, Turricula javana, Turritella vittata, Natica vitellus, Purpura bufo, Babylonia spirata* and *Babylonia zeylanica.*
24.	*Diogenes merguiensis* de man 1888	*Babylonia zeylanica,Babylonia spirata* and *Bufonaria crumena*
25.	*Diogenes miles* Herbst, 1791	*Agaronia gibbosa*
26.	*Diogenes planimanus* Henderson, 1893	*Fusinuslaticostatus, Purpura bufo* and *Indothais lecera*.
27.	*Diogenes violaceus* Henderson, 1893	*Turris tornata, Natica pulcaria, Bullia vitellus, Indothais lacera* and *Euchelus asper.*

Sl.No.	Hermit crab species	Preferred shell species
28.	Genus: *Calcinus*Dana, 1851 *Calcinus morgani*Rahayu and Forest, 1999	*Turbo intercoastalis*and *Trochus radiatus*
29.	*1.* *Calcinus laevimanus* (Randall, 1840)	*Thiasmoncinella*and *Turbo intercostalis*
30.	**Family: Paguridae** Genus: *Nematopagurus* A. Milne-Edwards and Bouvier, 1892 *Nematopagurus squamichelis* Alcock, 1905	*Cantharus* sp., *Indothais lacera* and *Natica* sp.
31.	Genus: *Pagurus*Fabricius, 1775 *Pagurus carpoforaminatus* (Alcock, 1905)	*Nassariacrematus* and*Distorsio reticularis*
32.	*2.* *Pagurus kulkarni*Sankoli, 1962	*Indothais lacera*
33.	*Pagurus pitagsaleei* McLaughlin, 2002	*Indothais lacera*
34.	*Pagurus spinossior*Komai, Reshmi and Bijukumar, 2013	*Ficusinvestigatoris*
35	Genus: *Phylopaguropsis*Alcock, 1905 *Pylopaguropsis magnimanus (*Henderson, 1896)	*Biplexperca* and *Gemmula*sp

Table 2. Regression equation showing morphometric relationship between hermit crabs and their host gastropod shells collected from natural condition.

Hermit crab species	Shell species	Relation	Linear equation	r value
Coenobita rugosus	*Euchelus asper* (n=26)	Sh.L x SL	ln Sh.L= -1.84+ 0.32 lnSL	0.838**
		Sh.L x SW	ln Sh.L= -1.50 + 0.38 lnSW	0.881**
		Sh.W x SL	ln Sh.W= -0.30 + 0.32 lnSL	0.849**
		Sh.W x SW	ln Sh.W= 1.24 + 0.36 ln SW	0.826**
		AL x SL	lnAL= -0.43 + 0.48 ln SL	0.776**
		AL x SW	lnAL=1.55+ 0.68 ln SW	0.767**
		AW x SL	lnAW= -1.04 + 0.66 ln SL	0.840**
		AW x SW	lnAW=1.55 + 0.68 ln SW	0.767**

Hermit crab species	Shell species	Relation	Linear equation	r value
Diogenes alias	*Babylonia spirata* (n=9)	Sh.L x SL	ln Sh.L= -12.48+ 0.479lnSL	0.892**
		Sh.L x SW	ln Sh.L= 20.00- 0.052 lnSW	0.159
		Sh.W x SL	ln Sh.W= -4.15+0.469lnSL	0.818**
		Sh.W x SW	ln Sh.W=16.13+0.052 lnSW	0.149
		AL x SL	lnAL= -3.79+0.491 ln SL	0.897**
		AL x SW	lnAL=21.431-0.143 ln SW	0.427
		AW x SL	lnAW= 1.170+0.459 ln SL	0.783**
		AWxW	lnAW=20.99-0.191 ln SW	0.532
	Cantharus tranquebaricus (n=16)	Sh.L x SL	ln Sh.L= 6.96+0.081 lnSL	0.538*
		Sh.L x SW	ln Sh.L= 8.94+0.151 lnSW	0.671**
		Sh.W x SL	ln Sh.W= 7.44+ 0.098 lnSL	0.497*
		Sh.W x SW	ln Sh.W= 9.35+0.20 ln SW	0.678**
		AL x SL	lnAL= 7.190+0.117 ln SL	0.585**
		AL x SW	lnAL=9.72+0.206 ln SW	0.687**
		AW x SL	lnAW= 8.127+0.145 ln SL	0.401
		AWxSW	lnAW=11.06+0.275 ln SW	0.509*
	Babylonia zeylanica (n=15)	Sh.L x SL	ln Sh.L= 1.05+0.18 lnSL	0.780**
		Sh.L x SW	ln Sh.L= 7.38+0.17 lnSW	0.504*
		Sh.W x SL	ln Sh.W= -1.37+0.37 lnSL	0.830**
		Sh.W x SW	ln Sh.W= 0.56+0.50 ln SW	0.766**
		AL x SL	lnAL= 1.40+0.31ln SL	0.730**
		AL x SW	lnAL=9.84+0.21 ln SW	0.336
		AW x SL	lnAW= 0.66+0.49 ln SL	0.734**
		AWxSW	lnAW=8.52+0.37 ln SW	0.384
	Bursa crumenacrumena (n=14)	Sh.L x SL	ln Sh.L= 5.85+0.09 lnSL	0.508*
		Sh.L x SW	ln Sh.L= 9.15+0.13 lnSW	0.543*
		Sh.W x SL	ln Sh.W= 4.95+0.15 lnSL	0.640**
		Sh.W x SW	ln Sh.W= 9.03+0.18 ln SW	0.578*
		AL x SL	lnAL= 6.42+0.12 ln SL	0.578*
		AL x SW	lnAL=10.23+0.17 ln SW	0.587*
		AW x SL	lnAW= 7.19+0.17 ln SL	0.575*
		AWxSW	lnAW=10.90+0.25 ln SW	0.630**
	Murex ternispina (n=11)	Sh.L x SL	ln Sh.L= 0.761+0.16 lnSL	0.880**
		Sh.L x SW	ln Sh.L= 3.027+0.19lnSW	0.988**
		Sh.W x SL	ln Sh.W= 4.94+0.21 lnSL	0.873**
		Sh.W x SW	ln Sh.W= 8.524+0.22 ln SW	0.886**
		AL x SL	lnAL= 2.56+0.21ln SL	0.826**
		AL x SW	lnAL=5.84+0.22 ln SW	0.860**
		AW x SL	lnAW= 5.04+0.34 ln SL	0.774**
		AWxSW	lnAW=8.14+0.37 ln SW	0.841**

Hermit crab species	Shell species	Relation	Linear equation	r value
Diogenes dubius	*Bursa crumenacrumena* (n=15)	Sh.L x SL	ln Sh.L= 6.74+0.07 lnSL	0.441
		Sh.L x SW	ln Sh.L= 7.18+0.13 lnSW	0.844**
		Sh.W x SL	ln Sh.W= 4.85+0.14 lnSL	0.545*
		Sh.W x SW	ln Sh.W= 4.81+0.23 ln SW	0.797 **
		AL x SL	lnAL= 6.43+0.11 ln SL	0.418
		AL x SW	lnAL=6.37+0.23 ln SW	0.714**
		AW x SL	lnAW= 8.86+0.05 ln SL	0.154
		AWxSW	lnAW=9.11+0.19 ln SW	0.456
	Babylonia spirata (n=15)	Sh.L x SL	ln Sh.L= -10.13+3E-15lnSL	0
		Sh.L x SW	ln Sh.L= 18.25-0.07 lnSW	0.146
		Sh.W x SL	ln Sh.W= 6.04+0.129 lnSL	0.600*
		Sh.W x SW	ln Sh.W= 9.81+ 0.16 ln SW	0.350
		AL x SL	lnAL= 10.04+0.002ln SL	0.017
		AL x SW	lnAL=16.90- 0.05 ln SW	0.141
		AW x SL	lnAW= 8.95+0.06 ln SL	0.311
		AWxSW	lnAW=15.15-0.004 ln SW	0.009
	Babylonia zeylanica (n=15)	Sh.L x SL	ln Sh.L= 8.77+0.06 lnSL	0.290
		Sh.L x SW	ln Sh.L= 4.15+0.23 lnSW	0.581*
		Sh.W x SL	ln Sh.W= 12.22-0.01 lnSL	0.031
		Sh.W x SW	ln Sh.W= 4.23+0.39 ln SW	0.560*
		AL x SL	lnAL= 11.87+0.02 ln SL	0.051
		AL x SW	lnAL=7.11+0.28 ln SW	0.340
		AW x SL	lnAW= 16.27-0.23 ln SL	0.500*
		AWxSW	lnAW=21.32-0.30ln SW	0.321
Diogenes miles	*Oliva gibbosa* (n=30)	Sh.L x SL	ln Sh.L= 9.131– 0.001lnSL	0.006
		Sh.L x SW	ln Sh.L= 7.707+0.264 lnSW	0.682**
		Sh.W x SL	ln Sh.W= 11.03-0.088 lnSL	0.224
		Sh.W x SW	ln Sh.W= 8.99+0.441 ln SW	0.725**
		AL x SL	lnAL= 9.4299-0.0116 ln SL	0.036
		AL x SW	lnAL=10.296+0.267 ln SW	0.541**
		AW x SL	lnAW= 10.077-0.086 ln SL	0.229
		AW x SW	lnAW=16.789+0.172 ln SW	0.295
Clibanarius longitarsus	*Telescopium telescopium* (n=15)	Sh.L x SL	ln Sh.L= 4.32+0.066 lnSL	0.602**
		Sh.L x SW	ln Sh.L= 4.71+0.10 lnSW	0.641**
		Sh.W x SL	ln Sh.W= 3.52+0.13 lnSL	0.812**
		Sh.W x SW	ln Sh.W= 3.73+0.20 ln SW	0.832**
		AL x SL	lnAL= 7.44+0.05 ln SL	0.603**
		AL x SW	lnAL=9.84+0.08 ln SW	0.640**
		AW x SL	lnAW= 6.15+0.14 ln SL	0.422
		AWxSW	lnAW=7.89+0.23 ln SW	0.442

Hermit crab species	Shell species	Relation	Linear equation	r value
Ciliopaguruskrempfi	*Conus inscriptus* (n=17)	Sh.L x SL	ln Sh.L= -7.08+0.25 lnSL	0.79**
		Sh.L x SW	ln Sh.L= -0.34+0.30 lnSW	0.40
		Sh.W x SL	ln Sh.W= 3.07+0.12 lnSL	0.28
		Sh.W x SW	ln Sh.W= 6.57+0.32 ln SW	0.31
		AL x SL	lnAL= -8.99+0.34 ln SL	0.58**
		AL x SW	lnAL= -0.33+0.35 ln SW	0.25
		AW x SL	lnAW= -1.55+0.91 ln SL	0.60**
		AWxSW	lnAW=3.92+1.33ln SW	0.37
Ciliopagurusgrandis	*Conus inscriptus* (n=15)	Sh.L x SL	ln Sh.L= -5.41+0.35 lnSL	0.864**
		Sh.L x SW	ln Sh.L= 16.82+0.26 lnSW	0.490*
		Sh.W x SL	ln Sh.W= -1.47+0.54 lnSL	0.732**
		Sh.W x SW	ln Sh.W= 21.15+0.35 ln SW	0.364
		AL x SL	lnAL= -4.39+0.40 ln SL	0.844**
		AL x SW	lnAL=17.63+0.29 ln SW	0.498*
		AW x SL	lnAW= 6.72+0.79 ln SL	0.280
		AWxSW	lnAW=23.92+0.78 ln SW	0.216

(**= significant correlation, P<0.01; *= significant correlation, P<0.05)

Fig. 1. Map showing the study sites along the Kerala coast.

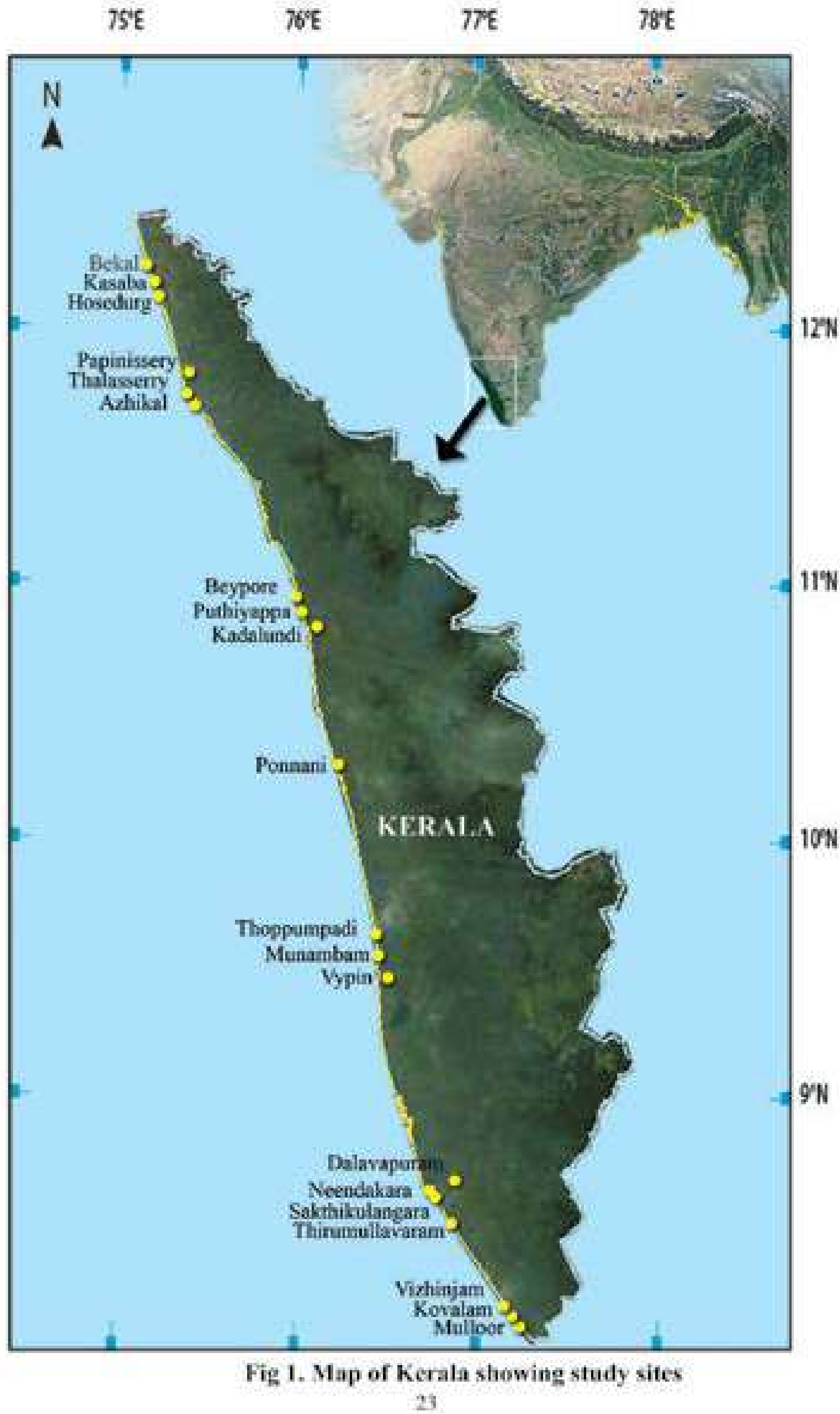

Fig.2. Diagrammatic representation of hermit crab and shell showing key measurements. Modified after Sardar *et al.* (2019).

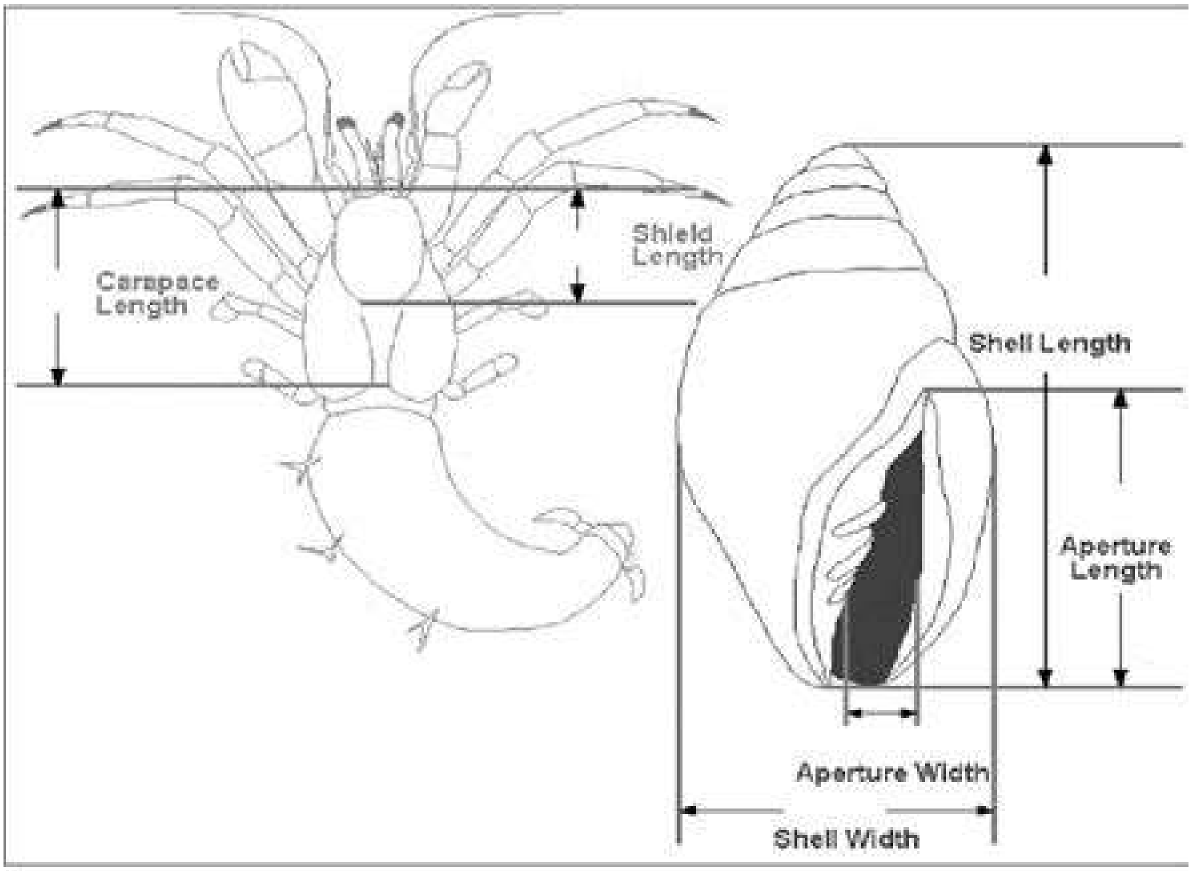

Fig.3. Number of shells selected by each species of the family Diogenidae.

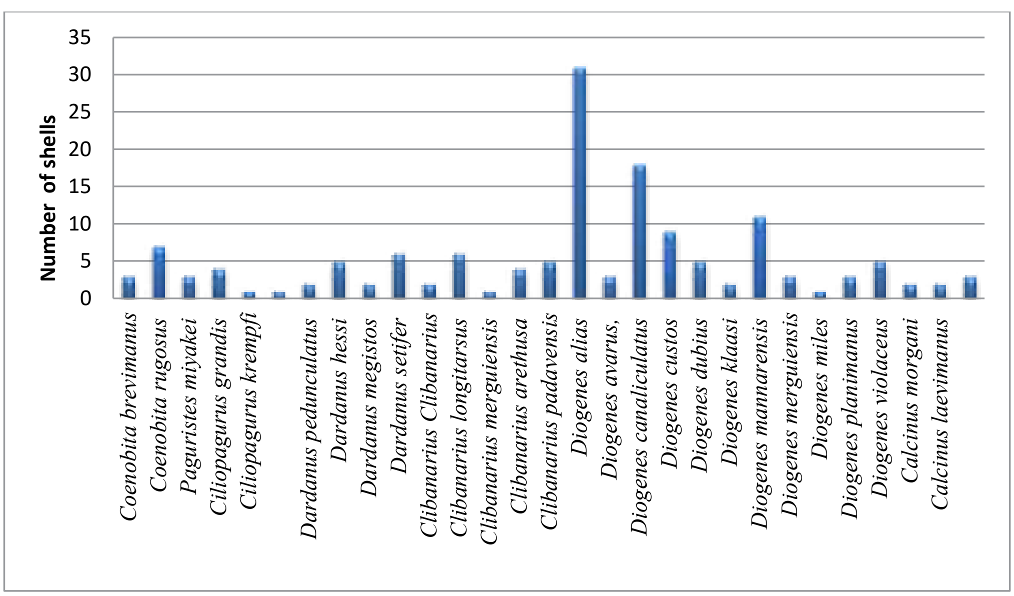

Fig. 4. Some species of hermit crabs with their shells.

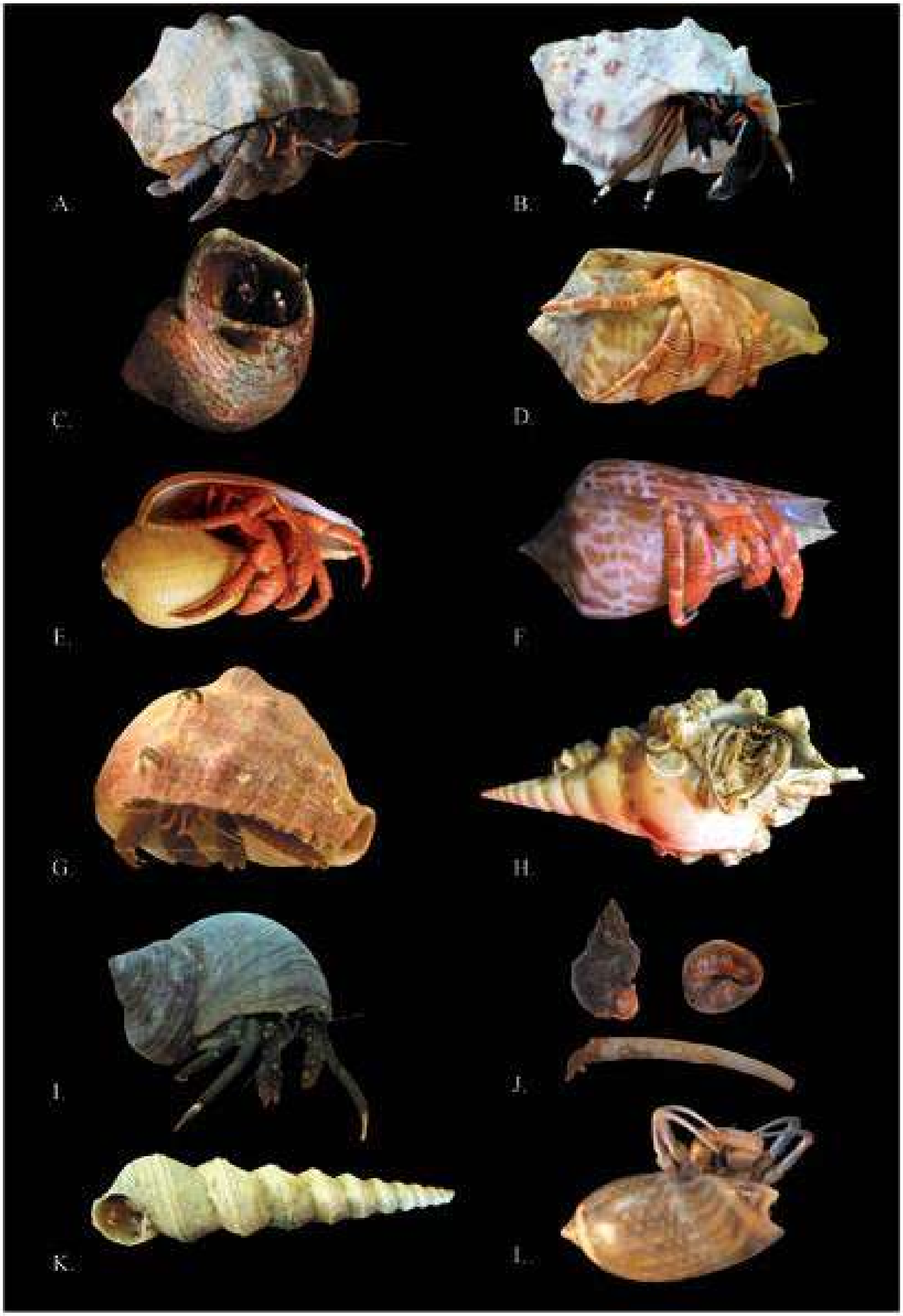

Fig.A. *Coenobita rugosus;* Fig.B. *Calcinus laevimanus*; Fig.C. *Calcinus morgani*; Fig.D. *Ciliopagurus liui*; Fig.E. *Ciliopagurus grandis*; Fig.F. *Ciliopagurus krempfi*; Fig.G. *Clibanarius arethusa*; Fig.H. *Clibanarius longitarsus*; Fig.I. *Clibanarius merguiensis*; Fig.J. *Diogenes cannaliculatus*; Fig.K. *Diogenes custos*; Fig.L. *Diogenes miles*; Fig.M. *Diogenes alias*; Fig.N. *Diogenes planimanus*; Fig.O. *Diogenes violaceus*; Fig.P. *Dardanus pedunculatus*; Fig.Q. *Dardanus hessi*; Fig.R. *Dardanus megistos*; Fig.S. *Dardanus setifer*; Fig.T. *Nematopagurus squamichelis*; Fig.U. *Oncopagurus monstrosus*; Fig.V. *Phylopaguropsis magnimanus*; Fig.W. *Paguristes miyakei*; Fig.X. *Pagurus spinossor*; Fig.Y. *Pagurus kulkarnii.*

Acknowledgement

The authors thank the Head of the Department of Aquatic Biology and Fisheries, University of Kerala for the facilities and encouragement throughout the study.

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