

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/236204953>

Natural History of Zebrafish (*Danio rerio*) in India

Article in *Zebrafish* · March 2013

DOI: 10.1089/zeb.2012.0803 · Source: PubMed

CITATIONS

104

READS

4,553

5 authors, including:



[Muthukumarasamy Arunachalam](#)

Central University of Kerala

133 PUBLICATIONS 2,519 CITATIONS

[SEE PROFILE](#)



[M. Raja](#)

Periyar University

34 PUBLICATIONS 582 CITATIONS

[SEE PROFILE](#)



[Richard Mayden](#)

Saint Louis University

300 PUBLICATIONS 9,798 CITATIONS

[SEE PROFILE](#)

Natural History of Zebrafish (*Danio rerio*) in India

Muthukumarasamy Arunachalam,¹ Manickam Raja,¹ Chinnian Vijayakumar,²
Punniyam Malaïammal,¹ and Richard L. Mayden³

Abstract

The Zebrafish, *Danio rerio*, is a well-known vertebrate model species widely used in research associated with biomedical areas and comparative and evolutionary biology. Interestingly, despite the importance of this species, little is known about the natural history, habitats, and native distribution. In our study of the species, we collected individuals from twenty-one wild populations from within the species' natural distribution, ranging from streams/rivers of the Western Ghats of Peninsular India to those of the Western and North-Eastern Himalayas. Habitat types are identified from various geographic locations. *Danio rerio* is largely confined to and most frequently associated with habitats of low flow and with a sandy substrate in secondary and tertiary channels connected with the main channel of a stream/river, or habitats adjacent to wetlands and paddy fields. These connections can be natural channels or man-made irrigation canals, beels, or culture ponds. Among the 21 populations, individuals from two populations (one from Orissa and another from Arunachal Pradesh) were much larger in size (total length) when compared to other populations. The general habitats of *Danio rerio* vary from small to large mountainous and lowland streams/rivers, wetlands, and paddy fields.

Introduction

DANIO RERIO, A VERTEBRATE MODEL species, commonly referred to as Zebrafish or zebra *danio*, has gained great importance in the fields of developmental genetics, functional genomics, aquatic toxicology, neuroscience, and many other areas of biomedical research. More recently this species and data from the ZFIN web resources (<http://zfin.org/>) have been used as a critical linkage to evolutionary morphological studies and systematics via linking morphological divergence in wild-types (varied species in the wild) with mutant phenotypes of the Zebrafish where the genetic mutations of specific genes¹ are known. These varied types of investigations are, in many cases, used with direct application to evolution and human health.^{2,3} Over the past 15–20 years, this experimental animal has been used worldwide.⁴ Though growth of research related to organismal biology and particularly this model species has been immense, its natural geographical distribution, the physical habitats where it lives, diet, and reproductive patterns in the wild habitats are largely unknown. Only meager information is available on its general natural history except for two publications.^{5,6} One of these involves habitats of the species from Bangladesh and the other includes observations from a few states in India. Herein, we address the habitat types of *Danio rerio* in various streams/

rivers, secondary channels, oxbow lakes, and ponds, and irrigation canals connected to paddy fields from the Indian states of Kerala, Karnataka, Orissa, Uttar Pradesh, Meghalaya, Assam, and Arunachal Pradesh.

Taxonomy and Phylogeography

Danio rerio was originally described by Hamilton in 1822⁷ from the Kosi River, Bengal. Day (1878)⁸ also recorded this species from Bengal to the Coromandal coast. Menon (1963)⁹ documented the distribution of the species from the Brahmaputra, Gandak, Rapti, Karnal, Kali, Ramganga, Ganges, Yamuna, and Indus river drainages. Hora^{10,11} recorded its distribution from Nadhave and Kalauma rivers in Kumaon Himalayas and also from Rajmahal. Chauhan and Ramakrishna (1954)¹² reported the species from the Balangi district, Orissa and Tilak (1968)¹³ reported this species from Sikkim. Recently, two distributional records¹⁴ have been observed in the Western Ghats, one from the Thunga River in Karnataka and another from the Kabini River, Wynad district of Kerala. These populations were used in a study of population genomics.¹⁵ Thus, based on a broad literature review, our current understanding of the distribution of this globally important species, *Danio rerio*, in the wild, includes rivers, small streams, channels, and paddy fields^{16–18} from Myanmar, Pakistan, India, Bangladesh, and Nepal.

¹Sri Paramakalyani Centre for Environmental Sciences, Manonmaniam Sundaranar University, Tamil Nadu, India.

²Department of Zoology, St. Andrews College, Gorakhpur, Uttar Pradesh, India.

³Department of Biology, Saint Louis University, St. Louis, Missouri.

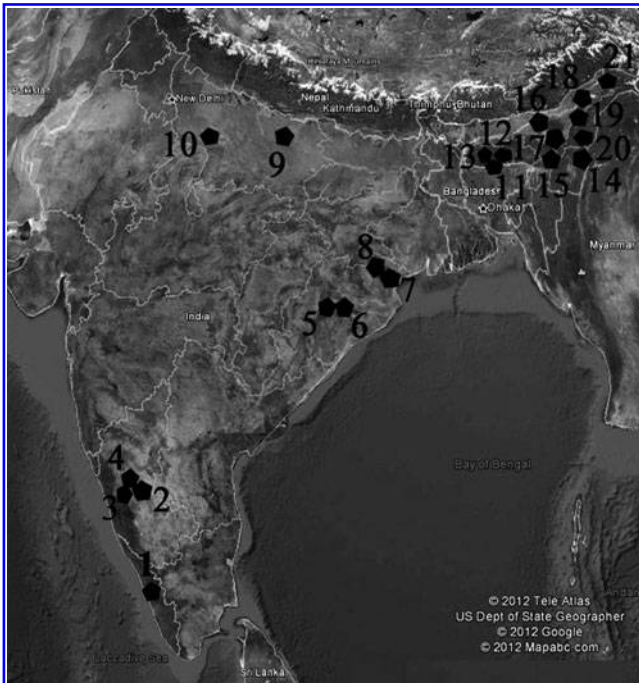


FIG. 1. Localities in India where *Danio rerio* species were collected.

Danio is reported to be paraphyletic with respect to *Esomus*, *Chela*, and *Inlecypris*.¹⁹ In this study, one clade consisted of *Danio rerio*, *D. dangila*, *D. nigrofasciatus*, *D. albolineatus*, and *D. kerni*, while the other clade with the resurrected genus name *Devario* included *D. devario* and *D. regina*. However, a recent study²⁰ revealed that the genus *Danio* is a monophyletic group and *D. rerio* is sister to *D. kyathi* and that comparisons of *Danio* species with species of *Devario* and/or *Esomus*/*Microsborra* have often been simply misleading.

We collected wild populations (Fig. 1) across a range of geographical locations with various elevational ranges from the states of Kerala and Karnataka of Western Ghat mountain ranges and one of the hotspots of biodiversity, and from north and northeastern states of Orissa, Uttar Pradesh, Meghalaya, Assam and Arunachal Pradesh of India (Figs. 2 and 3). Habitats of the wild populations were studied randomly as a part of the detailed inventory in rivers of India and ongoing ichthyological surveys of various ecoregions of the country.

Methods

Habitat inventory/observations in streams and rivers are based on channel gradient, stream depth, stream width, riparian cover, and bank stability are the microhabitat features.^{21,22} Stream habitat features were estimated in a 100 m thalweg length (the longitudinal path following the fastest cross sectional water velocities) and included pools, riffles, cascades, alcoves, and backwaters.^{21,22} Riparian cover was measured using a spherical densiometer, and riparian vegetation was estimated with a clinometer and was determined by averaging three repeated measurements. Instream fish cover was boulder edge, canopy (overstory, midstory, understory), root, and undercut banks.²³ Water velocity was measured us-

ing electronic flow meter (propeller type). We used seines, rectangular hand nets, cast nets, and gill nets based on the habitat conditions. Local fisherman was also engaged for fishing in larger bodies. The habitats of *Danio rerio* could be well easily identified and quantified throughout the country.

Morphometric measurements were taken with digital calipers to a precision of 0.1 mm. Counts, measurements, and color pattern terminology are according to Fang.²⁴ The following abbreviations are used herein: SL=standard length and HL=head length. Body measurements are expressed as percentage of standard length (%SL) and head measurements as percentage of head length (%HL). Gut contents were taken from two individuals where the relative biovolumes of algae, detritus, higher plant matter, and animal matter were determined.²⁵ Gut content analysis was carried out for all the *Danio rerio* populations throughout its range of present study.

Results

Feeding habits

Gut contents of *Danio rerio* in all populations showed allochthonous materials, mostly red ants, in the Western Ghat streams and also the habitats where there was much overhanging vegetation such as in Budapalang River, Simla village, Orissa; Mathumathi River, Sonauli, Uttar Pradesh; Rani village, Siang, Arunachal Pradesh; Thore, Siang, Arunachal Pradesh. In the rest of the habitats, the gut contents were of terrestrial arthropods and to a lesser extent aquatic insects.

Habitat types

Thirunelli, Wynaad, Kerala. This area is a second order, low-gradient and forested stream inside the Wynaad Wildlife Sanctuary (Table 1 and Fig. 4a). *Danio rerio* was found below overhanging vegetation over a substrate type of pebbles and sand. Both banks were stable despite the stream being a low gradient one; the left bank (looking upstream) was covered by understory vegetation with dense riparian cover. *Devario aequipinnatus* was found in high velocity habitats. *Danio rerio* was confined to shallow habitat areas (water depth range 10–35 cm) of the stream with low flow, ranging 9–9.7 cm/s. Other species recorded from this location included: *Esomus danricus*, *Chela fasciatus*, *Devario aequipinnatus*, *Barilius gatensis*, *Rasbora daniconius*, *Salmophasia boopis*, *Puntius conchoniensis*, *P. carnaticus*, *P. bimaculatus*, *P. fasciatus*, *Garra mullya*, *Aplocheilichthys lineatus*, and *Xenentodon cancila*.

Thunga River at Sringeri, Karnataka. The river stretch in this area where we found *Danio rerio* was in the Thunga River at Sringeri, Karnataka. The habitat in this area where *Danio rerio* was collected was mostly a stream run (Table 1 and Fig. 4b). Species was also found in secondary channels where the substrate type was mostly cobble and sand. The river meandered to the left bank (looking upstream) during the sampling period (dry season of the year) with a flow range of 6.3–6.8 cm/s and the water depth range is 10–32 cm. The waterway is a relatively larger river (width 98 m) with stable banks with good riparian vegetation. In some areas, undercut banks and overhanging vegetation were noted. Other species recorded from this area were: *Esomus danricus*, *Chela fasciatus*,

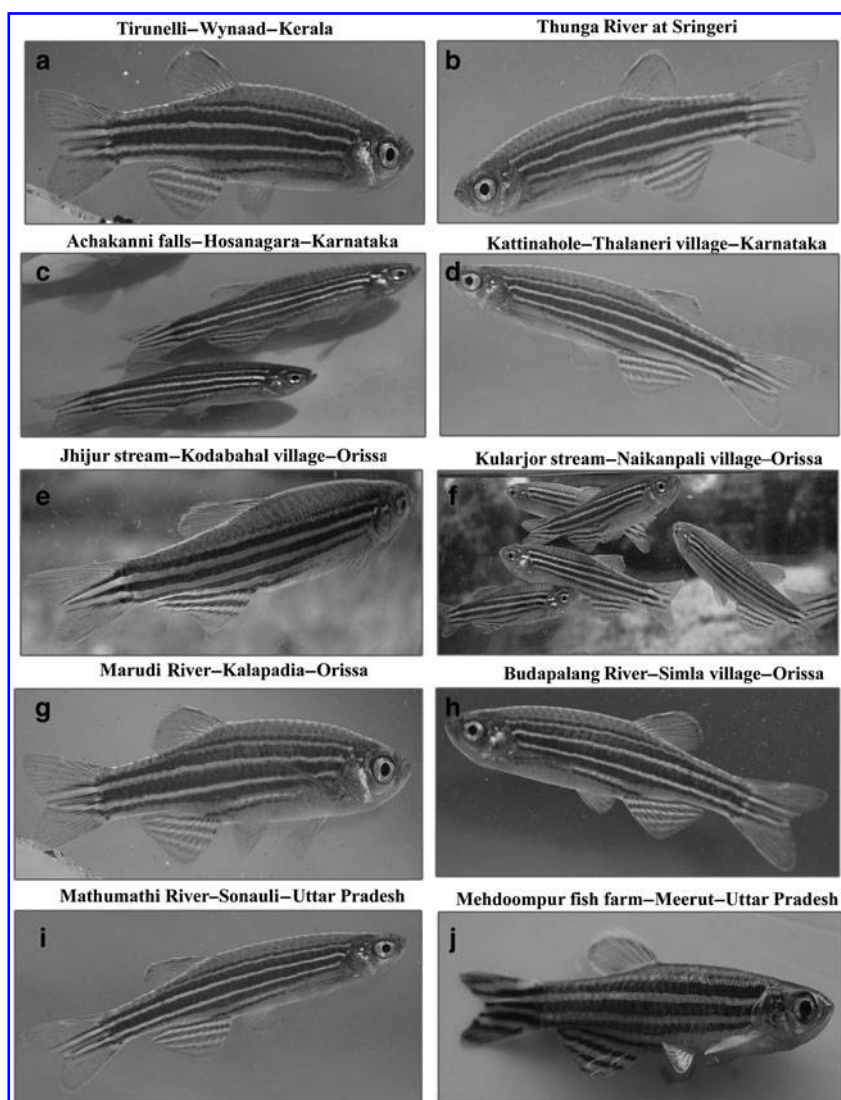


FIG. 2. *Danio rerio* in the wild. (a) Tirunelli-Wynaad-Kerala; (b) Thunga River at Sringeri; (c) Achakanni Falls-Hosanagara-Karnataka; (d) Kattinahole-Thalaneri village-Karnataka; (e) Jhijur stream-Kodabahal village-Orissa; (f) Kularjor stream-Naikanpali village-Orissa; (g) Marudi River-Kalapadia-Orissa; (h) Budapalang River-Simla village-Orissa; (i) Mathumathi River-Sonauli-Uttar Pradesh; (j) Mehdoompur fish farm-Meerut-Uttar Pradesh.

Devario aequipinnatus, *Barilius gatensis*, *Rasbora daniconius*, *Salmophasia boopis*, *Puntius conchoni*, *P. carnaticus*, *P. bimaculatus*, *P. fasciatus*, *Hypseleobarbus jerdoni*, *Osteochilichthys nashi*, *Tor khudree*, *Psilorhynchus tenura*, *Garra mullya*, *Aplocheilichthys lineatus*, and *Xenentodon cancila*.

Achakanni stream and falls, Hosanagara, Karnataka. In this area *Danio rerio* was located below a small waterfall of the Achakanni falls which is located in a 2 km diversion from Hosanagara village along the Thirthahalli main road. This water way is a tributary of Sharawati River in the mountain ranges of the Western Ghats, South India (Table 1 and Fig. 4c). The stream was clear and had dense forest canopy. The substrate type was bedrock and boulders, and a small proportion of sand. *Danio rerio* habitats were backwater areas created by bedrock and the alcoves created by large boulders. The species occurred in a large pool largely surrounded by bedrock with a flow range of 5.2–5.8 cm/s and water depth range of 0.1–1.1 m.

Water in this stream was clear and suitable for snorkeling. While walking along the edges of a pool, *Danio rerio* was commonly found along the sandy areas of alcoves and backwater habitats. Other species collected in the study area included *Devario aequipinnatus*, *Rasbora daniconius*, *Puntius conchoni*, *P. sarana*, *Acanthocobitis botia*, and *Xenentodon cancila*.

Kattinahole stream, Thalaneri village, Karnataka. This waterway is a third-order stream with thick canopy cover (Table 1 and Fig. 4d, e). Banks were stable and the substrates were cobbles and sand. *Danio rerio* was confined to a secondary channel formed by a sand dune and the exact microhabitat was below the overhanging vegetation of the secondary channel. Instream vegetation providing canopy was common in the secondary channel. Leaf litter was 40%–50% in the main channel, and 20%–30% along the side channel in a 100 m reach. *Danio rerio* was collected from the above habitats with a flow range of 5.5–6.2 cm/s and the water depth range of 30–45 cm. Farming

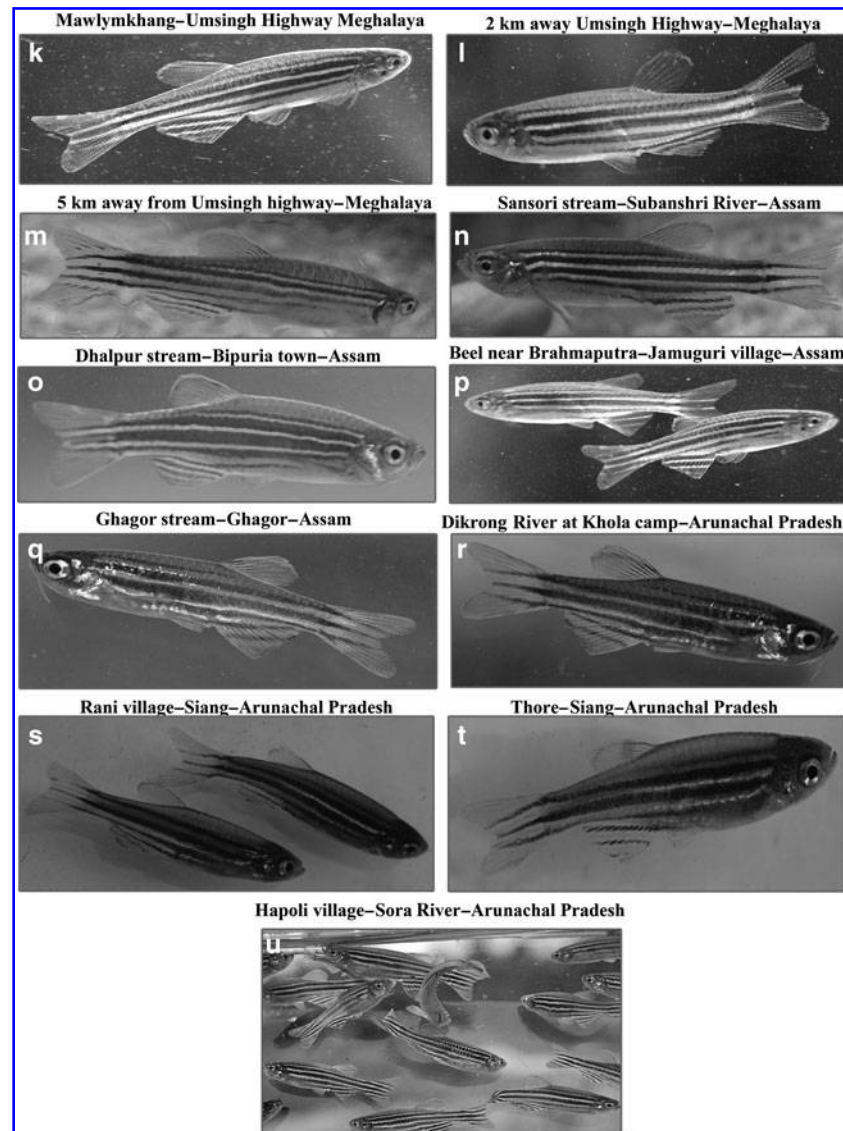


FIG. 3. *Danio rerio* in the wild. (k) Mawlymkhang–Umsingh Highway–Meghalaya; (l) 2 km away from Umsingh Highway–Meghalaya; (m) 5 km away from Umsingh Highway–Meghalaya; (n) Sansori stream–Subanshri River–Assam; (o) Dhalpur stream–Bipuria town–Assam; (p) Beel near Brahmaputra–Jamuguri village–Assam; (q) Ghagor stream–Ghagor–Assam; (r) Dikrong River at Khola camp–Arunachal Pradesh; (s) Rani village–Siang–Arunachal Pradesh; (t) Thore–Siang–Arunachal Pradesh; (u) Hapoli village–Sora River–Arunachal Pradesh.

activities were common beyond the riparian zone. Other species in the study area included *Devario aequipinnatus*, *Rasbora dani-conius*, *Puntius conchoni*, *P. sarana*, *Salmophasia boopis*, *Hypse-lobarbus kolus*, *Acanthocobitis botia*, *Xenentodon cancila*, *Aplocheilus lineatus*, *Anabas testudineus*, and *Chanda nama*.

Jhijur stream, Kodabahal village, Orissa. *Danio rerio* was found in the main channel of this fourth-order waterway (Table 1 and Fig. 4f, g). Substrate types were mostly sandy; water flow was low. The population occurred below overhanging vegetation. Both banks were stable with midstory and overstory vegetation. An additional population was found along the secondary channel of the main stream with a flow range of 6.1–6.8 cm/s and water depth of 15–35 cm; the substratum was sandy. The floodplain in this area is vast and the river meanders along the left bank (looking upstream). Other species in the study area included *Devario aequipinnatus*,

D. devario, *Salmophasia bacaila*, *Osteobrama cotio peninsularis*, *Puntius ticto*, *P. conchoni*, *Cirrihinus reba*, *Tor mosal mahana-dicus*, *Parambasis ranga*, *Acanthocobitis botia*, *Lepidocephalichthys guntea*, *Myxus cavasius*, *Macrogynathus aral*, *Mastacembelus ar-matus*, *Ompok bimaculatus*, *Glossogobius giuris*, *Gudusia chapra*, *Nandus nandus*, *Channa stewartii*, and *Xenentodon cancila*.

Kularjor stream, Naikanpali village, Orissa. Kularjor is a lowland, third-order stream with cobbles and sand as the dominant types of substrates (Table 1 and Fig. 4h). Major cover for the fish was midstory canopy and *Eichhornia cras-sipes* was the major weed along banks. Bathing, and washing of clothes and utensils, and washing of buffaloes and cows from the nearby village were the common activities in the stream. *Danio rerio* was found in the areas with low gradient and with riffle habitats characterized by a cobble substrate with a flow range of 6.2–6.5 cm/s. *Danio rerio* population also

TABLE 1. FOOD AND HABITAT FEATURES OF *DANIO RERIO* IN STREAMS/RIVERS, INDIA

No	Name	GPS coordinates	Elevation (m)	Temp. °C	pH	Nature of water	Substrate types	Gut contents (In percent ^a)	Date and time
1	Thirunelli–Wynaad–Kerala	N 11°54'399" E 75°59' 396"	328	26.3	6.7	Clear water, bottom visible	Pebbles, gravels and sand	A = 10; D = 15 HPM = 15; AM = 60	06.27.2009, 2 PM
2	Thunga River at Sringeri–Karnataka	N 13° 55'213" E 75°26'426"	680	25.9	7.1	Clear water, bottom visible	Pebbles, gravels and sand	A = 20; D = 18 HPM = 22; AM = 40	03.26.2012, 3 PM
3	Achakanni falls–Hosanagara–Karnataka	N 13° 48'488" E 75°10'348"	615	16.5	7.9	Clear water, bottom visible	Bedrock, boulders, pebbles, sand	A = 22; D = 20 HPM = 25; AM = 33	05.01.2011, 2.40 PM
4	Kattinahole–Thalaneri village–Karnataka	N 13° 39'557" E 75°12'514"	599	17.2	7.1	Dirty water, bottom visible	Boulders, pebble, gravel, sand	A = 30; D = 15 HPM = 15; AM = 40	05.01.2011, 11.20 PM
5	Jhijur stream–Kadobahal village–Orissa	N 22° 16'538" E 83°33'467"	418	27.2	6.6	Clear water, bottom visible	Gravel, pebbles and sand	A = 15; D = 15 HPM = 30; AM = 40	05.30.2011, 11.20 AM
6	Kularjor stream–Naikanpali village–Orissa	N 21° 55'204" E 83°54'695"	432	26.9	6.4	Clear water, bottom visible	Pebble and sand	A = 20; D = 15 HPM = 15; AM = 50	05.30.2011, 1.40 PM
7	Marudi River–Kalapadia–Orissa	N 22° 05'124" E 86°38'268"	245	26.5	7.2	Turbid water, bottom not visible	Silt	A = 20; D = 10 HPM = 30; AM = 40	08.19.2010, 12.10 PM
8	Budapalang River–Simla village–Orissa	N 22° 07'534" E 86°38'268"	238	25.4	9.8	Turbid water, bottom not visible	Sand	A = 26; D = 14 HPM = 22; AM = 38	08.19.2010, 5.15 PM
9	Mathumathi River–Sonauli–Uttar Pradesh	N 27°46'324" E 83°12'310"	268	28.4	6.4	Bottom visible, clear water	Silt	A = 15; D = 10 HPM = 22; AM = 53	05.06.2010, 11.45 AM
10	Mehdoompur fish farm, Marana Meerut–Uttar Pradesh	N 29° 05'184" E 78°01'511"	656	24.3	7.5	Bottom visible, clear water	Silt	A = 26; D = 14 HPM = 22; AM = 38	05.25.2010, 12.30 PM
11	Mawlymkhang–Umsingh highway–Meghalaya	N 25° 38'634" E 91°53'186"	647	19.5	6.3	Clear water, bottom visible	Sand and silt	A = 14; D = 16 HPM = 32; AM = 38	12.30.2010 12.20 PM
12	2 Km away from Umsingh highway–Meghalaya	N 25° 41'935" E 91°54'144"	675	19.4	6.9	Clear water, bottom visible	Sand and silt	A = 18; D = 24 HPM = 16; AM = 42	12.30.2010, 10 AM
13	5 Km away from Umsingh highway–Meghalaya	N 25° 43'880" E 91°53'423"	710	19.6	7.3	Clear water, bottom visible	Sand and silt	A = 25; D = 15 HPM = 22; AM = 38	12.30.2010, 10 PM
14	Sansori stream–Subanshri River–Subanshri (Dk)–Assam	N 26° 51'204" E 93°48'843"	236	22.4	7	Clear water, bottom visible	Sand and silt	A = 15; D = 20 HPM = 30; AM = 35	11.13.2010, 10 AM
15	Dhalpur stream–Bipuria town–Subanshri (Dk)–Assam	N 27° 24'357" E 94°11'425"	214	21.3	7.2	Clear water, bottom visible	Sand, pebbles and gravels	A = 18; D = 24 HPM = 18; AM = 40	11.14.2010, 1 PM

(continued)

TABLE 1. (CONTINUED)

No	Name	GPS coordinates	Elevation (m)	Temp. °C	pH	Nature of water	Substrate types	Gut contents (In percent ^a)	Date and time
16	Beel near Brahmaputra River, Jamuguri village–Dhalpur–Subanshri (Dk)–Assam	N 27° 00'273" E 94°00'538"	274	22.1	7.3	Muddy water algae formed, bottom not visible	Silt	A = 25; D = 10 HPM = 30; AM = 35	11.12.2010, 4 PM
17	Ghagor stream–Ghagor–Subanshri (Dk)–Assam	N 27° 27'311" E 94°32'454"	342	20.4	7.1	Clear water, bottom visible	Sand and silt	A = 18; D = 16 HPM = 28; AM = 38	11.14.2010, 11.35 AM
18	Dikrong River at Khola camp–Arunachal Pradesh	N 27° 97'222" E 93°45'311"	218	18.5	6.3	Clear water, bottom visible	Bedrock, boulders, pebbles and sand	A = 15; D = 15 HPM = 25; AM = 45	11.10.2010, 5.30 PM
19	Rani village–Siang (Dk) Arunachal Pradesh	N 27° 56'439" E 95°19.5'546"	396	21	7.3	Clear water, bottom visible	Sand	A = 26; D = 14 HPM = 22; AM = 38	11.14.2010, 2.10 PM
20	Thore–Siang (Dk) Arunachal Pradesh	N 27° 58.2'218" E 95°24'722"	341	20.3	6.5	Clear water, bottom visible	Silt, sand and pebbles	A = 18; D = 14 HPM = 30; AM = 38	11.14.2010, 5 PM
21	Sora River–Hapoli village–Siro–Arunachal Pradesh	N 27° 33'914" E 93°50'971"	1576	12.3	6.2	Clear water, bottom visible	Silt and sand	A = 24; D = 16 HPM = 25; AM = 35	06.19.2011, 8 AM

^aA = Algae; D = detritus; HPM = Higher plant materials; AM = Animal matter.

occurred below a midstory vegetation with little undercut to the bank. However, riparian vegetation was disturbed due to recent rain and the depth was in the range of 0.1–0.8 m. Otherwise banks are relatively stable with replacement of big boulders along the bathing ghat. Other species in the study area included *Devario aequipinnatus*, *D. devario*, *Puntius ticto*, *P. conchoniis*, *Salmophasia bacaila*, *Osteobrama cotio peninsularis*, *Parambasis ranga*, *Cirrihinus reba*, *Acanthocobitis botia*, *Lepidocephalichthys guntea*, *Mystus cavasius*, *Channa stewartii*, *Glossogobius giuris*, and *Xenentodon cancila*.

Marudi River, Kalapadia, Orissa. The Marudi River is a second-order lowland stream with a gradient less than 1% (Table 1 and Fig. 5i). The stream is highly degraded with little midstory vegetation and the banks were highly unstable, a condition resulting from its secondary confinement. Two habitats were identified in a 100 m length where *Danio rerio* occurred, a shallow pool and in the inflow and outflow areas of the shallow pool. Substrate type was mostly silt and clay. Leaf litter input through leaves falling into the habitats originating from understory grasses and other riparian vegetation, contributed to 10%–20% leaf litter to the system. There was little flow in the pool other than the areas of inflow and outflow, with a range of 7.2–7.8 cm/s. Water depth was from 0.1–0.5 m in the pool area. In the outflow and inflow areas, water depth ranged from 0.1–0.3 m. As it is a low gradient stream, a small degree of meandering occurred that resulted in secondary channel confinement. Other species in the study area included *Puntius conchoniis*, *Acanthocobitis botia*, *Glossogobius giuris*, and *Xenentodon cancila*.

Budapalang River, Simla village, Orissa. The Budapalang River is a lowland, second-order stream surrounded by paddy fields beyond the riparian zone. Stream banks were stable; as a typical lowland stream it had dense understory, midstory and overstory tree canopy (Table 1 and Fig. 5j). *Danio rerio* was found in the low gradient riffle area followed by a pool. Substrates are mostly silt and fine silt and 10% of the thalweg length included small boulders. *Danio rerio* was confined to riffle areas where the flow was 9.8–10.2 cm/s. In pool areas, water was turbid. Other species collected in the study area included *Devario devario*, *Devario aequipinnatus*, *Puntius conchoniis*, and *Channa stewartii*.

Mathumathi River, Sonauli, Uttar Pradesh. The Mathumathi River is a lowland third-order stream with unstable banks (Table 1 and Fig. 5k, l). The left bank (looking upstream) is more or less stable with sparse overstory vegetation. Beyond the riparian zone, there are plantations. In a 100 m thalweg length, the predominant habitat type was a run with low flow and alcoves (side pools). The active floodplain was sparsely vegetated and most of the sands had been removed. A secondary channel was formed by a sand dune on the left bank (looking upstream). *Danio rerio* was identified to occur in three habitats in this stream. One was a side pool on the right bank and the second was a secondary channel (5 m length) with little flow to the main channel. The third was a shallow pool formed by the sand dune. Substrate type was uniformly sand and silt, typical of a slow run habitat. Water flow ranged from 7.0–7.5 cm/s. The pool with 8 m length, 8 m width, and

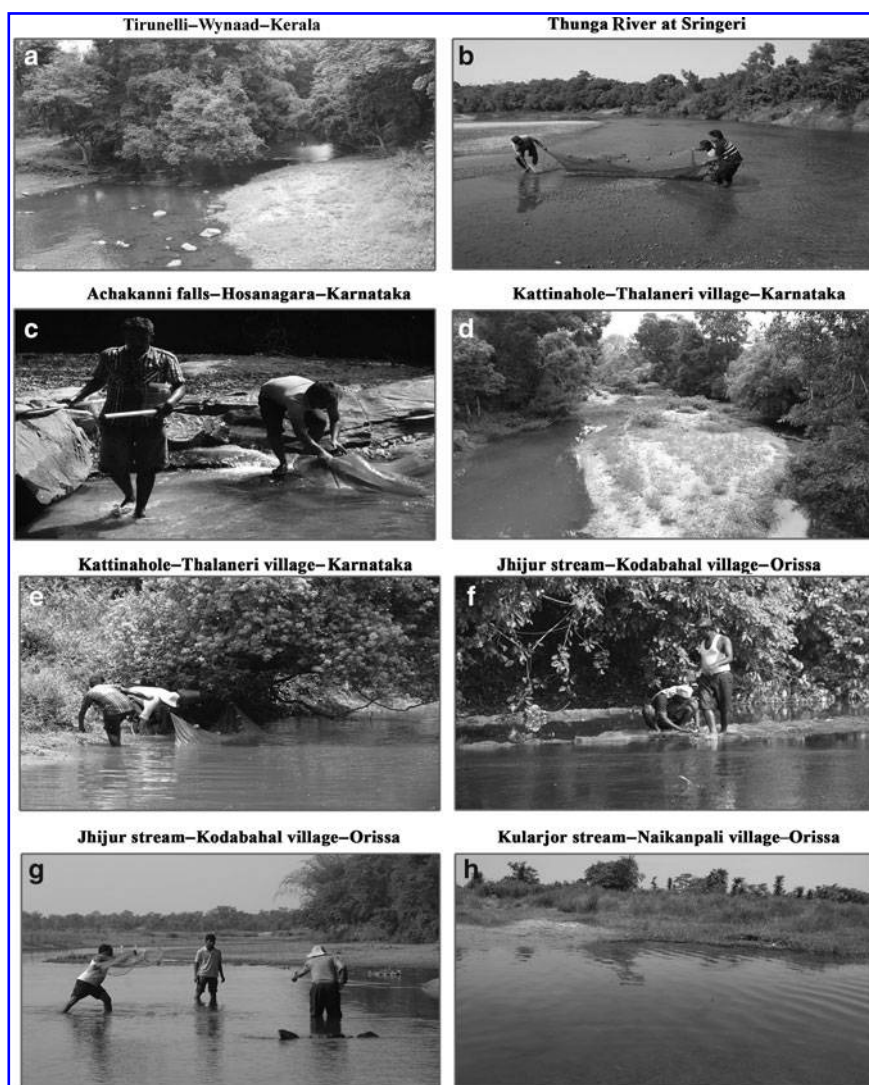


FIG. 4. Study sites of streams/rivers where *Danio rerio* was collected. (a) Tirunelli-Wynaad-Kerala; (b) Thunga River at Sringeri; (c) Achakanni falls-Hosanagara-Karnataka; (d) Kattinahole-Thalaneri village-Karnataka; (e) Kattinahole-Thalaneri village-Karnataka; (f) Jhijur stream-Kodabahal village-Orissa; (g) Jhijur stream-Kodabahal village-Orissa; (h) Kularjor stream-Naikanpali village-Orissa.

0.3 m depth was identified in the secondary channel. Other species occurring in all the habitats in the study area included *Puntius sophore*, *Puntius conchoni*, *Barilius bendelisis*, *Devario devario*, *Aspidoparia jaya*, *Salmophasia bacaila*, *Acanthocobitis botia*, *Botia almorae*, *Lepidocephalichthys guntea*, *Schistura* sp., *Colisa fasciatus*, and *Xenentodon cancila*.

Mehdooampur fish farm, Marana, Meerut, Uttar Pradesh. Preference of this population of *Danio rerio* in this area was the flowing water habitat (Table 1 and Fig. 5m). We collected *Danio rerio* from a private fish farm receiving water from the adjacent irrigation canal system of Yamuna River. The occurrence of *Danio rerio* was noted only from inflow and outflow regions of the fish pond that is used to culture carps such as *Gibelion catla* and *Labeo rohita*. Inflow and outflow regions were characterized by sand and silt substrates and the flow ranged from of 11–11.8 cm/s. *Danio rerio* was absent in the nearby canal system where we found only two species, *Puntius conchoni* and *Colisa fasciatus*.

Mawlymkhang, Umsingh Highway, Meghalaya. This is a lowland first-order stream surrounded by midstory and understory vegetation (Table 1 and Fig. 5n). Banks were relatively stable and the water velocity was uniform, exhibiting a water sheath representing a typical run habitat. Here, the mean stream width ranged from 0.6–1.2 m. Substrate types were fine sand and clay. *Danio rerio* occurred along the shadowed area of the stream with little undercut bank habitat. The study site is located in between the plains below the hills where paddy fields were used for cultivation. Water velocity was 4–4.5 cm/s. Other species occurring in all the habitats in the study area included *Devario aequipinnatus*, *Lepidocephalichthys guntea*, *Macrognaathus aral*, *Channa stewartii*, and *Xenentodon cancila*.

Two km from Umsingh Highway, Meghalaya. This waterway is a lowland stream with little or no tree canopy on the left bank (looking upstream). (Table 1 and Fig. 5o) Right bank (looking upstream) was characterized by understory vegetation. Beyond the riparian zone, agriculture activities

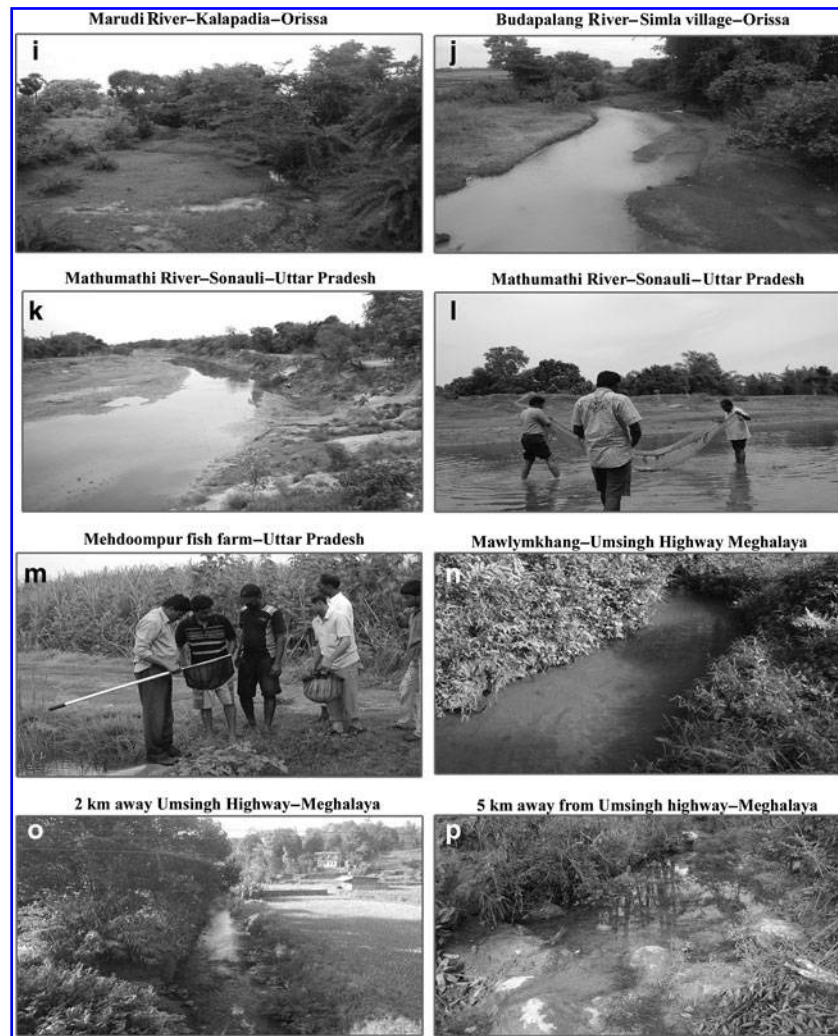


FIG. 5. Study sites of streams/ivers where *Danio rerio* was collected. (i) Marudi River–Kalapadia–Orissa; (j) Budapalang River–Simla village–Orissa; (k) Mathumathi River–Sonauli–Uttar Pradesh; (l) Mathumathi River–Sonauli–Uttar Pradesh; (m) Mehdoompur fish farm–Uttar Pradesh; (n) Mawlymkhang–Umsingh Highway–Meghalaya; (o) 2 km away from Umsingh Highway–Meghalaya; (p) 5 km away from Umsingh Highway–Meghalaya.

were common and the major crop was rice/paddy. Bank erosion was mainly due to the loss of vegetation on both stream banks. On the right side the channel was modified to a secondary confinement. Stream width was only 3.6 m and substrate type was mostly fine sand and gravel. Almost all of the habitats in this stream reach can be designated as slow to fast runs (flow range 3.5–4.8 cm/s). *Danio rerio* was found below the undercut banks on the left side with vegetation cover. Other species occurring in all the habitats in the study area included *Devario aequipinnatus*, *Lepidocephalichthys guntea*, *Channa Stewartii*, *Macrognathus aral*, and *Xenentodon cancila*.

Five km from Umsingh Highway, Meghalaya. This waterway is a typical first-order stream with unstable banks (Table 1 and Fig. 5p). Water flow was in the range of 3.8–4.6 cm/s and the depth range was 10–15 cm. Substrate was bedrock, boulders, and fine sand with disturbed riparian vegetation. From the road, the stream is not visible because of the vegetation all along the small pool with the major substrate being bedrock. Other species occurring in all the habitats in the

study area included *Devario aequipinnatus*, *Lepidocephalichthys guntea*, and *Channa Stewartii*.

Sansori stream, Subanshri River, Assam. This waterway is a larger river system, and a major tributary of Brahmaputra River basin. Width of the river was more than 2 km (Table 1 and Fig. 6q). *Danio rerio* was located in an oxbow pond with little water exchange with a secondary channel. The secondary channel was formed due to sand dunes by the meandering processes. Substrates were almost exclusively sand and silt and flow ranged from 5.1–5.5 cm/s. The oxbow pond was small and 3 m in length and 2.81 m wide, with a single outlet with a width of 40 cm. In the main channel we collected *Rasbora rasbora*, *Barilius bendelisis*, *Devario devario*, *Puntius chola*, *P. conchoniensis*, *Rainas bola*, *Labeo boga*, *L. pangusia*, *Garra nasuta*, *Botia dario*, *Gagata cenia*, *Mastacembelus armatus*, and *Chanda nama*.

Dhalpur stream, Bipuria town, Assam. The Dhalpur stream is a clear-water third-order stream with stable banks

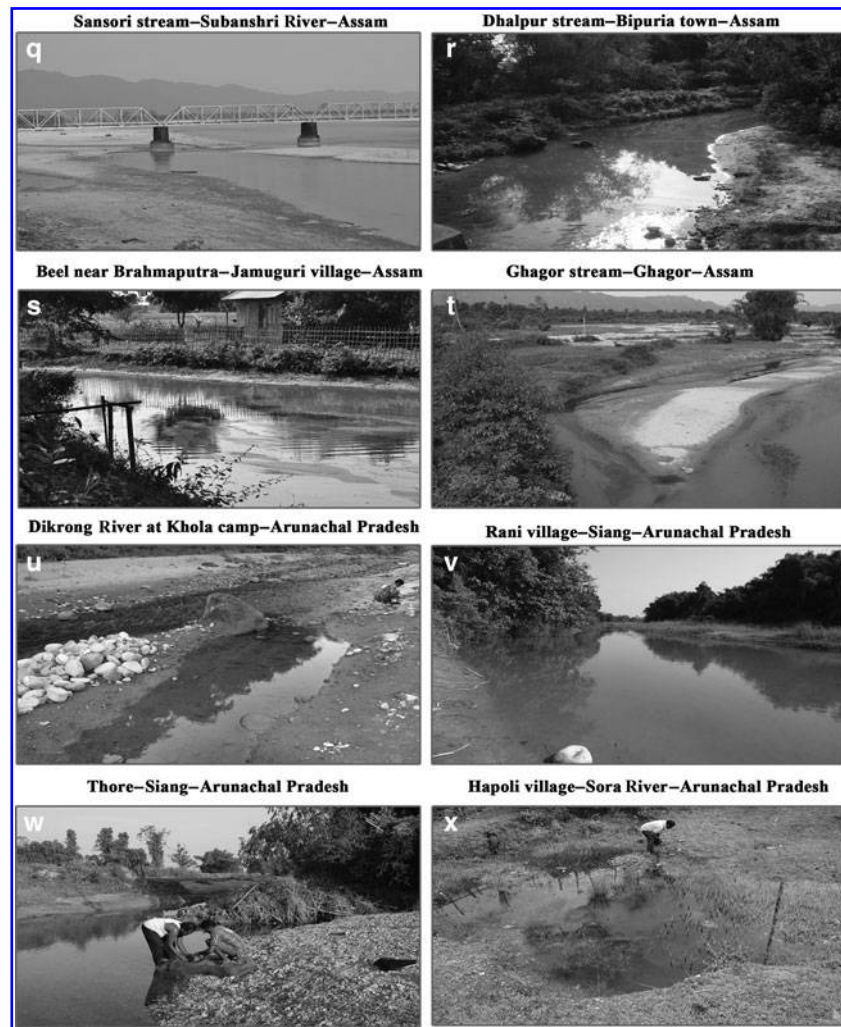


FIG. 6. Study sites of streams/ivers where *Danio rerio* was collected. **(q)** Sansori stream–Subanashri River–Assam; **(r)** Dhalpur stream–Bipuria town–Assam; **(s)** Beel near Brahmaputra–Jamuguri village–Assam; **(t)** Ghagor stream–Ghagor–Assam; **(u)** Dikrong River at Khola camp–Arunachal Pradesh; **(v)** Rani village–Siang–Arunachal Pradesh; **(w)** Thore–Siang–Arunachal Pradesh; **(x)** Hapoli village–Sora River–Arunachal Pradesh.

and mostly midstory canopy cover (Table 1 and Fig. 6r). Substrate types were small boulders and cobbles, along with gravel and sand. *Danio rerio* was found in a shallow pool with little flow (10–13 cm/s). Habitats are mostly run and glide and the mean depth of the 100 m reach was 0.7 m; the width ranged from 1.8 m to 5.2 m. Washing of clothes and bathing by the local people is common. Other species occurring in all the habitats in the study area included *Devario devario*, *Barilius bendelisis*, *Puntius chola*, *P. stoliczkanus*, *Salmophasia bacaila*, *Cirrhinus reba*, *Psilorhynchus balitora*, *Garra nasuta*, *Acanthocobitis botia*, *Lepidocephalichthys irrorata*, *L. guntea*, *Mystus vittatus*, *Mastacembelus alboguttatus*, *Ompak bimaculatus*, *Xenentodon cancila*, and *Channa punctatus*.

Beel near Brahmaputra, Jamuguri village, Dhalpur, Assam. At this location, *Danio rerio* was found in a beel (wetland) in a kitchen pond used for aquaculture (Table 1 and Fig. 6s). Throughout the lowland of the Brahmaputra River basin in Assam, isolated ponds were connected by the floodwaters during the wet seasons and receiving water become stagnant along the floodplain for 5–6 months. These oxbow ponds are

used for culture of native fishes drifted during flooding. *Danio rerio* was confined to the inflow areas where the pond receives water, and juveniles were confined to areas with grasses. Other species occurring in all the habitats in the study area included *Chela khujairokensis*, *Devario devario*, *Puntius chola*, *P. stoliczkanus*, *Chagunius chagunio*, *Lepidocephalichthys annandalei*, *Nandus nandus*, *Xenentodon cancila*, and *Tetraodon cutcutia*.

Ghagor stream, Ghagor, Assam. The Ghagor stream is a low gradient, alluvial river with a high meandering process (Table 1 and Fig. 6t). Water was clear and the habitat was mostly run with smooth substrate type of sand and silt. Floodplains were vast with little vegetation cover. *Danio rerio* population was found in shallow secondary channels formed with the sand dune in the middle of the river channel, along the secondary channel where there was overhanging vegetation and undercut bank. The undercutting of the bank was common due to erosion and the banks are almost unstable. Algal mats were noted in areas exposed to sunlight. Another population was found in a shallow pool created by the

undercut bank where the water velocity was from 7.0 to 7.9 cm/s. Water depth in this area ranged from 0.1 to 0.6 m along the 100 m reach. Other species occurring in all the habitats in the study area included *Rasbora rasbora*, *Devario devario*, *D. aequipinnatus*, *Barilius bendelisis*, *B. vagra*, *Puntius sophore*, *P. conchoni*, *Psilorhynchus balitora*, *Glyptothorax* sp., *Lepidocephalichthys guntea*, and *Acanthocobitis botia*.

Dikrong River at Khola camp, Arunachal Pradesh. The Dikrong River is a tributary of Brahmaputra River drainage in Arunachal Pradesh. Collection of cobbles and small boulders is a major activity in this stream and is a big threat to the entire stretch of this river (Table 1 and Fig. 6u). Banks were stable and had good riparian vegetation. Water was clear. *Danio rerio* population was found in a side channel created inside a stream for vehicle movement carrying loads of boulders. Immediately after the bank, or in some places along the floodplain, there were crusher units for breaking of river stones. Boulders were removed also from the secondary channel and hence the dominant substrates were sand and silt. There was little flow in the areas where the secondary channel was connected to the main stream and the water velocity here ranged from 11.8 to 12.9 cm/s. Depth of the habitat was 0.2–0.6 m. In the main channel we collected *Rasbora rasbora*, *Barilius bendelisis*, *B. vagra*, *Cirrhinus mrigala*, *Puntius chola*, *Poropuntius marginatus*, *Neolissochilus hexastichus*, *Labeo gonius*, *Cyprinus carpio*, *Garra annandalei*, *G. lissorhynchus*, *Psilorhynchus balitora*, *Acanthocobitis botia*, *Botia rostrata*, *Lepidocephalichthys guntea*, *Schistura arunachalensis*, and *Mystus vittatus*.

Rani village, Siang, Arunachal Pradesh. This waterway is a third-order stream with thick vegetation along the right bank (looking upstream) and the left bank is mostly midstory cover (Table 1 and Fig. 6v). Banks are more or less stable and *Danio rerio* was found along the right bank area where the substrate was sand. Flow rate was in the range of 13.0–13.9 cm/s. Most of the populations were confined to areas below overhanging vegetation and were absent in the mid-channel area in deeper pools. *Danio rerio* also occurred in a backwater pool with roots forming habitats, as well as in undercut banks. Washing of clothes and bathing by the local village people were common in this region. In the upstream habitat areas there were slow riffles with pebbles and sand from where we collected a good number of *Psilorhynchus* sp. In these habitats *Psilorhynchus* were easily picked up by hand before using fishing nets. Other species occurring in all the habitats in the study area included *Amblypharyngodon mola*, *Devario devario*, *Barilius vagra*, *B. bendelisis*, *Raimas bola*, *Puntius conchoni*, *P. chola*, *Acanthocobitis botia*, *Mystus vittatus*, *Gagata cenia*, *Pseudochensis sulcatus*, *Eutropichthys vacha*, and *Xenentodon cancila*.

Thore, Siang, Arunachal Pradesh. This waterway is a third-order stream with a mostly cobble substrate. Stream width ranged from 5–8 m. Water was clear with 100% visibility (Table 1 and Fig. 6w) and water flow ranged from 5.3–5.8 cm/s. Snorkeling was done in this stream, and *Psilorhynchus* was the abundant fish species found by underwater observation. *Danio rerio* habitats were identified near the confluence of this stream with a first-order stream (with fish cover). Specific habitats of *Danio rerio* were below overhanging vegetation with 80%–90% cover. Most of the populations pre-

ferred these habitats and few were located near the confluence zone. Substrate included cobble and sand. It is a shallow (depth 1–15 cm) and narrow (30–70 m width) stream with relatively stable banks and good vegetation cover. Other species occurring in all the habitats in the study area included *Rasbora rasbora*, *Devario devario*, *Barilius bendelisis*, *B. vagra*, *Puntius conchoni*, *Psilorhynchus balitora*, *Garra lissorhynchus*, *Acanthocobitis botia*, *Lepidocephalichthys guntea*, and *Xenentodon cancila*.

Sora River, Hapoli village, Arunachal Pradesh. At this location *Danio rerio* was found in a small ditch with grasses and semi-aquatic vegetation (Table 1 and Fig. 6x). This was the only habitat where *Danio rerio* was observed; other habitats studied were without direct contact with the adjacent stream, though subterranean seepage was also possible. *Danio rerio* was absent from the main stream, though other species such as *Devario aequipinnatus*, *Esomus danricus*, *Puntius conchoni*, and *Garra lissorhynchus* were recorded. Terrace cultivation of rice fields was located around the main stream. Among all the populations throughout its range of distribution from Peninsular India to north and northeast, this population showed with deeper body (Table 2A and B). Other species occurring in all the habitats in the study area included *Esomus danricus*, *Puntius ticto*, and *P. conchoni*.

Discussion

Alcoves and backwaters are habitats of *Danio rerio* in streams of the Western Ghat mountain ranges (four populations). In Wynaad, while occurring in the lowland streams, the species preferred secondary channels with little flow. In a relatively larger river in Western Ghats (Thunga River), it was found in two separate types of habitats: in shallow flowing secondary channels, where it co-occurred with juveniles of *Hypsobarbus jerdoni* and *Barilius gatensis*, or isolated pools in the secondary channels where it co-occurred with *Aplocheilichthys lineatus*. *Danio rerio* was completely absent from the main channel; species in the main channel included *Devario aequipinnatus*, *Barilius gatensis*, and *Osteochilichthys nashi*. Larval habitats of *Danio rerio* were identified in streams/rivers of peninsular India as backwater areas or alcoves over a sandy substrate in areas with limited flow but in contact with the main habitats (run or riffle). In Orissa, *Danio rerio* occurred only in highly disturbed habitats resulting from the removal of riparian vegetation and overhanging canopy, important factors altering freshwater ecosystems and fish faunas as this practice can lead to the complete drying of streams in some lowland areas.

As noted previously,⁵ in our study we also observed habitat degradation and loss in Meghalaya due to rapid destruction and conversion of paddy fields for human settlements and for small industrial establishments. This disturbance included the removal of the riparian zone and any overhanging vegetation for streams along the highway between Shillong and Guwahati. In these areas, *Danio rerio* populations were absent and the only species noted in these stagnant waters was *Aplocheilichthys panchax*. This provides clear evidence that in lowland streams of this area *Danio rerio* prefers habitats with overhanging vegetation, flowing water (even if minimal), or both habitat conditions.

The patterns of occurrence of *Danio rerio* in the state of Arunachal Pradesh, India, is notably different in that the species exhibits a wide range of habitat tolerances. The species

TABLE 2A. MORPHOMETRIC MEASUREMENTS OF *Danio rerio* (CHARACTERS 2-5 EXPRESSED AS % SL AND CHARACTERS 6-10 EXPRESSED AS % HL; N=NUMBER OF SPECIMENS)

	Thirunelli- Wynaad- Kerala	Thunga River- Karnataka	Achakanni falls- Karnataka	Kattina hole- Karnataka	Jhijur stream- Orissa	Kularjor stream- Orissa	Marudi River-Orissa	Budapalang River- Orissa	Mathumathi River-Uttar Pradesh	Meldoompur- Uttar Pradesh	Marulym khang- Meghalaya
	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)	Range (n=10)
1 Total length (mm)	22.1-24.1	21.3-24.5	27.1-29.8	20.0-22.7	22.6-28.2	25.4-27.9	30.1-34.2	20.0-21.5	17.8-22.6	24.6-26.0	17.8-22.6
2 Standard length (mm)	20.6-22.6	18.4-22.3	23.3-25.5	14.8-17.2	16.9-21.5	18.9-21.9	26.7-29.0	15.3-16.3	13.6-17.9	18.7-20.4	13.6-17.9
% of SL											
3 Body depth	22.6-25.2	21.8-24.3	23.8-26.1	23.0-28.0	22.5-24.6	22.1-24.8	22.4-26.0	22.6-25.0	24.9-27.3	23.0-25.2	24.9-27.3
4 Caudal peduncle length	9.6-11.9	9.8-10.3	11.0-12.1	10.7-12.6	9.8-10.9	10.2-11.1	9.8-10.9	9.3-10.7	10.6-11.9	9.7-11.7	10.6-11.9
5 Head length (mm)	25.8-27.6	24.3-26.4	24.8-27.2	25.7-28.3	25.9-29.0	25.2-28.1	26.2-27.5	24.1-26.9	25.2-29.0	26.1-26.7	25.2-29.0
% of HL											
6 Orbit width	25.3-27.2	23.1-26.4	26.6-29.8	34.4-36.3	26.4-29.2	26.7-32.2	28.4-33.2	30.9-38.8	34.7-38.9	33.1-37.7	34.7-38.9
7 Max. head width	39.9-41.2	36.5-39.8	44.6-50.2	50.9-53.3	40.9-48.6	46.1-52.6	43.6-48.0	47.2-56.3	45.1-54.1	50.8-54.3	45.1-54.1
8 Max. head depth	50.6-51.7	49.6-50.4	62.8-71.3	66.5-70.1	51.7-59.6	54.4-62.8	55.3-58.8	61.8-70.4	60.3-69.6	62.1-64.9	60.3-69.6
9 Maxillary barbel length	40.9-43.9	40.1-42.2	62.5-72.3	30.5-40.8	42.9-51.9	42.6-65.2	44.9-62.9	33.4-46.2	31.1-39.5	50.1-60.0	31.1-39.5
10 Rostral barbel length	20.1-22.6	20.3-22.1	24.0-32.5	9.8-12.5	19.6-26.9	10.6-20.0	17.9-23.1	18.2-23.7	9.6-12.4	12.1-16.1	10.2-12.8
11 No. of I stripe	4	4	4-5	4	4-5	4	4	4	4	4	4
12 No. of P stripe	5	5	5	5	5	5	5	5	4-5	5	4-5
13 No. of A stripe	3	3	3	2-3	3	3	3	2	2-3	2-3	2-3

TABLE 2B. MORPHOMETRIC MEASUREMENTS OF *DANTO RERIO* (CHARACTERS 2–5 EXPRESSED AS % SL AND CHARACTERS 6–10 EXPRESSED AS % HL; N = NUMBER OF SPECIMENS)

	2 Km away from Umsingh highway– Meghalaya	5 Km away from Umsingh highway– Meghalaya	Sansori stream– Assam		Dhalpur stream– Assam		Beel near Brahmaputra River, Assam		Ghagor stream– Assam		Dikrong River Arunachal Pradesh		Rani village– Arunachal Pradesh		Thore– Siang (Dk) Arunachal Pradesh		Sora River– Hapoli village– Arunachal Pradesh
			Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)	Range (n = 10)			
1	Total length (mm)	22.3–26.1	22.9–26.3	26.1–36.2	20.3–24.7	28.9–32.1	27.4–29.5	25.5–28.5	25.0–27.4	27.2–29.7	32.5–36.8						
2	Standard length (mm)	17.1–19.8	17.2–20.4	19.8–28.0	15.7–18.7	22.5–25.6	22.8–25.0	18.6–22.7	18.4–21.1	21.8–28.2	26.8–31.4						
3	% SL																
3	Body depth	24.1–25.7	22.0–27.2	23.6–25.9	23.8–26.1	23.3–24.4	23.8–26.1	22.9–26.7	22.4–26.3	22.5–28.6	21.8–25.7						
4	Caudal peduncle length	9.9–11.3	9.5–11.4	10.5–12.1	10.8–11.3	10.3–11.2	11.0–12.1	9.5–11.9	10.1–11.7	11.0–12.2	9.8–11.3						
5	Head length (mm)	26.8–29.0	24.7–27.8	25.8–27.0	25.7–27.0	22.5–25.6	24.3–25.8	25.0–29.1	27.2–28.5	26.3–28.5	23.5–27.6						
6	% HL																
6	Orbit width	28.0–34.0	27.1–35.3	27.3–35.8	34.5–38.3	27.9–32.5	24.9–29.8	28.0–32.5	26.0–31.8	23.6–31.1	26.8–28.7						
7	Max. head width	47.0–50.7	47.1–52.5	48.8–53.9	47.5–53.4	47.5–49.9	47.7–54.2	37.1–47.1	45.6–50.3	44.8–50.8	46.7–53.4						
8	Max. head depth	56.5–64.7	60.1–67.3	64.4–70.7	61.3–67.9	57.3–62.6	60.6–68.4	54.0–58.5	55.8–59.9	68.4–76.8	58.2–62.4						
9	Maxillary barbel length	42.0–50.2	48.2–58.4	45.4–58.4	30.9–55.5	64.9–75.1	62.0–88.0	61.9–70.1	44.9–49.3	44.0–52.9	45.9–48.7						
10	Rostral barbel length	10.8–24.3	18.8–27.7	14.5–21.4	7.7–16.8	27.0–31.4	32.6–41.8	25.0–28.1	21.9–24.1	11.6–13.8	22.6–31.8						
11	No. of I stripe	4	4	4	4	4	4	4	4	4	4						
12	No. of P stripe	5	5	5	5	5	5	5	5	5	5						
13	No. of A stripe	3	2–3	2–3	2–3	3	3	3	3	3–4	3						

was observed as occurring in several streams and habitats ranged from stagnant pools (beel in local language) to secondary channels with low flow and shallow areas. In lowland streams and in large alluvial rivers, such as the Dikrong River, the primary habitats of *Danio rerio* included shallow and flowing secondary channels and, in some places, even tertiary channels with shallow low flow areas.

Danio rerio populations from beels and household fish ponds in the Brahmaputra River drainage face a major threat by villagers that are attempting to eliminate the so-called weedy species such as *Rasbora*, *Esomus*, *Puntius*, and *Parambassis* and replace these species with introduced culture carps (*Gibelion catla*, *Labeo rohita*, *Cyprinus carpio*). However, in these habitat types *Danio rerio* populations are confined to the inlet and outlet areas of culture ponds where there is an exchange of water. Earlier reports from Bangladesh⁴ and from Indian states⁵ stated that *Danio rerio*, when occurring in lowland streams/rivers or in irrigation canals, tends to confine itself to habitats connecting with paddy fields. This pattern is consistent with our observations based on this survey; however, *Danio rerio* also occurs in paddy fields that are connected to a lowland stream or irrigation canal where it confines itself to the areas where water overflows into the channel/stream. Also *Danio rerio* occurs in habitats with wide pH from 6.2 in Arunachal Pradesh in the high terrain with a temperature of 12.3°C and also in the habitats in Orissa with a pH of 9.8 and a peak temperature of 28.4°C in the summer season in the Mathumathi River in Uttar Pradesh.

Based on our field collections and observations in various streams/rivers in India, the zebrafish prefers to occupy areas with overhanging vegetation and/or areas with undercut banks. The species feeds primarily on allochthonous materials, usually ants and other insects falling into streams, secondary channels, and pools. This is consistent with our inspection and observations of gut contents from almost all habitat types where the species occurs. *Danio rerio* also occupies surface waters in rivers and lowland streams as does *Devario aequipinnatus*, a species already established as a surface dweller in streams of the Western Ghats.²² The surface dwelling and surface feeding guild of fishes includes *Danio rerio*, *Devario aequipinnatus*, species of *Barilius*, *Rasbora daniconius*, and species of *Salmophasia*, *Chela*, and *Esomus*. This surface dwelling guild of fishes in streams of peninsular South India is highly consistent across many areas sampled and is a commonly observed phenomenon where there is habitat partitioning for all these species via their use of various microhabitat parameters.^{23,26–28}

However, across all the habitats in north and northeastern India, *Danio rerio* exhibited a pattern of large environmental tolerances from stagnant beels to secondary channel habitats with low velocity and shallow depths where it utilized the wide range of resources. Furthermore, in the lowland streams and the larger alluvial rivers such as the Dikrong River in Arunachal Pradesh, the habitats of *Danio rerio* were secondary channels isolated from the main channels, and in some places tertiary channels, with low flow and shallow water habitats. Low-flow, shallow habitats were the preferred habitats that we observed for *Danio rerio*. In general, in this region *Danio rerio* utilized a wide range of habitats across the countryside and hence was widely distributed.

Partitioning of habitat or other resource is the mechanism for the co-existence of different species in the same environ-

ment^{29–33} and the tropical fish assemblages are more structured and are well segregated in their food usage.²⁵ With the great diversity of fishes in the streams of India, the diversity is likely correlated with or associated with habitat segregation and within this it is based on feeding microhabitats related to their behaviors and anatomical adaptations (mouth morphologies). In this situation and with respect to notably important species *Danio rerio*, surface feeding species include those of *Danio*, *Devario*, *Barilius*, *Aspidoparia*, *Rasbora*, *Salmophasia*, *Esomus*, and *Chela* where in at the macrohabitat level there is consistent overlap for habitats. We hypothesize though that, within this macrohabitat, these species also maintain consistent microhabitats that are necessary for their continued existence and coexistence. Segregation of *Danio rerio* is observed in microhabitat usage in all the habitats studied and also found no aggressive behavior of all populations with co-existing species when there is an overlap in using the habitats while moving from one microhabitat to other (personal observation).

Disclosure Statement

No competing financial interests exist.

References

1. Mabee PM, Arratia G, Coburn M, et al. Connecting evolutionary morphology to genomics using ontologies: A case study from Cypriniformes including zebrafish. *J Exp Zool Part B: Mol Devel Evol* 2007;308:655–668.
2. De Jong JL, Zon LI. Use of the zebrafish system to study primitive and definitive hematopoiesis. *Annu Rev Genet* 2005;39:481–501.
3. Grabher C, Look AT. Fishing for cancer models. *Nat Biotechnol* 2006;24:45–46.
4. Schilling TF, Webb J. Considering the zebrafish in a comparative context. *J Exp Zool* 2007;308B:515–522.
5. Spence R, Fatema, MK, Reichard M, et al. The distribution and habitat preference of the zebrafish in Bangladesh. *J Fish Biol* 2006;69:1435–1448.
6. Engeszer ER, Patterson LB, Rao AA, Parichy DM. Zebrafish in the wild: A review of natural history and new notes from the field. *Zebrafish* 2007;4:21–38.
7. Hamilton F. *An Account of the Fishes Found in the River Ganges and its Branches*. Constable, Edinburgh and London, 1822.
8. Day F. *The Fishes of India: Being a Natural History of the Fishes Known to Inhabit the Seas and Fresh Waters of India, Burma and Ceylon*. Indian Reprint by Jagminder Book Agency, New Delhi, 1878.
9. Menon AGK. A distributional list of fishes of Himalayas. *J Zool Soc India* 1962;2:23–32.
10. Hora SL. Notes on fishes in the Indian museum XXXI. On a small collection of fish from Sandoway, lower Burma. *Rec Indian Mus* 1937;39:323–331.
11. Hora SL. Notes fishes of the Indian museum, XXXVI. On a collection of fish from the Rajmahal Hills, Santhalparganes, Bihar, *Rec Indian Mus* 1938;40:169–181.
12. Chauhan BS, Ramakrishna, G. Fauna of the Balangi district (formerly Patna state), Orissa. *Rec Indian Mus* 1953;51:395–416.
13. Tilak R. On a collection of fish from Sikkim. *Rec Zool Surv India* 1968;66:277–286.
14. Arunachalam M, Johnson JA, Sankaranarayanan A. *Fishes of Rain Forest Streams/ Rivers of India. A Research Overview*. ENVIS. Bulletin on Conservation of rain forests in India, Wild Life Institute of India (ed.). pp. 153–172, 2003.

15. Whitely AR, Anuradha Bhat, Martins EP, et al. Population genomics of wild and laboratory Zebrafish (*Danio rerio*). *Mol Ecol* 2011;20:4259–4276.
16. Datta Munshi JS, Srivastava MP. *Natural History of Fishes and Systematics of Freshwater Fishes of India*. Narendra Publishing House, Delhi, 1988.
17. Sen N. *Pisces. Fauna of Meghalaya: Part 1, Vertebrates. Zoological Survey of India: Calcutta*. Ghosh AK (eds.), pp. 483–592, 1995.
18. Menon AGK. Check list—Fresh water fishes of India. *Rec Zool Surv India Occ Pap* 175, p. 366, 1999.
19. Fang F. Phylogenetic analysis of the Asian cyprinid genus *Danio* (Teleostei: Cyprinidae). *Copeia* 2003;714–728.
20. Mayden RL, Tang KL, Conway KW, et al. Phylogenetic relationships of *Danio* within the order Cypriniformes: A framework for comparative and evolutionary studies of a model species. *J Exp Zool B Mol Dev Evol* 2007;308B:642–654.
21. Armantrout NB. *Aquatic Habitat Inventory*. Bureau of Land Management, Eugene District, USA, p. 32, 1990.
22. Arunachalam M. Methods for fish habitat inventory in stream/rivers. *Proc Workshop Germplasm Invent Gene Banking Freshwat Fish NBFGR*, Lucknow, 1999.
23. Arunachalam M. Assemblage structure of stream fishes in Western Ghats of Peninsular India. *Hydrobiologia* 2000;430: 1–31.
24. Fang F. *Danio kyathit*, a new species of cyprinid fish from Myitkyina, northern Myanmar. *Ichthyol Expl Freshwaters* 1998;8:273–280.
25. Arunachalam M, Madhusoodanan Nair KC, Vijverberg J, Kortmulder K. Food and habitat partitioning among fishes in stream pools of a south Indian river. *Int J Ecol Envir* 1997;23:271–295.
26. Johnson JA, Arunachalam M. Diversity, distribution and assemblage structure of fishes in streams of southern Western Ghats, India. *J Threatened Taxa* 2009;1:507–513.
27. Johnson JA, Arunachalam M. Relations of physical habitat to fish assemblages in streams of Western Ghats, India. *Appl Ecol Environ Res* 2010;8:1–10.
28. Johnson JA, Arunachalam M. Feeding habit and food partitioning in a stream fish community of Western Ghats, India. *Environ Biol Fish* 2012;93:51–60.
29. Conell JH. Diversity in tropical rainforest and coral reefs. *Science* 1978;199:1302–1310.
30. Whitham TG. The theory of habitat selection: Examined and extended using *pemphigus* Aphids. *Am Natur* 1980;115:449–446.
31. Moyle PB, Vondracek B. Persistence and structure of the fish assemblage of rainforest streams in Sri Lanka. *J Zool London*.1985;202:95–223.
32. Ross ST. Resource partitioning in fish assemblages: A review of field studies. *Copeia* 1986;352–388.
33. Sone S, Inoue M, Yanagisawa Y. Habitat use and diet of two stream gobies of the Genus *Rhinogobius* in south-western Shikoku, Japan *Ecol Res* 2001;16:205–219.

Address correspondence to:

Muthukumarasamy Arunachalam, PhD
Sri Paramakalyani Centre for Environmental Sciences
Manonmaniam Sundaranar University
Alwarkurichi - 627 412
Tamil Nadu
India

E-mail: arunacm@gmail.com