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## The non-native freshwater fishes of Hong Kong: diversity, distributions, and origins

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**Abstract.** Non-native fishes are widespread in Hong Kong and many are likely to be established. Extensive field surveys, literature reviews, and citizen science data were used to determine the diversity, geographic distribution, potential introduction sources, and known impacts of non-native freshwater fishes in Hong Kong. In total, 95 species, including five putative hybrids, were recorded. In comparison, there are 65 species of native freshwater fishes. The majority (62 species) of non-native fishes belonged to five families: Cichlidae (27 species), Cyprinidae (15 species), Poeciliidae (eight species), Xenocypridae (eight species), and Channidae (four species). Half of all non-native species had at least one breeding population. Potential introduction sources were grouped broadly into three categories: aquarium trade (associated with 62 species and two hybrids); aquaculture (20 species and three hybrids); and water transfers from mainland China (13 species). Most of the species recorded are native to Central and South America (27 species), East Asia (21 species), Southeast Asia (15 species), or Africa (15 species). However, a lack of experimental or manipulative studies and a scarcity of historical data limits our understanding of the extent of their ecological impacts. This synthesis of all currently available information could provide a basis for future research work and policy/management strategies that seek to pre-emptively reduce the likelihood of further species introductions to minimise potential harm to the environment.

**Key words.** invasive species, aquarium trade, reservoirs, aquaculture, water transfers, South China

### INTRODUCTION

Hong Kong is a special administrative region of mainland China, situated on the tropical fringe of the country's southern coast. It encompasses three regions: Hong Kong Island, Kowloon peninsula, and the New Territories. While known for its high rises and dense infrastructure, approximately 76% of Hong Kong is undeveloped, and 40% comprises statutorily protected country parks (Environment Bureau, 2016) that are largely uninhabited. These are drained by relatively undisturbed streams providing habitat for native freshwater fishes. Some of these streams feed into reservoirs that lack indigenous lacustrine fish fauna, as there are no natural lakes in the territory.

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Non-native freshwater fishes are becoming increasingly widespread in Hong Kong (Tricarico et al., 2016; Tsang & Dudgeon, 2021a), reflecting similar trends across the globe (Gozlan et al., 2010; Strayer, 2010). Non-native fishes affect multiple levels of biological organisation (genes, individuals, populations, communities, and ecosystems), with notable ecological impacts including disruption of stream food webs as well as predation of and/or competition with native species (Cucherousset & Olden, 2011; Dudgeon, 2020). Despite this, we lack comprehensive information about the extent of this issue (e.g., which non-native fishes are present in Hong Kong), while their impacts on local ecosystems are not fully understood. For instance, recent findings suggest that poeciliids, such as *Gambusia affinis* and *Poecilia reticulata*, can reduce the species richness of freshwater invertebrates in mesocosms (i.e., an enclosed artificial system) and wetland field experiments (Tsang & Dudgeon, 2021b; Tsang & Dudgeon, 2021c), but evidence of any clear effect on native fishes in natural streams is still lacking (Tsang & Dudgeon, 2021a).

Historically, the majority of Hong Kong's non-native fish species originate from aquaculture, with most recorded in reservoirs. This includes species stocked by the government for angling and mosquito control (Lin, 1949). However, since 1965, raw water from the Dongjiang (East River) of Guangdong Province in southern China has been piped to Hong Kong to augment the local water supply (WSD, 2021), carrying with it propagules of non-native fishes (Lai, 2011).

This potential introduction pathway has grown significantly over time, constituting 79% of total freshwater supply in Hong Kong by 2020/2021 (WSD, 2021). Although water from the Dongjiang itself is only channelled to two reservoirs (e.g., Tai Lam Chung and Plover Cove Reservoirs), Hong Kong's reservoirs are connected by an underground tunnel network that may facilitate the spread of non-native fishes to other localities (Dudgeon, 1996).

Another major source of non-native fishes is the aquarium trade, which peaked in Hong Kong between 1965 and 1970 when there were more than 600 ornamental fish farms often culturing various species in outdoor ponds (Man, 1988). Despite the industry's subsequent decline due to competition from mainland China (Man, 1988) and Singapore, legacy escapees, particularly poeciliids, have established long-term populations (Dudgeon & Corlett, 1994). Through some of these sources (i.e., aquaculture and the aquarium trade), non-native fishes can be further dispersed through a combination of pathways including intentional stocking, release of unwanted pets and during religious rituals. The latter is a common practice among Hong Kong's Buddhists and Taoists (Shiu & Stokes, 2008), and may be an underestimated pathway of introduction (Magellan, 2019), especially for freshwater fishes (Chan, 2006).

The most recent comprehensive catalogue of freshwater fishes in Hong Kong was published three decades ago (Chong & Dudgeon, 1992). Here, a total of 18 non-native species were recorded from streams and rivers, but the tally did not include reservoirs. A more recent survey of non-native fishes in reservoirs (Lai, 2011), recorded 26 non-native fishes. Additionally, field guides and checklists produced by the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong Government (see Lee et al., 2004; AFCD, 2021a; AFCD, 2021b) provide supplemental records of non-native fishes, although these accounts often lack information about species distributions. This paper aims to consolidate all available information about the diversity, distribution, and plausible introduction sources of non-native freshwater fishes in Hong Kong using a combination of literature reviews and ecological surveys.

## MATERIAL AND METHODS

This checklist was compiled using data from field surveys, literature reviews (scientific publications and local technical reports from 1949–2021; environmental impact assessments; environmental permit applications; and management agreements), and citizen science observations from the iNaturalist platform deposited on the Global Biodiversity Information Facility (GBIF.org, 2021). Species recorded from literature were verified as far as possible from photographic records, specimens, or descriptions of the species concerned in the studies. Suspected misidentifications (i.e., single records of species unlikely to survive in Hong Kong reported from places where similar non-native species are known to occur; e.g., *Siluris glanis* recorded in places where *Clarias gariepinus* are present) that were unsupported by specimens

or photographs have been excluded. Only citizen science observations that attained 'research grade' (with a date, photograph, location coordinates, and at least two independent confirmations of the species identification), which were also verified by the authors, have been included in the current study. Additional records from other sources (e.g., websites) were included only if locality and species identity (e.g., via clear photographs) could be confirmed.

Ad-hoc field surveys were conducted in streams, river systems, concrete channels, ponds, marshes, reservoirs, and ditches in agricultural and village areas around Hong Kong between January 2018 to March 2022. A total of 128 sites (Appendix 1) were selected based on previous publications (Chong & Dudgeon, 1992; Chan, 2001; Lai, 2011; Tsang & Dudgeon, 2021a), citizen science databases, or environmental impact assessment reports. Each site was surveyed at least once. Surveys were non-standardised but comprised a minimum of one 100-metre transect. Each transect was sampled for 30 minutes using scoop nets (25cm × 25cm, 1–2 mm mesh size, 90cm handle length) and cast nets (4 m diameter, 2 cm mesh size). Fish were identified to the species-level following Pan et al. (1991) and Chong & Dudgeon (1992). DNA barcoding of the 12S rRNA gene was also used to verify the lineage or identity of putative hybrids and morphologically complex genera (e.g., *Oreochromis*), respectively. We used the MiFish-U-F and MiFish-U-R universal primers (Miya et al., 2015; Hayami et al., 2020). For the purposes of this study, recorded species were considered to be part of a breeding population if both juveniles and adults of the species were observed in the same locality. Conversely, species were categorised as 'introduced' if we only observed a single life stage with no evidence of reproduction. A species was assumed to be locally extinct if it had not been recorded for more than 20 years.

We classified all species recorded into one of three potential sources: aquaculture; aquarium trade; and water transfer. Species were grouped under the most likely/dominant source for summary statistics, if more than one exists. Nevertheless, all likely sources are listed in individual species accounts, along with detailed description of introduction pathways (e.g., stocking, religious release).

Ad-hoc market surveys were conducted in food fish markets and aquarium shops in Hong Kong's 'Goldfish Street' (Tung Choi Street, Mongkok) from January 2018 to January 2022. These market surveys focused on determining whether non-native species that had been reported during the field surveys and in the literature (Chong & Dudgeon, 1992; Chan, 2001; Lai, 2011; Tsang & Dudgeon, 2021a) were sold locally, thus constituting a possible source of introduction. We conjectured that a species is potentially introduced via water transfer from the Dongjiang if non-native species observed in reservoirs, watercourses, and water tunnels that received water from the river, also have source populations in the Dongjiang (based on Pan et al., 1991).

Voucher specimens were euthanised in the field using MS-222, in accordance with international standards (Underwood

Table 1. Non-native freshwater fishes of Hong Kong (95 species, including five putative hybrids). Asterisks denote species identified during surveys of the current study (61 species, including four putative hybrids). Region of origin is based on FishBase (Froese & Pauly, 2021), while introduction sources and status are as stipulated in the Material & Methods. Two species are listed as ‘Uncertain’ due to the difficulty of distinguishing between juveniles without comprehensive genetic work.

Order and Family	Species	Region of Origin	Main Source	Status
<b>LEPISOSTEIFORMES</b>				
Lepisosteidae	<i>Atractosteus spatula</i>	North America	Aquarium trade	Introduced
	<i>Lepisosteus oculatus</i>	North America	Aquarium trade	Introduced
<b>OSTEOGLOSSIFORMES</b>				
Osteoglossidae	<i>Osteoglossum bicirrhosum*</i>	Central and South America	Aquarium trade	Introduced
	<i>Scleropages formosus</i>	Southeast Asia	Aquarium trade	Introduced
Notopteridae	<i>Chitala chitala</i>	South Asia	Aquarium trade	Introduced
	<i>Chitala ornata*</i>	Southeast Asia	Aquarium trade	Introduced
<b>CLUPEIFORMES</b>				
Engraulidae	<i>Coilia grayii*</i>	East Asia	Water transfers	Breeding
<b>CYPRINIFORMES</b>				
Gyrinocheilidae	<i>Gyrinocheilus aymonieri</i>	Southeast Asia	Aquarium trade	Introduced
Cobitidae	<i>Misgurnus dabryanus*</i>	East Asia	Aquarium trade	Introduced
Cyprinidae	<i>Decorus decorus</i>	East Asia	Aquaculture	Extinct
	<i>Barbonymus schwanenfeldii</i>	Southeast Asia	Aquarium trade	Introduced
	<i>Carassius auratus*</i>	East Asia	Aquarium trade	Breeding
	<i>Cirrhinus molitorella*</i>	Southeast Asia	Aquaculture	Breeding
	<i>Cirrhinus mrigala</i>	South Asia	Aquaculture	Introduced
	<i>Cyprinus carpio*</i>	Europe	Aquaculture	Introduced
	<i>Dawkinsia denisonii*</i>	South Asia	Aquarium trade	Introduced
	<i>Dawkinsia filamentosa</i>	South Asia	Aquarium trade	Introduced
	<i>Hampala macrolepidota*</i>	Southeast Asia	Aquarium trade	Breeding
	<i>Labeo rohita*</i>	South Asia	Aquaculture	Breeding
	<i>Mylopharyngodon piceus</i>	East Asia	Aquaculture	Extinct
	<i>Parabramis pekinensis</i>	East Asia	Water transfers	Introduced
	<i>Puntigrus tetrazona*</i>	Southeast Asia	Aquarium trade	Introduced
	<i>Puntius titteya*</i>	South Asia	Aquarium trade	Introduced
	<i>Squaliobarbus curriculus</i>	East Asia	Aquaculture	Introduced
Xenocyprididae	<i>Chanodichthys erythropterus</i>	East Asia	Water transfers	Introduced
	<i>Ctenopharyngodon idella*</i>	East Asia	Aquaculture	Introduced
	<i>Culter recurvirostris</i>	East Asia	Water transfers	Breeding
	<i>Hemiculter bleekeri</i>	East Asia	Water transfers	Extinct
	<i>Hypophthalmichthys molitrix*</i>	East Asia	Aquaculture	Introduced
	<i>Hypophthalmichthys nobilis*</i>	East Asia	Aquaculture	Introduced
	<i>Opsariichthys sp.*</i>	East Asia	Water transfers	Breeding
	<i>Toxabramis houdeimeri</i>	East Asia	Water transfers	Breeding
Gobionidae	<i>Sarcocheilichthys nigripinnis</i>	East Asia	Water transfers	Breeding
<b>CHARACIFORMES</b>				
Serrasalmidae	<i>Colossoma macropomum</i>	Central and South America	Aquarium trade	Introduced
	<i>Piaractus brachypomus</i>	Central and South America	Aquarium trade	Introduced
Characidae	<i>Psalidodon anisitsi*</i>	Central and South America	Aquarium trade	Introduced
<b>SILURIFORMES</b>				
Loricariidae	<i>Pterygoplichthys cf. disjunctivus</i>	Central and South America	Aquarium trade	Breeding
	<i>Pterygoplichthys spp.*</i>	Central and South America	Aquarium trade	Breeding

Order and Family	Species	Region of Origin	Main Source	Status
Bagridae	<i>Tachysurus vachellii</i>	East Asia	Water transfers	Introduced
	<i>Tachysurus sinensis*</i>	East Asia	Water transfers	Breeding
	<i>Tachysurus virgatus</i>	East Asia	Water transfers	Introduced
Clariidae	<i>Clarias gariepinus*</i>	Africa	Aquaculture	Breeding
Malapteruridae	<i>Malapterurus electricus</i>	Africa	Aquarium trade	Breeding
Mochokidae	<i>Synodontis eupterus*</i>	Africa	Aquarium trade	Introduced
GOBIIFORMES				
Eleotridae	<i>Oxyeleotris marmorata*</i>	Southeast Asia	Aquaculture	Breeding
Gobiidae	<i>Eugnathogobius siamensis</i>	Southeast Asia	Water transfers	Breeding
SYNBRANCHIFORMES				
Synbranchidae	<i>Ophichthys cuchia*</i>	South Asia	Aquaculture	Breeding
ANABANTIFORMES				
Anabantidae	<i>Anabas testudineus*</i>	South Asia	Aquaculture	Breeding
Osphronemidae	<i>Osphronemus goramy*</i>	Southeast Asia	Aquarium trade	Introduced
	<i>Trichopodus trichopterus*</i>	Southeast Asia	Aquarium trade	Introduced
Channidae	<i>Channa argus*</i>	East Asia	Aquaculture	Uncertain
	<i>Channa argus</i> × <i>Channa maculata</i> hybrid*	—	Aquaculture	Uncertain
	<i>Channa limbatu*</i>	Southeast Asia	Aquarium trade	Breeding
	<i>Channa micropeltes*</i>	Southeast Asia	Aquarium trade	Breeding
	<i>Channa striata*</i>	Southeast Asia	Aquaculture	Breeding
CICHLIFORMES				
Ambassidae	<i>Parambassis ranga*</i>	Southeast Asia	Aquarium trade	Breeding
Cichlidae	<i>Amphilophus citrinellus*</i>	Central and South America	Aquarium trade	Breeding
	<i>Amphilophus labiatus*</i>	Central and South America	Aquarium trade	Breeding
	<i>Astronotus ocellatus*</i>	Central and South America	Aquarium trade	Introduced
	<i>Cichla monoculus</i>	Central and South America	Aquarium trade	Introduced
	<i>Cichla temensis*</i>	Central and South America	Aquarium trade	Introduced
	<i>Coptodon zillii*</i>	Africa	Aquaculture	Breeding
	<i>Geophagus brasiliensis</i>	Central and South America	Aquarium trade	Introduced
	<i>Hemichromis cf. camerounensis*</i>	Africa	Aquarium trade	Breeding
	<i>Hemichromis fasciatus</i>	Africa	Aquarium trade	Introduced
	<i>Hemichromis guttatus*</i>	Africa	Aquarium trade	Breeding
	<i>Herichthys cf. carpintis*</i>	North America	Aquarium trade	Introduced
	<i>Herichthys cyanoguttatus</i>	North America	Aquarium trade	Introduced
	<i>Heros efasciatus</i>	Central and South America	Aquarium trade	Introduced
	<i>Heterotilapia buttikoferi*</i>	Africa	Aquarium trade	Breeding
	<i>Labidochromis caeruleus*</i>	Africa	Aquarium trade	Introduced
	<i>Maylandia lombardoi*</i>	Africa	Aquarium trade	Introduced
	<i>Melanochromis auratus</i>	Africa	Aquarium trade	Introduced
	<i>Mesonauta festivus</i>	Central and South America	Aquarium trade	Introduced
	<i>Oreochromis aureus*</i>	Africa	Aquaculture	Breeding
	<i>Oreochromis mossambicus*</i>	Africa	Aquaculture	Breeding
	<i>Oreochromis niloticus*</i>	Africa	Aquaculture	Breeding
	<i>Oreochromis mossambicus</i> × <i>O. niloticus</i> hybrid*	—	Aquaculture	Breeding
	<i>Oreochromis niloticus</i> × <i>O. aureus</i> hybrid*	—	Aquaculture	Introduced
	<i>Parachromis managuensis*</i>	Central and South America	Aquarium trade	Breeding
	<i>Pelmatolapia mariae*</i>	Africa	Aquarium trade	Breeding

Order and Family	Species	Region of Origin	Main Source	Status
	<i>Vieja bifasciata</i> *	Central and South America	Aquarium trade	Breeding
	<i>Vieja fenestrata</i> *	Central and South America	Aquarium trade	Breeding
	<i>Vieja melanurus</i> *	Central and South America	Aquarium trade	Breeding
	<i>Vieja zonata</i>	Central and South America	Aquarium trade	Breeding
	Blood-red Parrot Cichlid	—	Aquarium trade	Introduced
	Flowerhorn Cichlid*	—	Aquarium trade	Introduced
<b>ATHERINIFORMES</b>				
Melanotaeniidae	<i>Melanotaenia trifasciata</i> *	Australasia	Aquarium trade	Introduced
<b>CYPRINODONTIFORMES</b>				
Aplocheilidae	<i>Aplocheilus lineatus</i> *	South Asia	Aquarium trade	Breeding
Poeciliidae	<i>Gambusia affinis</i> *	Central and South America	Aquarium trade	Breeding
	<i>Poecilia reticulata</i> *	Central and South America	Aquarium trade	Breeding
	<i>Poecilia wingei</i> *	Central and South America	Aquarium trade	Breeding
	<i>Poecilia salvatoris</i> *	Central and South America	Aquarium trade	Breeding
	<i>Poecilia sphenops</i>	Central and South America	Aquarium trade	Introduced
	<i>Xiphophorus hellerii</i> *	Central and South America	Aquarium trade	Breeding
	<i>Xiphophorus maculatus</i> *	Central and South America	Aquarium trade	Breeding
	<i>Xiphophorus variatus</i> *	Central and South America	Aquarium trade	Breeding
<b>BELONIFORMES</b>				
Hemiramphidae	<i>Hyporhamphus intermedius</i> *	East Asia	Water transfers	Breeding
	<i>Xenentodon cancila</i>	South Asia	Aquarium trade	Breeding
<b>CENTRARCHIFORMES</b>				
Centrarchidae	<i>Micropterus salmoides</i> *	North America	Aquarium trade	Breeding

& Anthony, 2020). Specimens were then brought back to the laboratory and fixed in 10% formalin for two weeks, rinsed in tap water, and then stored in 70% ethanol. The notation '[LU]' (below the species names) indicates that voucher specimens have been deposited in the Lingnan University Natural History Collection (LUNHC), Hong Kong. We provide photographs of many species along with accounts of their distribution. All photographs were taken by the first author unless otherwise stated. Standard length of specimens are listed in species accounts of all photographed specimens deposited in the LUNHC, and other specimens (i.e., in-situ, from the aquarium trade) where available. Historical and present distribution of species are placed under the 'distribution' heading of the species accounts. All observation localities were listed in chronological order (with the most recent record listed last). Records based on specimens collected during surveys by the authors have been denoted by 'current survey'. Native ranges of fish species were obtained from FishBase.org (Froese & Pauly, 2021) with the region of origin (see Table 1) placed in parentheses for widespread species, which were based on their most widespread native region listed on FishBase.org. Regions were grouped biogeographically: East Asia, South

Asia, Southeast Asia, Central and South America (including species endemic to Mexico), North America, Africa, and Europe. All maps were produced using QGIS version 3.16.8 (QGIS.org, 2021).

## RESULTS

A total of 95 species of non-native freshwater fishes from 28 families in 15 orders were recorded (Table 1). Sixty-two species were from five families: Cichlidae (27 species), Cyprinidae (15 species), Poeciliidae (eight species), Xenocyprididae (eight species), and Channidae (four species). The remaining 33 species belonged to 23 families (Table 1). Five non-native fishes were putative hybrids: four cichlids and a channid. Half (48) of the non-native species had breeding populations, with cichlids being dominant with 15 species (31% of breeding species) followed by poeciliids (seven species, 15%), and cyprinids (four species, 8%). The three main sources of introduction for all species and hybrids were the aquarium trade (64 species), aquaculture (23 species), and water transfers (13 species).

## INVENTORY OF NON-NATIVE FRESHWATER FISHES

### Order Lepisosteiformes

#### Family Lepisosteidae

*Atractosteus spatula* (Lacepède)  
(Fig. 1)



Fig. 1. *Atractosteus spatula*, aquarium trade, photographed by Heok Hui Tan.

**Distribution.** Ng Tung River (A.C. Lam, pers. comm., 2017); Shing Mun Reservoir (GBIF.org, 2021).

**Native range.** North America.

#### *Lepisosteus oculatus* (Winchell)

**Distribution.** Pun Chun Yuen area (starfish\_gaia, 2021).

**Native range.** North America.

**Remarks.** This was a record from iNaturalist (<https://www.inaturalist.org/observations/72235295>), but has not been included in the GBIF database due to only recently attaining ‘research grade’ recognition.

### Order Osteoglossiformes

#### Family Osteoglossidae

*Osteoglossum bicirrhosum* (Cuvier)  
(Fig. 2)



Fig. 2. *Osteoglossum bicirrhosum*, 215 mm SL, aquarium trade, photographed by Heok Hui Tan.

**Distribution.** Ng Tung River, Plover Cove Reservoir (A.C. Lam, pers. comm., 2017); Tsing Yi Park, Tai Tam Reservoir (GBIF.org, 2021); Lai King area, Shing Mun Reservoir (current survey).

**Native range.** South America.

**Remarks.** Commonly in the aquarium trade, but breeding has not been reported locally.

#### *Scleropages formosus* (Müller & Schlegel)

**Distribution.** Tai Tam Reservoir (A.C. Lam, pers. comm., 2021; GBIF.org, 2021).

**Native range.** Southeast Asia.

**Remarks.** Highly prized in the aquarium trade and listed in CITES Appendix 1 (CITES, 2021).

### Family Notopteridae

#### *Chitala chitala* (Hamilton)

**Distribution.** Shing Mun Reservoir, Kowloon Reservoir, Plover Cove Reservoir (Lai, 2011 as *Nopterus chitala*).

**Native range.** India (South Asia).

**Remarks.** Rare in the aquarium trade. May possibly be a misidentification of *C. ornata* due to similar morphological characteristics, which were unable to be verified in the current study.

#### *Chitala ornata* (Gray)

**Distribution.** Plover Cove Reservoir (A.C. Lam, pers. comm., 2020); Aberdeen Lower Reservoir (GBIF.org, 2021); Lai King area (current survey).

**Native range.** Chao Phraya and Mekong basins across Southeast Asia.

### Order Clupeiformes

#### Family Engraulidae

#### *Coilia grayii* (Richardson)

**Distribution.** Plover Cove Reservoir (Man & Hodgkiss, 1977; Man & Hodgkiss, 1981; Lai, 2011; GBIF.org, 2021; current survey); Tai Lam Chung Reservoir (Lai, 2011; AFCD, 2021c).

**Native range.** East and South China seas, and the Indian Ocean (East Asia).

**Remarks.** Based on the presence of juveniles and adults, there is likely a breeding population at Plover Cove Reservoir. It was first recorded in Plover Cove Reservoir in Hong Kong in 1967 (the year the reservoir was completed) where it was suspected to originate from water piped from Shenzhen Reservoir in Guangdong (Man, 1974).

**Order Cypriniformes****Family Gyrinocheilidae*****Gyrinocheilus aymonieri* (Tirant)**  
(Fig. 3, [LU])

Fig. 3. *Gyrinocheilus aymonieri*, 136 mm SL, aquarium trade, photographed by Heok Hui Tan.

**Distribution.** Siu Lek Yuen area (GBIF.org, 2021); Plover Cove Reservoir (H.T. Cheng, pers. comm., 2021).

**Native range.** Southeast Asia.

**Remarks.** The golden variety of this species is commonly sold as a ‘cleaner fish’ in the aquarium trade.

**Family Cobitidae*****Misgurnus dabryanus* (Dabry de Thiersant)**  
(Fig. 4, [LU])

Fig. 4. *Misgurnus dabryanus*, 141.6 mm SL, Shing Mun Reservoir.

**Distribution.** Lam Tsuen River, Siu Lek Yuen area (GBIF, 2021); Sham Tseng Settlement Basin, Tai Po Kau Nature Reserve; Shing Mun Reservoir (current survey).

**Native range.** Central China, South China, and Taiwan (East Asia).

**Remarks.** This species is morphologically similar to the native *Misgurnus anguillicaudatus*, and has been known to hybridise with it in the wild (You et al., 2009). DNA sequencing of the specimen from Shing Mun Reservoir (Fig. 18) matched with multiple *P. dabryanus* purebreds and a single hybrid, suggesting the 12S RNA gene may not be sufficient to delineate hybrids of this species. The localities listed in the distribution also have records of *M. anguillicaudatus*, which may already be hybridising in Hong Kong. Alarmingly, *M. dabryanus* and *M. anguillicaudatus* are commonly sold admixed as live feeder fish and are sometimes released during Buddhist rituals. It is possible both species hybridised in the aquarium trade before release. Further genetic work is required to resolve this issue.

**Family Cyprinidae*****Barbonymus schwanefeldii* (Bleeker)**  
(Fig. 5)

Fig. 5. *Barbonymus schwanefeldii*, 95.8 mm SL, aquarium trade, photographed by Heok Hui Tan.

**Distribution.** Shing Mun Reservoir, Aberdeen Upper and Lower Reservoirs (Lee et al., 2004); Lau Shui Heung Reservoir (AFCD, 2021c).

**Native range.** Southeast Asia.

***Carassius auratus* (Linnaeus)**  
(Fig. 6, [LU])

Fig. 6. *Carassius auratus*, Little Hawaii Stream.

**Distribution.** Plover Cove Reservoir (Dudgeon, 1983; Lai, 2011); Sandy Ridge Cemetery, Sha Ling, Ma Dai Stream, Cheung Po, Lin Ma Hang (Wilson et al., 1997); Nam Long Shan area (within Ocean Park) (Maunsell Environmental Management Consultants Limited, 2006); Fung Lok Wai area (CH2M HILL Hong Kong Limited, 2008); Hok Tau Reservoir (Lai, 2011); Lok Ma Chau Loop, Tse Koo Hang area, Ma Tso Lung area (Ove Arup & Partners Hong Kong Limited, 2013a); Ha Che area (Atkins China Limited, 2020); Tai Po Kau Nature Reserve, Tai Lam Chung Reservoir (AFCD, 2021c); Kam Tin River, Ho Pui River, Tong Fuk River, Ma Wat River, Lam Tsuen River, Wong Lung Hang, (DSD, 2021); Ng Tung River, Lai Chi Kok Park, Mui Tsz Lam Stream, Mui Wo River, Sheung Yue River, Shui Chuen O Stream, Tan Shan River, Shing Mun River, (GBIF.org, 2021); Tung Chung River (Green Power, 2021); Mai Po Nature Reserve (WWF, 2021); Sam Dip Tam Stream, Kau Lung Hang Lo Wai, Fung Yuen Stream (Tsang & Dudgeon, 2021a); Little Hawaii Stream; Lohas Park area, Deep Water

Bay Stream, Kowloon Reservoir, Miu Shan Stream (current survey).

**Native range.** East Asia, including South China.

**Remarks.** Wild-types of this popular aquarium species were reportedly present in lowland streams and ditches in the New Territories during the 1940s (Lin, 1949). Their presence in remote streams in the New Territories (e.g., Lin Ma Hang) suggests wild-types may naturally occur in Hong Kong. However, these may also be relict aquarium trade escapees from breeding ponds seen in Lin (1949).

***Cirrhinus molitorella* (Valenciennes)**

(Fig. 7, [LU])



Fig. 7. *Cirrhinus molitorella*, 63.8 mm SL, Kowloon Reservoir.

**Distribution.** Plover Cove Reservoir (Dudgeon, 1983; Lai, 2011; current survey); Tai O River (Ove Arup & Partners Hong Kong Limited, 2002; current survey); Mai Po Nature Reserve (WWF, 2006; WWF, 2021); Hok Tau Reservoir, Upper Shing Mun Reservoir, Kowloon Reservoir, Shek Lei Pui Reservoir (Lai, 2011; current survey); Tung Chung River (Green Power, 2021); Sandy Ridge area (Ove Arup & Partners Hong Kong Limited, 2016); Lau Shui Heung Reservoir, Tai Po Kau Nature Reserve, Tai Lam Chung Reservoir, Tai Ho River (AFCD, 2021c); Wong Lung Hang, Cheung Po Stream, Shek Kong Stream, Lam Tsuen River, Ho Chung River (DSD, 2021); Mui Tsz Lam Stream, Ng Tung River, Wu Kau Tang Stream (GBIF.org, 2021); Sam Dip Tam Stream (Tsang & Dudgeon, 2021a); Deep Water Bay Stream, Yung Shue O Stream, Kowloon Reception Reservoir (current survey).

**Native range.** (Southeast Asia) to Vietnam and South China.

**Remarks.** This species was imported from Guangzhou and introduced into the fish farms of New Territories prior to the 1950s (Lin, 1949). It is still reared as food and sold in local markets. Fingerlings are sold as feeder fish for large carnivorous ornamental species and are sometimes released during Buddhist rituals.

***Cirrhinus mrigala* (Hamilton)**

**Distribution.** Wong Lung Hang, Lam Tsuen River (DSD, 2021); Ng Tung River, Ho Chung River (GBIF.org, 2021).

**Native range.** South Asia.

**Remarks.** Fingerlings are sold as feeder fish for large, carnivorous ornamental species and are sometimes released during Buddhist rituals.

***Cyprinus carpio* (Linnaeus)**

(Fig. 8, [LU])



Fig. 8. *Cyprinus carpio* wild type, 307 mm SL, Tai O River (top), ornamental variety, 596mm SL, Shing Mun Reservoir (bottom).

**Distribution.** Sandy Ridge Cemetery (Chan, 2001; Ove Arup & Partners Hong Kong Limited, 2016); Kam Tin River (Black & Veatch Hong Kong Limited, 2005; current survey); Wo Shang Wai area (Mott Connell Limited, 2008); San Tau area (Ove Arup & Partners Hong Kong Limited, 2009); High Island Reservoir, Ho Pui Reservoir, Hok Tau Reservoir, Shing Mun Reservoir, Kowloon Reservoir, Kowloon Reception Reservoir, Pok Fu Lam Reservoir (Lai, 2011; current survey); Tai Lam Chung Reservoir (Lai, 2011; AFCD, 2021c; GBIF.org, 2021; current survey); Plover Cove Reservoir (Lai, 2011; GBIF.org, 2021); Kong Nga Po area (Mott MacDonald Hong Kong Limited, 2013); Tai Sheung Tok area (Ove Arup & Partners Hong Kong Limited, 2014); Tseng Lan Shue area (Black & Veatch Hong Kong Limited, 2018); Ha Che area (Atkins China Limited, 2020); Nam Wa Po area (DSD, 2020); Shek Kiu Tau area (Mott MacDonald Hong Kong Limited, 2020); Shek Pik Reservoir (AFCD, 2021c); Wong Lung Hang, Shek Kong Stream, Ho Chung River, Yuen Long Bypass Floodway, Lam Tsuen River, Ma Wat River (DSD, 2021); Ng Tung River, Hong Kong Park, Tin Shui Wai River, Yuen Long Park, Tin Shui Wai Park, Kowloon Park, Wetland Park, Sheung Wo Hang Stream, Tai Tam Byewash Reservoir, Plover Cove Reservoir (GBIF.org, 2021, as *Cyprinus carpio* and *Cyprinus rubrofuscus*); Mai Po Nature Reserve (WWF, 2021); Sham Tseng Settlement Basin, Aberdeen Upper Reservoir, Hoi Ha Stream, Tai O River, Yung Shue O Stream (current survey).

**Native range.** Black, Caspian, and Aral seas basins, Europe.

**Remarks.** Only *Cyprinus carpio* has been recorded in the results of our DNA barcoding despite citizen science suggesting the presence of both *C. carpio* and *C. rubrofuscus*. The latter is not considered to occur in Hong Kong until genetic evidence is obtained. Wild-types are most commonly encountered in Hong Kong's fresh waters and likely originate from aquaculture while the ornamental variety originate from the aquarium trade, with the latter now becoming increasingly

common in village streams. Juvenile ornamental varieties are sometimes released during Buddhist rituals.

***Dawkinsia denisonii* (Day)**

**Distribution.** Wong Lung Hang Stream (current survey).

**Native range.** South Asia.

**Remarks.** Common in the aquarium trade.

***Dawkinsia filamentosa* (Valenciennes)**

**Distribution.** Kowloon Reservoir (Lai, 2011 as *Puntius filamentosus*); Aberdeen Lower Reservoir (GBIF.org, 2021).

**Native range.** South Asia.

***Decorus decorus* (Peters)**

**Distribution.** Kau Sai Chau area (Wilson et al., 1997 as *Bangana decora*).

**Native range.** Endemic to the Xijiang (West River), South China (East Asia).

**Remarks.** A single individual reported was likely mixed-up with other aquacultured fish that were released into ponds in the Kau Sai Chau Golf Course (Wilson et al., 1997). It has not been observed in Hong Kong since its initial discovery and is considered to be locally extinct.

***Hampala macrolepidota* (Kuhl & Van Hasselt)  
(Fig. 9, [LU])**



Fig. 9. *Hampala macrolepidota*, 49 mm SL, Lower Shing Mun Reservoir.

**Distribution.** Shing Mun Reservoir (GBIF.org, 2021; current survey); Lower Shing Mun Reservoir (current survey).

**Native range.** Southeast Asia.

**Remarks.** Large individuals (over 30cm TL) have been observed to have penetrated as far as the middle reaches of hill streams that flow into Shing Mun Reservoir during the wet season.

***Labeo rohita* (Hamilton)**

**Distribution.** Ho Chung River, Ng Tung River, Shing Mun Reservoir (GBIF.org, 2021); Plover Cove Reservoir (current survey).

**Native range.** (South Asia), Myanmar, Southeast Asia.

**Remarks.** Commonly found in the aquarium trade (as fingerlings and often mixed with *Cirrhinus* spp.) as food for large, carnivorous fishes.

***Mylopharyngodon piceus* (Richardson)**

**Distribution.** Unknown.

**Native range.** Amur River basin to South China (East Asia).

**Remarks.** Listed as an uncommon pond fish by Man & Hodgkiss (1981) with no notes on exact localities. It was likely an escapee from an aquaculture facility, and is presumably no longer present since there have been no subsequent records (Chong & Dudgeon, 1992).

***Parabramis pekinensis* (Basilewsky)**

**Distribution.** Tai Lam Chung Reservoir (Lai, 2011).

**Native range.** Amur River basin to East China (East Asia).

**Remarks.** Restricted to a single reservoir that receives water from the Dongjiang. Previously, it has been cultivated in fishponds (Man & Hodgkiss, 1981), suggesting it may also have individuals released from aquaculture.

***Puntigrus tetrazona* (Bleeker)  
(Fig. 10, [LU])**



Fig. 10. *Puntigrus tetrazona*, 35 mm SL, Plover Cove Reservoir.

**Distribution.** Kowloon Reception Reservoir (C.Y. Tse, pers. comm., 2020); Plover Cove Reservoir (current survey).

**Native range.** Southeast Asia.

**Remarks.** Common in the aquarium trade.

***Puntius titteya* (Bleeker)**  
(Fig. 11, [LU])



Fig. 11. *Puntius titteya*, 17.3 mm SL, Black Hill, note damaged caudal fin.

**Distribution.** Black Hill (current survey).

**Native range.** South Asia.

**Remarks.** Common in the aquarium trade.

***Squaliobarbus curriculus* (Richardson)**

**Distribution.** Ng Tung River, Tai Ho River (GBIF.org, 2021).

**Native range.** Amur river basin to Vietnam (East Asia).

**Family Xenocyprididae**

***Chanodichthys erythropterus* (Basilewsky)**

**Distribution.** Plover Cove Reservoir (Man & Hodgkiss, 1981 as *Culter erythropterus*; Dudgeon, 1983 as *Culter erythropterus*; Chong & Dudgeon, 1992 as *Culter erythropterus*; Lai, 2011 as *Cultrichthys erythropterus*); Tai Lam Chung Reservoir (AFCD, 2021c).

**Native range.** East Asia.

**Remarks.** Restricted to reservoirs that receive water from mainland China.

***Ctenopharyngodon idella* (Valenciennes)**

**Distribution.** Tai Ho River (Chan, 2001 as *Ctenopharyngodon idellus*; AFCD, 2021c); Lok Ma Chau Loop (Ove Arup & Partners Hong Kong Limited, 2013a); Hok Tau Reservoir (AFCD, 2021c; current survey); Ho Chung River (DSD, 2021; current survey); Ng Tung River, Sheung Yue River, Long Valley, Hong Kong Wetland Park (GBIF.org, 2021); Mai Po Nature Reserve (WWF, 2021).

**Native range.** East China and Russia (East Asia).

**Remarks.** Actively farmed in aquaculture ponds in the New Territories. It is sometimes released during Buddhist rituals, presumably after having been purchased from wet markets.

***Culter recurviceps* (Richardson)**

**Distribution.** Kowloon Reception Reservoir, Tai Lam Chung Reservoir (Lai, 2011); Plover Cove Reservoir (Lai, 2011;

GBIF.org, 2021); Lam Tsuen River, Sheung Yue River, Ng Tung River (GBIF.org, 2021).

**Native range.** South China, East Asia.

**Remarks.** This species may have also been accidentally introduced during fish stocking of reservoirs (Lai, 2011).

***Hemiculter bleekeri* (Warpachowski)**

**Distribution.** Plover Cove Reservoir (Man & Hodgkiss, 1977; Dudgeon, 1983).

**Native range.** Central and South China, East Asia.

**Remarks.** Reportedly introduced into Plover Cove Reservoir from “various rivers” through water transfer in 1967 (Man & Hodgkiss, 1977). This species has not been reported since Dudgeon (1983) and is presumably locally extinct.

***Hypophthalmichthys molitrix* (Valenciennes)**

(Fig. 12, [LU])



Fig. 12. *Hypophthalmichthys molitrix*, 52 mm SL, Pak Ngau Shek Stream.

**Distribution.** Shing Mun River, Sandy Ridge Cemetery (Chan, 2001); Kam Tin River (A.C. Lam, pers. comm., 2015); Tai Lam Chung Reservoir (AFCD, 2021c); Ng Tung River, Sheung Yue River (GBIF.org, 2021); Pak Ngau Shek Stream (current survey).

**Native range.** China and Vietnam (East Asia).

**Remarks.** Juveniles are regularly stocked (suspected to be from aquaculture) in (unspecified) reservoirs to control algae as they are believed to be incapable of reproducing in Hong Kong’s fresh waters (WSD, 2019).

***Hypophthalmichthys nobilis* (Richardson)**  
(Fig. 13)

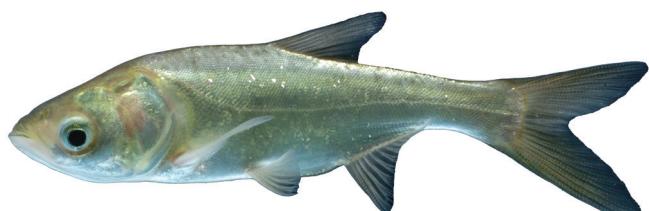


Fig. 13. *Hypophthalmichthys nobilis*, aquarium trade, photographed by Heok Hui Tan.

**Distribution.** Kau Sai Chau, Aberdeen Upper Reservoir, High Island Reservoir (Lee et al., 2004), Plover Cove Reservoir (Lee et al., 2004, GBIF.org, 2021); Kam Tin River (A.C. Lam, pers. comm., 2015); Tai Lam Chung Reservoir (AFCD, 2021c); Yuen Long Bypass Floodway (DSD, 2021); Wetland Park (GBIF.org, 2021); Tung Chung River (Green Power, 2021); Lam Tsuen River (current survey).

**Native range.** China, East Asia.

**Remarks.** As with *Hypophthalmichthys molitrix*, juveniles of this species are regularly stocked in reservoirs (WSD, 2019).

***Opsariichthys* sp. (Günther)**  
(Fig. 14, [LU])



Fig. 14. *Opsariichthys* sp., 93.5 mm SL, Tai Lam Chung Reservoir.

**Distribution.** Tai Lam Chung Reservoir (Wilson et al., 1997 as *Opsariichthys bidens*; Lai, 2011 as *Opsariichthys bidens*; AFCD, 2021c as *Opsariichthys bidens*; current survey).

**Native range.** East Asia.

**Remarks.** Restricted to a single reservoir that receives water from mainland China. DNA barcoding has indicated this species is not *Opsariichthys bidens*, but instead groups with an unnamed *Opsariichthys* sp. deposited on GenBank (accession number: KJ913670). It is not known where the specimen on GenBank originated from. Further taxonomic work is required to identify this species.

***Toxabramis houdeimeri* (Pellegrin)**

**Distribution.** Kowloon Reception Reservoir (Lai, 2011); Plover Cove Reservoir (H.T. Cheng, pers. comm., 2021).

**Native range.** China and Vietnam (East Asia).

**Remarks.** Restricted to reservoirs that receive water piped from mainland China

**Family Gobionidae**

***Sarcocheilichthys nigripinnis* (Günther)**

**Distribution.** Plover Cove Reservoir, Tai Lam Chung Reservoir (GBIF, 2021; H.T. Cheng, pers. comm., 2021).

**Native range.** East China, South China, Taiwan and Korea (East Asia).

**Remarks.** Restricted to reservoirs that receive raw water piped from mainland China.

**Order Characiformes**

**Family Serrasalmidae**

***Colossoma macropomum* (Cuvier)**  
(Fig. 15)



Fig. 15. *Colossoma macropomum*, 295 mm SL, aquarium trade, photographed by Heok Hui Tan.

**Distribution.** Ho Chung River, Lions Nature Education Centre (GBIF.org, 2021).

**Native range.** Central and South America.

***Piaractus brachypomus* (Cuvier)**

**Distribution.** Ng Tung River (A.C. Lam, pers. comm., 2017).

**Native range.** Central and South America.  
Family Characidae

***Psalidodon anisitsi* (Eigenmann)**

**Distribution.** Deep Water Bay Stream (current survey).

**Native range.** Central and South America.

**Remarks.** Common in the aquarium trade.  
Order Siluriformes

**Family Loricariidae**

***Pterygoplichthys* cf. *disjunctivus* (Weber)**

**Distribution.** Lam Tsuen River; Ma Wat River (DSD, 2021); Ng Tung River (GBIF.org, 2021).

**Native range.** Central and South America.

***Pterygoplichthys* spp.**  
(Fig. 16.)



Fig. 16. *Pterygoplichthys* sp., Lam Tsuen River, photographed by Tommy C.H. Hui.

**Distribution.** Plover Cove Reservoir, Kowloon Reception Reservoir (Lai, 2011); Ho Chung River (DSD, 2021); Ng Tung River (GBIF.org, 2021); Ko Po area (Fanling); Kam Tin River, Tin Shui Wai River, Aberdeen Upper Reservoir, Aberdeen Lower Reservoir, Kowloon Reservoir, Kowloon Byewash Reservoir, Tai Lam Chung Reservoir, Shing Mun Reservoir, Lower Shing Mun Reservoir, Pok Fu Lam Reservoir, Wong Nai Chung Reservoir, Tai Tam Byewash Reservoir, Tsing Tam Reservoir, High Island Reservoir (H.T. Cheng, pers. comm., 2021); Tan Shan River, Tung Tsz Stream, Lam Tsuen River (current survey).

**Native range.** Central and South America.

**Remarks.** These records might comprise several species, which are not identifiable to species level due to complex taxonomy and hybridisation (Wu et al., 2011).

**Family Bagridae**

***Tachysurus vachellii* (Richardson)**

**Distribution.** Man Kam To area (Chan & Ho, 2011 as *Pseudobagrus vachellii*); Sheung Yue River (GBIF.org, 2021).

**Native range.** China and Vietnam (East Asia).

**Remarks.** The localities where this species has been recorded are connected to mainland China water transfer outlets (Chan & Ho, 2011).

***Tachysurus sinensis* (Richardson)**

**Distribution.** Tai Lam Chung Reservoir (GBIF.org, 2021; current survey).

**Native range.** China and Korea (East Asia).

**Remarks.** Restricted to reservoirs that receive water from the mainland. It is also commonly sold in wet markets, which may represent an additional source of introductions from aquaculture.

***Tachysurus virgatus* (Oshima)**

**Distribution.** Man Kam To area (Chan & Ho, 2011).

**Native range.** China and Vietnam (East Asia).

**Remarks.** The locality where this species has been recorded in receives water from mainland China via transfer pipes (Chan & Ho, 2011).

**Family Clariidae**

***Clarias gariepinus* (Burchell)**  
(Fig. 17)



Fig. 17. *Clarias gariepinus*, 916 mm SL, Waterfall Bay Stream, photographed by Samuel C.L. Ho.

**Distribution.** Sandy Ridge Cemetery (Chan, 2001); Kam Tin River (Black & Veatch Hong Kong Limited, 2005; DSD, 2021; current survey); Nam Long Shan area (within Ocean Park) (Maunsell Environmental Management Consultants Limited, 2006); Kowloon Reservoir (Lai, 2011; current survey); Yuen Long Town Nullah (Black & Veatch Hong Kong Limited, 2020a); Nam Wa Po area (DSD, 2020; GBIF.org, 2021); Lok Ma Chau area (Ove Arup & Partners Hong Kong Limited, 2013a); Ho Chung River, Ping Yuen River, Yuen Long Bypass Floodway, Ngau Tam Mei River, Ping Kong Stream, Ho Pui River, Ma Wat River (DSD, 2021); Lin Ma Hang Stream, Ma Tso Lung area, Wong Yue Tan area, Sheung Yue River, Hung Leng Tsuen area, Shan Pui River, Long Valley (GBIF.org, 2021); Tin Shui Wai River, Mui Wo area, Pui O Stream, Tai Ho River, Jordan Valley (H.T. Cheng, pers. comm., 2021); Mai Po Nature Reserve (WWF, 2021); Waterfall Bay Stream, Ng Tung River, Kai Tak River (current survey).

**Native range.** Africa.

**Remarks.** This species thrives in rivers polluted by organic waste in the New Territories.

**Family Malapteruridae*****Malapterurus electricus* (Gmelin)****Distribution.** Kowloon Reservoir (Lai, 2011).**Native range.** Africa.**Remarks.** Breeding populations were discovered by Lai (2011) in Kowloon Reservoir, but none were observed during the current study.**Family Mochokidae*****Synodontis eupterus* (Boulenger)**

(Fig. 18, [LU])

Fig. 18. *Synodontis eupterus*, 112.6 mm SL, Tai Po Kau Nature Reserve.**Distribution.** Tai Po Kau Nature Reserve (current survey).**Native range.** Africa.**Remarks.** Juveniles are often present in the aquarium trade.**Order Gobiiformes****Family Eleotridae*****Oxyeleotris marmorata* (Bleeker)**

(Fig. 19, [LU])

Fig. 19. *Oxyeleotris marmorata*, 138 mm SL, Lau Shui Heung Irrigation Reservoir.**Distribution.** Plover Cove Reservoir (Lai, 2011; current survey); Kowloon Reservoir (GBIF.org, 2021; current survey); Tai Lam Chung Reservoir, Lau Shui Heung Reservoir; Hok Tau Reservoir, Shing Mun Reservoir, Lower

Shing Mun Reservoir, Lam Tei Irrigation Reservoir, Hung Shui Hang Irrigation Reservoir (current survey).

**Native range.** (Southeast Asia) and South Asia.**Remarks.** Commonly sold in wet markets and is a local delicacy.**Family Gobiidae*****Eugnathogobius siamensis* (Fowler)****Distribution.** Plover Cove Reservoir (GBIF.org, 2021); Tai Lam Chung Reservoir (H.T. Cheng, pers. comm., 2021).**Native range.** (Southeast Asia) and South China.**Remarks.** Restricted to reservoirs that receive raw water from mainland China but not known from the Dongjiang and adjacent river systems, although it may have been overlooked because of its tiny size ( $\leq 40$  mm TL (Froese & Pauly, 2021)). This goby is neither in the aquarium trade nor used in aquaculture. It has been recorded from Lai Chi Wo estuary in the New Territories, Hong Kong (Larson, 2009), but has not been reported from South China or Hong Kong since and does not appear to be represented by native populations in Hong Kong.**Order Synbranchiformes****Family Synbranchidae*****Ophichthys cuchia* (Hamilton)**

(Fig. 20)

Fig. 20. *Ophichthys cuchia*, Lau Shui Heung Reservoir, photographed by Tommy C.H. Hui.**Distribution.** Lui Kung Tin area, Ng Tung River (GBIF.org, 2021); Lau Shui Heung Reservoir, Wong Nai Chung Reservoir, Plover Cove Reservoir (current survey).**Native range.** (South Asia) and Southeast Asia.**Remarks.** Commonly sold as food in wet markets and is sometimes released during Buddhist rituals.

**Order Anabantiformes****Family Anabantidae**

*Anabas testudineus* (Bloch)  
(Fig. 21, [LU])



Fig. 21. *Anabas testudineus*, 70.7 mm SL, Shui Hau Stream.

**Distribution.** Lok Ma Chau area (Ove Arup & Partners Hong Kong Limited, 2013a; current survey); Tsung Yuen Stream, Long Valley area (Ove Arup & Partners Hong Kong Limited, 2013b); Nam Sang Wai area (Black & Veatch Hong Kong Limited, 2020a; current survey); Tung Chung River, Ma Tso Lung Stream (DSD, 2021); Tai Ho River, Shek Pik Reservoir, Tai O area, Mai Po Nature Reserve, Pui O Stream, Shui Lo Cho Stream, Sandy Ridge Cemetery area (GBIF.org, 2021); Tsing Tai Stream, Shui Hau Stream, Mui Wo area (current survey).

**Native range.** (South Asia), Southeast Asia, and China.

**Remarks.** Many breeding populations are found in the northern New Territories and some parts of Lantau Island, where they occur in stagnant waters. During heavy rain, they have been observed attempting to colonise new habitats by travelling across the inundated terrestrial landscape.

**Family Osphronemidae*****Osphronemus goramy* (Lacepède)**

**Distribution.** Wong Nai Chung Reservoir, Shing Mun Reservoir (current survey).

**Native range.** Southeast Asia.

**Remarks.** Common in the aquarium trade.

***Trichopodus trichopterus* (Pallas)**

**Distribution.** Tai Po Kau Nature Reserve (current survey).

**Native range.** (Southeast Asia) and South Asia.

**Remarks.** A single individual was observed in a man-made pond in the Reserve in 2020.

**Family Channidae**

***Channa argus* (Cantor)  
(Fig. 22A)**



Fig. 22. A, *Channa argus*, Ng Tung River, *Channa maculata*, B1, (dorsal head pattern), B2, (lateral pattern), She Shan River (uncertain origin), *Channa argus* × *Channa maculata* hybrid, C1, (dorsal head pattern), C2, (lateral pattern), Ng Tung River.

**Distribution.** Ng Tung River (GBIF.org, 2021); Kowloon Reservoir; Tai Lam Chung Reservoir (current survey).

**Native range.** Amur River Basin to South China (East Asia).

**Remarks.** This species is occasionally sold together with *Channa maculata* and *Channa argus* × *Channa maculata* hybrids in local wet markets. *Channa argus* is bigger than *C. maculata*, with larger lateral blotches and a well-separated dorsal head pattern (Fig. 22A, B1) between the eyes (Ou et al., 2018). Morphometrics cannot adequately differentiate between juveniles of *C. argus*, *C. maculata*, and *C. argus* × *C. maculata* hybrids in Hong Kong. A region-wide integrative taxonomic assessment is necessary to adequately understand the scale of introductions, breeding, and hybridisation of native and non-native channids. This species is sometimes released during Buddhist rituals.

***Channa argus* × *Channa maculata* hybrid  
(Fig. 22C)**

**Distribution.** Shing Mun Reservoir, Lower Shing Mun Reservoir, Ng Tung River, Kam Tin River, Ma Wat River, Sheung Yue River (current survey).

**Remarks.** Identification solely using morphometrics have not been reliable in Hong Kong, as putative hybrids that matched descriptions from Ou et al. (2018) that were DNA barcoded were identified as purebred *Channa argus*. The localities listed above are a tentative distribution of this putative hybrid whilst a comprehensive integrative taxonomic

assessment is pending. This species is sometimes released during Buddhist rituals.

***Channa limbata* (Cuvier)**  
(Fig. 23, [LU])



Fig. 23. *Channa limbata*, Fanling area.

**Distribution.** Lok Ma Chau area, Ho Hok Wai area, Tse Koo Hang area (Ove Arup & Partners Hong Kong Limited, 2013a); Tsung Yuen Stream (Ove Arup & Partners Hong Kong Limited, 2013b); Sandy Ridge area (Ove Arup & Partners Hong Kong Limited, 2016); Shan Ha Tsuen area (Ove Arup & Partners Hong Kong Limited, 2017); Sung Shan New Village (Atkins China Limited, 2020); Ping Kong Stream, Ho Pui River, Ma Tso Lung Stream, Yuen Long Bypass Floodway, Kam Tin River, Ping Yuen River (DSD, 2021); Lai Chi Chong area (H.T. Cheng, pers. comm., 2021); Fanling area, San Tin area, Tai Mei Tuk area, Nam Sang Wai, Hoi Ha Stream, San Tau Stream (current survey).

**Native range.** Southeast Asia.

**Remarks.** First recorded by Chan (1999) as a native species but subsequently considered to be non-native by AFCD (2021b). Individuals are restricted to sewage channels and degraded stream sections of continental New Territories except for a single individual recorded in the concretised canal of San Tau Stream, Lantau Island. Morphological and genetic analyses by Conte-grand et al. (2017) uncovered that specimens from Hong Kong overlap with a large number of other *Channa gachua*-type fishes from east of the Indo-Burma region, including several localities in mainland China. It is currently in a species complex with two widespread lineages, separated by being located east (*Channa limbata*) and west (*C. gachua*) of the Indo-Burma region. Hence, *C. limbata* should be used in preference to the name *C. gachua* for individuals in Hong Kong.

***Channa micropeltes* (Cuvier)**

**Distribution.** Tai Tam Reservoir (AC Lam, pers. comm., 2018); Tai Tam Tuk Reservoir (GBIF.org, 2021; current survey).

**Native range.** Southeast Asia.

**Remarks.** Juveniles are occasionally present in the aquarium trade.

***Channa striata* (Bloch)**  
(Fig. 24, [LU])



Fig. 24. *Channa striata*, 220 mm SL, Pui O Stream.

**Distribution.** Lin Ma Hang Stream, Sha Ling area (Chan, 2001); Tai Tong area (Chan, 2001; Ove Arup & Partners Hong Kong Limited, 2017); Man Uk Pin Stream (Black & Veatch Hong Kong Limited, 2007); Wo Shang Wai area (Mott Connell Limited, 2008); Lok Ma Chau Loop, Ho Hok Wai area (Ove Arup & Partners Hong Kong Limited, 2013a); Ma Wat River, Fung Kong Stream, Tsung Yuen Stream, Long Valley area (Ove Arup & Partners Hong Kong Limited, 2013b); Fung Lok Wai area (CH2M HILL Hong Kong Limited, 2008); Ping Kong Stream, Ma Tso Lung Stream (DSD, 2021); Pui O Stream, Mai Po area, Pak Tam Chung Stream, Tai O area, Ng Tung River, San Tin area, Sheung Yue River, Ha Shan Kai Wat area, Sandy Ridge Cemetery, Shui Lo Cho Stream, Shan Pui River (GBIF.org, 2021); Pak Long Stream (Tsang & Dudgeon, 2021a); Kam Tin River, Wetland Park, Nam Sang Wai area, Tsing Tai Stream, Yuen Long Bypass Floodway, Mui Wo area, Yi O Stream (current survey).

Native range. South China to (Southeast Asia) and South Asia.

**Remarks.** Abundant and widespread in the northern New Territories; sought-after by anglers.

**Order Cichliformes**

**Family Ambassidae**

***Parambassis ranga***  
(Fig. 25, [LU])



Fig. 25. *Parambassis ranga*, 37.5 mm SL, Kowloon Reception Reservoir.

**Distribution.** Kowloon Reception Reservoir (Lai, 2011 as *Chanda* sp.; current survey); Plover Cove Reservoir (GBIF.org, 2021; current survey); Tai Lam Chung Reservoir (current survey).

**Native range.** (Southeast Asia) and South Asia.

**Remarks.** Popular aquarium fish, often sold injected with fluorescent dye.

#### Family Cichlidae

##### *Amphilophus citrinellus* (Günther) (Fig. 26, [LU])



Fig. 26. *Amphilophus citrinellus*, 79.2 mm SL, Plover Cove Reservoir.

**Distribution.** Plover Cove Reservoir (GBIF.org, 2021; current survey).

**Native range.** Central and South America.

**Remarks.** Common in the aquarium trade.

##### *Amphilophus labiatus* (Günther)

**Distribution.** Plover Cove Reservoir (GBIF.org, 2021; current survey).

**Native range.** Central and South America.

**Remarks.** Breeding populations found in Plover Cove Reservoir but not as abundant as *Amphilophus citrinellus*.

##### *Astronotus ocellatus* (Agassiz) (Fig. 27)



Fig. 27. *Astronotus ocellatus*, Lai King area.

**Distribution.** Black Hill area, Kowloon Reservoir, Plover Cove Reservoir (GBIF.org, 2021); Shing Mun Reservoir; Lai King area (current survey).

**Native range.** Central and South America.

**Remarks.** Popular in the aquarium trade; frequently released in urban ponds. However, breeding populations have never been observed in Hong Kong.

##### *Cichla monoculus* (Spix & Agassiz)

**Distribution.** Shing Mun Reservoir; Kowloon Reservoir (GBIF.org, 2021).

**Native range.** Central and South America.

##### *Cichla temensis* (Humboldt)

**Distribution.** Shing Mun Reservoir (current survey).

**Native range.** Central and South America.

##### *Coptodon zillii* (Gervais) (Fig. 28, [LU])



Fig. 28. *Coptodon zillii*, 102.2 mm SL, Deep Water Bay Stream.

**Distribution.** Shing Mun River (Chan, 2001 as *Tilapia zillii*); High Island Reservoir, Hok Tau Reservoir, Kowloon Reservoir, Lau Shui Heung Reservoir, Plover Cove Reservoir, Pok Fu Lam Reservoir, Kowloon Reception Reservoir, Shek Lei Pui Reservoir, Tai Lam Chung Reservoir (Lai, 2011 as *Tilapia zillii*); Lok Ma Chau Loop, Tse Koo Hang area (Ove Arup & Partners Hong Kong Limited, 2013a as *Tilapia zillii*); Sham Wat River (Mott MacDonald Hong Kong Limited, 2014 as *Tilapia zillii*); Sandy Ridge Cemetery (Ove Arup & Partners Hong Kong Limited, 2016 as *Tilapia zillii*); Lin Fa Tei area (Atkins China Limited, 2020); Nam Sang Wai area (Black & Veatch Hong Kong Limited, 2020a; current survey); Shek Pik Reservoir (AFCD, 2021c); Ma Tso Lung Stream, Ping Yuen River, Yuen Long Bypass Floodway, Ho Chung River, Ma Wat River, Lam Tsuen River, Pak Ngan Heung Stream (DSD, 2021 as *Tilapia zillii*); Tung Chung River (Green Power, 2021); Wetland Park, Shui Lo Cho Stream, Pui O Stream, Shek Lei Pui Reservoir, Shap Long Irrigation Reservoir, Lamma Island area, Ting Kok area, Tai Tam Byewash Reservoir, Tan Shan River, Tai Ho River, Hang Hau Man Kuk Lane Park (GBIF.org, 2021); Deep Water Bay Stream, San Tin area, Ng Tung River, Sheung Yue River, Kam Tin River, Tsing Tai Stream, Shing Mun Reservoir, Lower Shing Mun Reservoir, Lam Tei Irrigation Reservoir, Hung Shui Hang Irrigation Reservoir, Kowloon Byewash Reservoir, Tai Tam Tuk Reservoir, Tai Tam Reservoir, Tai Tam Intermediate Reservoir (current survey).

**Native range.** Africa.

**Remarks.** One of the most widespread cichlids in Hong Kong, thriving in both degraded lowland streams and pristine hill streams. Abundant in reservoirs where they are now found in greater numbers than *Oreochromis* spp.

***Geophagus brasiliensis* (Quoy & Gaimard)**

**Distribution.** Shing Mun Reservoir (GBIF.org, 2021).

**Native range.** Central and South America.

***Hemichromis cf. camerounensis* (Bitja-Nyom, Agnèse, Pariselle, Bilong-Bilong, Gilles & Snoeks)**  
(Fig. 29, [LU])



Fig. 29. *Hemichromis camerounensis*, 86.4 mm SL, Lower Aberdeen Reservoir.

**Distribution.** Lower Aberdeen Reservoir (GBIF.org, 2021; current survey); Upper Aberdeen Reservoir (current survey).

**Native range.** Africa.

**Remarks.** Identified as the newly described *Hemichromis cf. camerounensis* due to the presence of two red opercular spots accompanied by a large black spot, separating it from all other *Hemichromis* species (Bitja-Nyom et al., 2021). However, DNA barcoding of the cytochrome b gene is necessary to confirm its identity, as some populations of *Hemichromis elongatus* are known to have the same feature (Bitja-Nyom et al., 2021).

***Hemichromis fasciatus* (Peters)**

**Distribution.** Tai Lam Chung Reservoir (AFCD, 2021c).

**Native range.** Africa.

***Hemichromis guttatus* (Günther)**  
(Fig. 30, [LU])



Fig. 30. *Hemichromis guttatus*, 66 mm SL, Tai Tam Tuk Reservoir.

**Distribution.** Kowloon Reservoir, Kowloon Reception Reservoir, Kowloon Byewash Reservoir (Mott MacDonald Hong Kong Limited, 2008 as *Hemichromis stellifer*; current survey); Tai O River (Atkins China Limited, 2016 as *Hemichromis stellifer*; Tsang & Dudgeon, 2021a; current survey); Tai Tong area (Ove Arup & Partners Hong Kong Limited, 2017 as *Hemichromis stellifer*); Tai Lam Chung Reservoir (AFCD, 2021c as *Hemichromis stellifer*; current survey); Pui O Stream, Lam Tsuen River (DSD, 2021 as *Hemichromis stellifer*; current survey); Tung Chung River (DSD, 2021 as *Hemichromis stellifer*; Green Power, 2021; current survey); Mui Tsz Lam Stream, Aberdeen Lower Reservoir, Shing Mun River (GBIF.org, 2021); Wong Lung Hang Stream, Sha Lo Wan Stream, Sham Wat River, Pak Tin area (Tai Wai) (Tsang & Dudgeon, 2021a as *Hemichromis stellifer*); Deep Water Bay Stream, San Tau Stream, Tai Tam Tuk Reservoir, Tai Tam Reservoir, Tai Tam Byewash Reservoir, Tai Tam Intermediate Reservoir, Wong Nai Chung Reservoir, Lam Tei Irrigation Reservoir, Hung Shui Hang Irrigation Reservoir, Hok Tau Reservoir, Lau Shui Heung Reservoir, Aberdeen Upper Reservoir, Pok Fu Lam Reservoir, Lower Shing Mun Reservoir, Shing Mun Reservoir, Shek Lei Pui Reservoir (current survey).

**Native range.** Africa.

**Remarks.** Previously misidentified as *Hemichromis stellifer* in Hong Kong. It occupies a wide range of habitats but tends to thrive in unpolluted and well-oxygenated streams. Unlike most other non-native fish species, *Hemichromis guttatus* has penetrated further upstream (over 150 m above sea level), in a similar manner to *Xiphophorus hellerii*.

***Herichthys cf. carpintis* (Jordan & Snyder)**  
(Fig. 31.)



Fig. 31. *Herichthys cf. carpintis*, Shing Mun Reservoir.

**Distribution.** Shing Mun Reservoir (current survey).

**Native range.** North America.

**Remarks.** The individual recorded from Shing Mun Reservoir resembles a variant of the ‘Aztec’ strain *Herichthys carpintis*, but DNA barcoding was inconclusive. Barcoding of other genes is necessary for confident species identification.

***Herichthys cyanoguttatus* (Baird & Girard)**

**Distribution.** Kai Tak River (GBIF.org, 2021).

**Native range.** Texas, North America.

***Heros efasciatus* (Heckel)**

**Distribution.** Aberdeen Lower Reservoir (GBIF.org, 2021).

**Native range.** Central and South America.

***Heterotilapia buttikoferi* (Hubrecht)**

(Fig. 32, [LU])



Fig. 32. *Heterotilapia buttikoferi*, 93.9 mm SL, Tai Tam Tuk Reservoir.

**Distribution.** Kowloon Byewash Reservoir (Mott MacDonald Hong Kong Limited, 2008 as *Tilapia joka*; current survey); Plover Cove Reservoir (Lai, 2011 as *Tilapia buttikoferi*; GBIF.org, 2021; current survey); Lai Chi Kok Park, Aberdeen Lower Reservoir, Tai Tam Tuk Reservoir, Shing Mun Reservoir (GBIF.org, 2021; current survey); Lok Ma Chau area, Aberdeen Upper Reservoir (current survey).

**Native range.** Africa.

***Labidochromis caeruleus* (Fryer)**

**Distribution.** Plover Cove Reservoir; Kowloon Reservoir (current survey).

**Native range.** Africa (Lake Malawi endemic).

**Remarks.** One of the most commonly sold ornamental cichlids in Hong Kong. However, they are rarely recorded in the wild.

***Maylandia lombardoi* (Burgess)**

**Distribution.** Shing Mun Reservoir (current survey).

**Native range.** Africa (Lake Malawi endemic).

**Remarks.** As with *Labidochromis caeruleus*, it is one of the most commonly sold ornamental cichlids in Hong Kong, but is rarely recorded in the wild.

***Melanochromis auratus* (Boulenger)**

**Distribution.** Unknown.

**Native range.** Africa (Lake Malawi endemic).

**Remarks.** No location data was provided by AFCD (2021a).

***Mesonauta festivus* (Heckel)**

**Distribution.** Aberdeen Lower Reservoir (GBIF.org, 2021).

**Native range.** Central and South America.

***Oreochromis aureus* (Steindachner)**

(Fig. 33 [LU])



Fig. 33. *Oreochromis aureus*, 330.1 mm SL, Tung Tsz Stream.

**Distribution.** She Shan River, Lai Chi Kok Park (GBIF.org, 2021); Tung Tsz Stream (current survey)

**Native range.** Africa.

**Remarks.** Not as widespread as other *Oreochromis* spp., but the frequency of records has risen in recent years. It differs from the morphologically similar *Oreochromis niloticus* by having faint variable bars on the caudal fin as opposed to regular dark vertical bar, and pink-red margins (Trewavas, 1983). Juveniles have a black spot at the rear of the dorsal fin, which is absent in *Oreochromis niloticus* (Gu et al., 2016). This species may also resemble *Oreochromis niloticus* × *Oreochromis mossambicus* hybrids, which can be preliminarily differentiated from them by the presence of blue spots on the dorsal and caudal fins and blue colouration of the snout in *Oreochromis aureus*.

***Oreochromis mossambicus* (Peters)**

(Fig. 34, [LU])



Fig. 34. *Oreochromis mossambicus*, breeding males, Ting Kok area, photographed by Tommy C.H. Hui.

**Distribution.** Plover Cove Reservoir (Man & Hodgkiss, 1977 as *Sarotherodon mossambicus*; Man & Hodgkiss,

1981 as *Sarotherodon mossambicus*; Dudgeon, 1983 as *Sarotherodon mossambicus*) Lamma Island area, Luk Keng area, Pui O area, Sham Chung area, Sha Lo Tung area (Dudgeon & Chan, 1996 as *Sarotherodon mossambicus*); Lok Ma Chau area, San Tin area (Environmental Resources Management Hong Kong Limited, 1999a as *Sarotherodon mossambicus*); Lam Tei area (Environmental Resources Management Hong Kong Limited, 1999b as *Sarotherodon mossambicus*); Pun Chun Yuen Stream, Lam Tsuen River (Mott Connell Limited, 2000 as *Sarotherodon mossambicus*); Tai Chung Hau area, Shuen Wan area, Lin Ma Hang Stream, Sandy Ridge Cemetery, Sha Ling area, Loi Tung area, Sheung Wo Hang, Tai Tong area, Cheung Po Stream, Wang Tong area, Sham Wat River (Chan, 2001 as *Sarotherodon mossambicus*); Tai O River (Ove Arup & Partners Hong Kong Limited, 2002 as *Sarotherodon mossambicus*); Sha Ha Stream, Pak Kong River (Maunsell Consultants Asia Limited, 2004 as *Sarotherodon mossambicus*); Sam Dip Tam Stream, Tso Kung Tam Stream (Mott Connell Limited, 2005 as *Sarotherodon mossambicus*); Luk Tei Tong River (Maunsell Consultants Asia Limited, 2005a as *Sarotherodon mossambicus*); Lam Tin area (Maunsell Consultants Asia Limited, 2005b as *Sarotherodon mossambicus*); Siu Ma Shan area (Black & Veatch Hong Kong Limited, 2006 as *Sarotherodon mossambicus*); Nam Long Shan area (within Ocean Park) (Maunsell Environmental Management Consultants Limited, 2006 as *Sarotherodon mossambicus*); Kam Tin River (Black & Veatch Hong Kong Limited, 2005 as *Sarotherodon mossambicus*; DSD, 2021; current survey); Man Uk Pin Stream (Black & Veatch Hong Kong Limited, 2007); Mai Po Nature Reserve (WWF, 2006; WWF, 2021); Wo Shang Wai area (Mott Connell Limited, 2008); Fung Lok Wai area (CH2M HILL Hong Kong Limited, 2008); Tsang Tsui area (Metcalf & Eddy Limited, 2008); Sha Lo Wan area, Pak Mong area (Ove Arup & Partners Hong Kong Limited, 2009); Big Wave Bay Stream (DSD, 2010); Hok Tau Reservoir, Kowloon Reservoir, Pok Fu Lam Reservoir, Shek Lei Pui Reservoir, Tai Tam Tuk Reservoir (Lai, 2011); Tei Lung Hau area (Ove Arup & Partners Hong Kong Limited, 2011); Kong Nga Po area (Mott MacDonald Hong Kong Limited, 2013); Fanling area, Kwu Tung area (Ove Arup & Partners Hong Kong Limited, 2013b); Cheung Chau Island (Atkins China Limited, 2013); Tai Sheung Tok area (Ove Arup & Partners Hong Kong Limited, 2014); Tseng Lan Shue area (Black & Veatch Hong Kong Limited, 2018); Nam Sang Wai area (Black & Veatch Hong Kong Limited, 2020a); Nam Wa Po area (DSD, 2020); Nai Chung Stream (AECOM Asia Company Limited, 2021b); Tai Po Kau Nature Reserve (AFCD, 2021c); Ma Wat River, Ping Yuen River, Ngong Ping Stream, Ma Tso Lung Stream, Tong Fuk River, Ho Chung River, Pak Ngan Heung Stream, Ngau Tam Mei River, Yuen Long Bypass Floodway, Deep Water Bay Stream, Ping Kong Stream, Cheung Po Stream, Wong Lung Hang Stream, Tai Tei Tong Stream, Shek Kong Stream, Sai Kung River, Fo Tan Nullah, Pui O Stream (DSD, 2021); Tai Po River, Lions Nature Education Centre, Kwu Tung Reservoir, Kwun Yam Shan Stream, Kowloon Reception Reservoir (GBIF.org, 2021); Tung Chung River (Green Power, 2021); Waterfall Bay Stream, Sha Po area, Lau Shui Heung Reservoir, Tai Lam Chung Reservoir, Shing

Mun Reservoir, Shap Long Irrigation Reservoir, Kai Tak River, Kowloon Byewash Reservoir, Kai Tak River; Ting Kok area (current survey).

**Native range.** Africa.

**Remarks.** First imported into Hong Kong as aquarium specimens during the 1940s, with further imports for the development of aquaculture in the 1950s (Man, 1974). It has been released in various reservoirs around Hong Kong by the local government. It is presently abundant and widespread in polluted river channels in the New Territories. However, many localities where *Oreochromis mossambicus* was historically recorded (especially reservoirs) are now dominated by *O. niloticus* and *Coptodon zillii*. *Oreochromis mossambicus* differs from other members of the genus in that females and non-breeding males are silver-coloured with 2–5 mid-lateral black blotches and occasionally black dorsal bars; breeding males are all black except for a pale patch on the operculum, and red margins on the dorsal and caudal fins (Trewavas, 1983).

***Oreochromis niloticus* (Linnaeus)**  
(Fig. 35, [LU])



Fig. 35. *Oreochromis niloticus*, 150.3 mm SL, Kowloon Reservoir.

**Distribution.** Tai Chung Hau area, Lam Tsuen River, Kau Lung Hang Lo Wai area, Shuen Wan area, Sha Ling area, Tan Shan River, Pui O Stream, Tong Fuk River, Tai O River, Tai Ho River (Chan, 2001); Lung Mei area (Halcrow China Limited, 2007); Fung Lok Wai area (CH2M HILL Hong Kong Limited, 2008); Tsang Tsui area (Metcalf & Eddy Limited, 2008); Sha Lo Wan area (Ove Arup & Partners Hong Kong Limited, 2009); Big Wave Bay Stream (DSD, 2010; current survey); Kong Nga Po area (Mott MacDonald Hong Kong Limited, 2013); Fanling area, Kwu Tung area (Ove Arup & Partners Hong Kong Limited, 2013b); Ho Pui Reservoir, Hok Tau Reservoir, Shing Mun Reservoir, Kowloon Reservoir, Plover Cove Reservoir, Pok Fu Lam Reservoir, Kowloon Reception Reservoir, Shek Lei Pui Reservoir (Lai, 2011; current survey); Sandy Ridge Cemetery (Ove Arup & Partners Hong Kong Limited, 2016); Mui Tsz Lam stream (AECOM Asia Company Limited, 2016a); Hung Shui Kiu area (AECOM Asia Company Limited, 2016b); Shan Ha Tsuen area, Muk Kiu Tau Tsuen area, Tai Tong area (Ove Arup & Partners Hong Kong Limited, 2017); Sung Shan New Village, Lin Fa Tei area, Ha Che area (Atkins China Limited, 2020); Yuen Long Town Nullah (Black & Veatch Hong Kong Limited, 2020a); Hong Po Road area (Black & Veatch Hong Kong Limited, 2020b); Nam Wa Po area

(DSD, 2020); Shek Kiu Tau area (Mott MacDonald Hong Kong Limited, 2020); Pak Tin area (Tai Wai) (AECOM Asia Company Limited, 2021a); Lau Shui Heung Reservoir (AFCD, 2021c); Ma Wat River, Ping Yuen River, Pak Ngan Heung Stream, Ma Tso Lung Stream, Ngau Tam Mei River, Yuen Long Bypass Floodway, Ho Chung River, Kam Tin River, Ping Kong Stream, Cheung Po Stream, Wong Lung Hang Stream, Tai Tei Tong Stream, Shek Kong Stream, Ho Pui River, Deep Water Bay Stream (DSD, 2021); Wetland Park, Hang Tau area, Tin Shui Wai Park, Tai Po Kau Nature Reserve, Sheung Yue River, Tin Shui Wai River, She Shan River, Ting Kok area, Nam Sang Wai area, San Tin area, Kai Tak River, High Island Reservoir, Hung Shui Hang Irrigation Reservoir, Shan Pui River (GBIF.org, 2021); Tung Chung River (Green Power, 2021; current survey); Mai Po Nature Reserve (WWF, 2021); Kowloon Byewash Reservoir; Lam Tei Irrigation Reservoir, Tai Shui Hang area, Aberdeen Lower Reservoir, Aberdeen Upper Reservoir, Tai Tam Reservoir, Tai Tam Tuk Reservoir, Tai Tam Byewash Reservoir, Tai Tam Intermediate Reservoir (current survey).

**Native range.** Africa.

**Remarks.** The introduction of this species has not been as well documented as that of *O. mossambicus*. However, this species may have been misidentified as *O. mossambicus* in earlier studies. Presently, *O. niloticus* appears to be relatively abundant and has replaced *O. mossambicus* in numerous habitats. It differs from other *Oreochromis* spp. in that the caudal fin has black bars, and the upper margin of the dorsal fin is black or grey and never entirely fringed with red as in *O. mossambicus*, *O. aureus*, or hybrids (Trewavas, 1983).

#### *Oreochromis mossambicus* × *O. niloticus* hybrid

**Distribution.** Tung Chung River, Pak Ngan Heung Stream, Shing Mun Reservoir, Lower Shing Mun Reservoir, Sha Kok Mei area, Tung Tsz Stream, Pui O Stream, Ting Kok area, Wang Tong River, Kai Tak River, Wong Lung Hang Stream, Shan Pui River, Tai O River, Po Toi Island, Lions Nature Education Centre, Big Wave Bay Stream, Tai Chung Hau area (H.T. Cheng, pers. comm., 2021); Sheung Yue River, Ho Chung River, Tai Shui Hang area (current survey).

**Remarks.** This hybrid is likely more widespread than currently reported, given that its morphological similarity to both parent species increases the likelihood of misidentification (Van der Bank & Deacon, 2007). While genetic analyses are the most effective mode of verification, hybrids can also be recognised by breeding males that do not turn completely black (usually dark grey), and the caudal fins with black bars and red margins (Tan et al., 2020).

#### *Oreochromis niloticus* × *O. aureus* hybrid (Fig. 36, [LU])



Fig. 36. *Oreochromis niloticus* × *O. aureus* hybrid, 128.8 mm SL, Pui O Stream.

**Distribution.** Pui O Stream (current study).

**Remarks.** A single hybrid (100% DNA match) was collected from Pui O Stream.

#### *Parachromis managuensis* (Günther) (Fig. 37, [LU])



Fig. 37. *Parachromis managuensis*, 35.1 mm SL, Plover Cove Reservoir.

**Distribution.** Plover Cove Reservoir (GBIF.org, 2021; current survey).

**Native range.** Central and South America.

#### *Pelmatolapia mariae* (Boulenger)

**Distribution.** Tai Lam Chung Reservoir (AFCD, 2021c); Pak Ngan Heung Stream (DSD, 2021); Ting Kok area (GBIF.org, 2021; current survey).

**Native range.** Africa.

#### *Vieja bifasciata* (Steindachner) (Fig. 38, [LU])



Fig. 38. *Vieja bifasciata*, 103.6 mm SL, Tai Tam Tuk Reservoir.

**Distribution.** Tai Tam Reservoir, Tai Tam Byewash Reservoir (GBIF.org, 2021; current survey); Hok Tau Reservoir; Tai Tam Tuk Reservoir (current survey).

**Native range.** Central and South America.

***Vieja fenestrata* (Günther)**  
(Fig. 39, [LU])



Fig. 39. *Vieja fenestrata*, 103.6 mm SL, Hok Tau Reservoir.

**Distribution.** Pak Ngan Heung Stream, Lam Tsuen River (DSD, 2021); Plover Cove Reservoir, Ng Tung River, Sheung Yue River, Aberdeen Lower Reservoir, Kwu Tung Reservoir, Tan Shan River, Shing Mun Reservoir, Kowloon Reception Reservoir (GBIF.org, 2021; current survey); Duck Pool (Kwan Tei North), Yung Shue O Stream, Aberdeen Upper Reservoir, Tai Lam Chung Reservoir, Pok Fu Lam Reservoir, Tai Tam Byewash Reservoir, High Island Reservoir (H.T. Cheng, pers. comm., 2021); Hok Tau Reservoir, Lower Shing Mun Reservoir (current survey).

**Native range.** Central and South America.

***Vieja melanurus* (Günther)**  
(Fig. 40)



Fig. 40. *Vieja melanurus*, Lai King area.

**Distribution.** Plover Cove Reservoir (GBIF.org, 2021); Lower Shing Mun Reservoir (GBIF.org, 2021); Lai King area (current survey).

**Native range.** Central and South America.

***Vieja zonata* (Meek)**

**Distribution.** Lam Tei Irrigation Reservoir (GBIF.org, 2021); Hung Shui Hang Irrigation Reservoir, Tin Shui Wai River (H.T. Cheng, pers. comm., 2021).

**Native range.** Central and South America.

**Blood-red Parrot Cichlid**

**Distribution.** Ng Tung River, Kowloon Reservoir, Shing Mun Reservoir (GBIF.org, 2021).

**Remarks.** This is a hybrid between *Amphilophus citrinellus* × *Vieja melanurus*, which is popular in the aquarium trade.

**Flowerhorn Cichlid**

**Distribution.** Ting Kok area (current survey).

**Remarks.** Likely a hybrid between *Amphilophus labiatus* × *Cichlasoma trimaculatum*, which is popular in the aquarium trade. However, it is possible for other cichlids to be crossed, which may give rise to various forms.

**Order Atheriniformes**

**Family Melanotaeniidae**

***Melanotaenia trifasciata* (Rendahl)**  
(Fig. 41)



Fig. 41. *Melanotaenia trifasciata*, Black Hill.

**Distribution.** Black Hill area (current survey).

**Native range.** Australasia.

**Remarks.** A single individual recorded in a hill stream on Black Hill is likely a released aquarium specimen as it is commonly sold in Hong Kong.

**Order Cyprinodontiformes**

**Family Aplocheilidae**

***Aplocheilus lineatus* (Valenciennes)**  
(Fig. 42, [LU])



Fig. 42. *Aplocheilus lineatus*, 54.5 mm SL, Deep Water Bay Stream.

**Distribution.** Deep Water Bay Stream (current survey).

**Native range.** India and Sri Lanka, South Asia.

**Remarks.** Found to have a sizable breeding population in a man-made pond in Deep Water Bay Stream in 2020 to 2021. However, it was not recorded during subsequent surveys in 2022.

#### Family Poeciliidae

##### *Gambusia affinis* (Baird & Girard) (Fig. 43, [LU])



Fig. 43. *Gambusia affinis*, 23.9 mm SL female (top), Lam Tsuen River, 18.2 mm SL male (bottom), Lin Au Stream.

**Distribution.** Lamma Island area, Luk Tei Tong area, Luk Keng area, Pui O area, Sham Chung area, Sha Lo Tung area (Dudgeon & Chan, 1996); Lok Ma Chau area (Environmental Resources Management Hong Kong Limited, 1999a); Lam Tei area (Environmental Resources Management Hong Kong Limited, 1999b); Pun Chun Yuen Stream, Lam Tsuen River (Mott Connell Limited, 2000); Tai Chung Hau area, Shuen Wan area, Lin Ma Hang Stream, Sandy Ridge Cemetery, Sha Ling area, Loi Tung area, Sheung Wo Hang Stream, Tai Tong area, Cheung Po Stream, Wang Tong River, Sham Wat Stream (Chan, 2001); Tai O River (Ove Arup & Partners Hong Kong Limited, 2002); Sha Ha Stream, Pak Kong River (Maunsell Consultants Asia Limited, 2004); Kam Tin River (Black & Veatch Hong Kong Limited, 2005; DSD, 2021); Sam Dip Tam Stream, Tso Kung Tam Stream (Mott Connell Limited, 2005); Luk Tei Tong River (Maunsell Consultants Asia Limited, 2005a); Lam Tin area (Maunsell Consultants Asia Limited, 2005b); Siu Ma Shan area (Black & Veatch Hong Kong Limited, 2006); Nam Long Shan area (within Ocean Park) (Maunsell Environmental Management Consultants Limited, 2006); Mai Po Nature Reserve (WWF, 2006; WWF, 2021); Man Uk Pin Stream (Black & Veatch Hong Kong Limited, 2007); Lung Mei area (Halcrow China Limited, 2007); Wo Shang Wai area (Mott Connell Limited, 2008); Fung Lok Wai area (CH2M HILL Hong Kong Limited, 2008); Tsang Tsui area (Metcalf & Eddy Limited, 2008); Sha Lo Wan area, Pak Mong area (Ove Arup & Partners Hong Kong Limited, 2009); Big Wave Bay Stream (DSD, 2010); Hok Tau Reservoir, Kowloon Reservoir, Pok Fu Lam Reservoir, Shek Lei Pui Reservoir, Tai Tam Tuk Reservoir (Lai, 2011; current survey); Tei Lung Hau area (Ove Arup & Partners Hong Kong Limited, 2011); Kong Nga Po area (Mott MacDonald Hong Kong Limited, 2013); Fanling area, Kwu Tung area (Ove Arup & Partners Hong Kong Limited, 2013b); Cheung Chau Island area (Atkins China Limited, 2013); Tai Sheung Tok area (Ove Arup &

Partners Hong Kong Limited, 2014); Muk Kiu Tau Tsuen area, Nam Hang Pai area, Shan Ha Tsuen area, Lam Hau Tsuen area, Shap Pat Heung area, Shek Tong Tsuen area (Ove Arup & Partners Hong Kong Limited, 2017); Tseng Lan Shue area (Black & Veatch Hong Kong Limited, 2018); Nam Sang Wai area (Black & Veatch Hong Kong Limited, 2020a; current survey); Nam Wa Po area (DSD, 2020); Pak Tin area (Tai Wai) (AECOM Asia Company Limited, 2021a); Nai Chung Stream (AECOM Asia Company Limited, 2021b); Tai Po Kau Nature Reserve (AFCD, 2021c); Ma Wat River, Ping Yuen River, Ngong Ping Stream, Ma Tso Lung Stream, Tong Fuk River, Ho Chung River, Pak Ngan Heung Stream, Ngau Tam Mei River, Yuen Long Bypass Floodway, Deep Water Bay Stream, Ping Kong Stream, Wong Lung Hang Stream, Tai Tei Tong Stream, Shek Kong Stream, Sai Kung River, Fo Tan Nullah (DSD, 2021); Tai Po River, Lions Nature Education Centre, Lamma Island area, Kwu Tung Reservoir, San Tin area, Kwun Yam Shan Stream, Kowloon Reception Reservoir (GBIF.org, 2021); Tung Chung River (Green Power, 2021; current survey); Little Hawaii Stream, Fung Yuen Stream, Tung Tsz Stream, Kau Lung Hang Lo Wai Stream, Heung Yuen Wai Stream, Tsing Tam Tsuen Stream, Yeung Ka Tsuen Stream, So Kwun Wat Stream (Tsang & Dudgeon, 2021a); Waterfall Bay Stream, Sha Po area, Lau Shui Heung Reservoir, Tai Lam Chung Reservoir, Shing Mun Reservoir, Plover Cove Reservoir, Shap Long Irrigation Reservoir, Hung Shui Hang Irrigation Reservoir, Lam Tei Irrigation Reservoir, Ho Pui Reservoir, Kowloon Byewash Reservoir, Kai Tak River, Aberdeen Lower Reservoir, Aberdeen Upper Reservoir, Wong Nai Chung Reservoir, Tai Tam Reservoir, Tai Tam Byewash Reservoir, Tai Tam Intermediate Reservoir, High Island Reservoir, Wong Nai Tun Irrigation Reservoir, Sham Tseng Settlement Basin, Shek Pik Reservoir, Yi O Stream, Kau Ling Chung Stream (current survey).

**Native range.** Central and North America.

**Remarks.** The most widespread non-native fish in Hong Kong, and was released by the Hong Kong Government for mosquito control around 1940 (Dudgeon & Corlett, 2004).

##### *Poecilia reticulata* (Peters) (Fig. 44, [LU])

**Distribution.** Lam Tsuen River, Shuen Wan area, Wang Tong River, Sha Lo Wan Stream, (Chan, 2001); Fung Yuen area (Mouchel Asia Limited, 2002); Tai Po Tsai area (Allied Environmental Consultants Limited, 2004); Lam Tin area (Maunsell Consultants Asia Limited, 2005b); Man Uk Pin Stream (Black & Veatch Hong Kong Limited, 2007); Lung Mei area (Halcrow China Limited, 2007); Ping Yuen River (Ove Arup & Partners Hong Kong Limited, 2007); Fanling area, Kwu Tung area (Ove Arup & Partners Hong Kong Limited, 2013b); Cheung Chau Island area (Atkins China Limited, 2013); Sandy Ridge Cemetery (Ove Arup & Partners Hong Kong Limited, 2016); Muk Kiu Tau Tsuen area, Tai Tong area, Shan Ha Tsuen area (Ove Arup & Partners Hong Kong Limited, 2017); Lai Chi Wo area (So, 2019); Sung Shan New Village area, Lin Fa Tei area, Ha Che area (Atkins



Fig. 44. *Poecilia reticulata*, 24.8 mm SL female (top), 18.1 mm SL wild-type male (middle), Lin Au Stream, 19 mm SL ornamental male (bottom), Lohas Park.

China Limited, 2020); Pak Tin area (Tai Wai), Pok Hong area, Chun Shek area (AECOM Asia Company Limited, 2021a); Sha Lo Tung Stream, Tai Po Kau Nature Reserve, Shap Long Irrigation Reservoir (AFCD, 2021c; current survey); Pak Ngan Heung Stream, Pui O Stream, Wong Lung Hang Stream, Tai Tei Tong Stream, Ngong Ping Stream, Shek Kong Stream (DSD, 2021); Lion's Nature Education Centre, Mui Tsz Lam Stream, Ha Wo Hang area, Ng Tung River, Tung Ma To Stream (GBIF.org, 2021); Tung Chung River (Green Power, 2021; current survey); Little Hawaii Stream, Tai Tung Wo Liu Stream, Man Hang Stream, Sam Dip Tam Stream, Tung Tsz Stream, Kau Lung Hang Lo Wai Stream, Tsing Tam Tsuen Stream, Tsui Keng area, So Kwun Wat Stream, Pak Long Stream (Tsang & Dudgeon, 2021a); Deep Water Bay Stream (current survey).

**Native range.** Central and South America.

**Remarks.** This species was introduced alongside *Gambusia affinis* by the Hong Kong Government for mosquito control around 1940 (Dudgeon & Corlett, 2004). Escapees or discards from the aquarium trade and individuals released during Buddhist rituals may have also contributed to their establishment in many parts of Hong Kong (Tricarico et al., 2016). However, this species appears to be less widespread than it was in the 1980s.

***Poecilia wingei* (Poeser, Kempkes & Isbrücker)**  
(Fig. 45.)



Fig. 45. *Poecilia wingei*, Sha Po area.

**Distribution.** Tsing Yi area, Sha Tin area (GBIF.org, 2021); Sha Po area (current survey).

**Native range.** Central and South America.

**Remarks.** Common in the aquarium trade.

***Poecilia salvatoris* (Regan)**  
(Fig. 46, [LU])



Fig. 46. *Poecilia salvatoris*, 30 mm SL female (top), Lam Tsuen River, 30 mm SL male (bottom), Sam Dip Tam Stream.

**Distribution.** Lam Tsuen River (DSD, 2021; current survey); Sam Dip Tam Stream, Tung Tsz Stream (Tsang & Dudgeon, 2021a; current survey).

**Native range.** Central and South America.

**Remarks.** Most abundant in a rocky hillstream (Sam Dip Tam Stream).

***Poecilia sphenops* (Valenciennes)**  
(Fig. 47.)



Fig. 47. *Poecilia sphenops* (melanistic variety), Lam Tsuen River, note damaged dorsal fin, photographed by Chun Hin Wan.

**Distribution.** Lam Tsuen River (Chan, 2001; C.H. Wan, pers. comm., 2021).

**Native range.** Central and South America.

**Remarks.** Has only been recorded twice, twenty years apart. It is scarce in the wild despite its prevalence in the local aquarium trade, suggesting that it has difficulty establishing itself.

***Xiphophorus hellerii* (Heckel)**  
(Fig. 48, [LU])



Fig. 48. *Xiphophorus hellerii*, 34.8 mm SL female (top), 35.1 mm SL male (middle), Wong Lung Hang Stream, 38.8 mm SL red-variety male (bottom), Tai Po Kau Nature Reserve.

**Distribution.** Lam Tsuen River (Chan, 2011; current survey) Shuen Wan area, Wang Tong River, Sha Lo Wan Stream (Chan, 2001); Fung Yuen area (Mouchel Asia Limited, 2002); Tai Po Tsai area (Allied Environmental Consultants Limited, 2004); Luk Tei Tong River (Maunsell Consultants Asia Limited, 2005a); Lung Mei area (Halcrow China Limited, 2007); Ping Yuen River (Ove Arup & Partners Hong Kong Limited, 2007); Tei Lung Hau area (Ove Arup & Partners Hong Kong Limited, 2011); Fanling area (Ove Arup & Partners Hong Kong Limited, 2013b); Tai O River (Atkins China Limited, 2016); Lai Chi Wo area (So, 2019); Sung Shan New Village area, Ha Che area (Atkins China Limited, 2020); Sha Lo Tung Stream, Tai Po Kau Nature Reserve, Shap Long Irrigation Reservoir (AFCD, 2021c; current study); Pak Ngan Heung Stream, Pui O Stream, Wong Lung Hang Stream, Tai Tei Tong Stream, Ngong Ping Stream, Shek Kong Stream (DSD, 2021); Lion's Nature Education Centre, Tung Tsz Stream, Mui Tsz Lam Stream, Ha Wo Hang area, Ng Tung River, Tung Ma To Stream (GBIF.org, 2021); Tung Chung River (Green Power, 2021; current survey); Little Hawaii Stream, Ho Chung River, Tai Chung Hau Stream, Tai Mong Tsai Stream, Hoi Ha Stream, Tai Tung Wo Liu Stream, Pak Tin area (Tai Wai), Yuen

Tun Ha Stream, She Shan River, Sam Dip Tam Stream, Kau Lung Hang Lo Wai Stream, Tan Shan River, Tsing Tam Tsuen Stream (Tsang & Dudgeon, 2021a); Deep Water Bay Stream (current survey).

**Native range.** Central and South America.

**Remarks.** Pathways of introduction include Buddhist release rituals and/or discarded pets from the aquarium trade (Tricarico et al., 2016). Aquarium cultivars (Fig 48, red-variety), of this species were encountered during the current study, indicating that they are still being actively released. This species is more widespread and abundant than *Gambusia affinis* in relatively unpolluted lowland streams (Tsang & Dudgeon, 2021a).

***Xiphophorus maculatus* (Günther)**

**Distribution.** Wong Lung Hang Stream, Tan Shan River, Sam Dip Tam Stream, Kau Lung Hang Lo Wai Stream, Fung Yuen Stream (Tsang & Dudgeon, 2021a); Tai Po Tsai area, Deep Water Bay area (H.T. Cheng, pers. comm., 2021); Shui Hau Stream (current survey).

**Native range.** Central and South America.

**Remarks.** Breeding populations (wild-type) have been found only in the Tan Shan River, while other populations comprised only of freshly released ornamental variants. These fish are usually sold as live fish food but have also been sold for use in Buddhist release rituals.

***Xiphophorus variatus* (Meek)**  
(Fig. 49, [LU])



Fig. 49. *Xiphophorus variatus*, 37.2 mm SL female (top), 27.7 mm SL male (bottom), Wong Lung Hang Stream.

**Distribution.** Ho Chung River, Hoi Ha Stream, Shap Sze Heung area, Lam Tsuen River, Kau Lung Hang Lo Wai Stream, Wang Tong River (Chan, 2001); Sha Ha Stream (Maunsell Consultants Asia Limited, 2004); Sam Dip Tam Stream, Tso Kung Tam Stream (Mott Connell Limited,

2005); Lung Mei area (Halcrow China Limited, 2007); Big Wave Bay Stream (DSD, 2010); Tai Tam Tuk Reservoir (Lai, 2011); Pok Fu Lam Reservoir (Lai, 2011; GBIF.org, 2021); Tei Lung Hau area (Ove Arup & Partners Hong Kong Limited, 2011); Tai Sheung Tok area (Ove Arup & Partners Hong Kong Limited, 2014); Mui Tsz Lam stream (AECOM Asia Company Limited, 2016a; current survey); Hung Shui Kiu area (AECOM Asia Company Limited, 2016b); Tai O River (Atkins China Limited, 2016; current survey); Tseng Lan Shue area (Black & Veatch Hong Kong Limited, 2018); Ha Che area (Atkins China Limited, 2020); Pak Tin area (Tai Wai) (AECOM Asia Company Limited, 2021a); Sha Lo Tung Stream (AFCD, 2021c); Sai Kung River, Wong Lung Hang Stream, Pak Ngan Heung Stream, Tai Tei Tong Stream, Cheung Po Stream, Shek Kong Stream (DSD, 2021); Fung Yuen area, Chuen Lung area, Sha Kok Mei area, Pui O Stream, Tung Ma To Stream (GBIF.org, 2021); Tung Chung River (Green Power, 2021; current survey); Little Hawaii Stream, Tai Chung Hau Stream, Hoi Ha Stream, Tai Lung Wo Liu Stream, Yuen Tun Ha Stream, She Shan River, Tung Tsz Stream, Tan Shan River, Tsing Tam Tsuen Stream (Tsang & Dudgeon, 2021a); Tong Fuk River, Deep Water Bay Stream (current survey).

**Native range.** Central and South America.

**Remarks.** Often coexists with *Xiphophorus hellerii* in Hong Kong streams.

#### Order Beloniformes

##### Family Hemiramphidae

##### *Hyporhamphus intermedius* (Cantor)

(Fig. 50, [LU])



Fig. 50. *Hyporhamphus intermedius*, 118.2 mm SL, Tai Lam Chung Reservoir.

**Distribution.** Plover Cove Reservoir; Tai Lam Chung Reservoir (current survey).

**Native range.** Northwest Pacific, including South China (East Asia).

**Remarks.** Individuals DNA sequenced from both localities revealed a 4.1% divergence from *Hyporhamphus intermedius*, indicating it could be a different species despite morphological similarities. Integrative taxonomic work and genetic sampling from this genus is necessary for further verification.

#### *Xenentodon cancila* (Hamilton)

**Distribution.** Kowloon Reservoir (Lai, 2011; GBIF.org, 2021); Kowloon Byewash Reservoir (GBIF.org, 2021).

**Native range.** South Asia.

#### Order Centrarchiformes

##### Family Centrarchidae

##### *Micropterus salmoides* (Lacepède)

(Fig. 51, [LU])



Fig. 50. *Micropterus salmoides*, Lam Tei Irrigation Reservoir.

**Distribution.** Tai Tam Reservoir (Man & Hodgkiss, 1981); Ho Pui Reservoir (Lai, 2011); Hok Tau Reservoir (Lai, 2011; AFCD, 2021c); Lau Shui Heung Reservoir (AFCD, 2021c); Hung Shui Hang Irrigation Reservoir, Lam Tei Irrigation Reservoir; Kwu Tung Reservoir, Tai Tam Intermediate Reservoir, Plover Cove Reservoir (GBIF.org, 2021; current survey); Shing Mun Reservoir (current survey).

**Native range.** North America.

**Remarks.** First released into some local reservoirs for angling purposes around 1935 (Law, 2006) and still has breeding populations.

#### DISCUSSION

**Composition of non-native freshwater fishes in Hong Kong.** A total of 95 non-native freshwater fishes (and five putative hybrids) were recorded, half of which were associated with breeding populations. Cichlidae, Cyprinidae, Poeciliidae, and Xenocyprididae were the most speciose families, resembling reports from mainland China (Xiong et al., 2015) and Singapore (Tan et al., 2020). Cichlids and cyprinids were similarly dominant in the Philippines (Cagauan, 2007). Most non-native fishes entered Hong Kong via the aquarium trade (64 species) or aquaculture (23 species). This is again similar to findings from the Philippines (Cagauan, 2007), mainland China (Xiong et al., 2015) and Singapore (Tan et al., 2020), as well as the United States (Nico & Fuller, 1999).

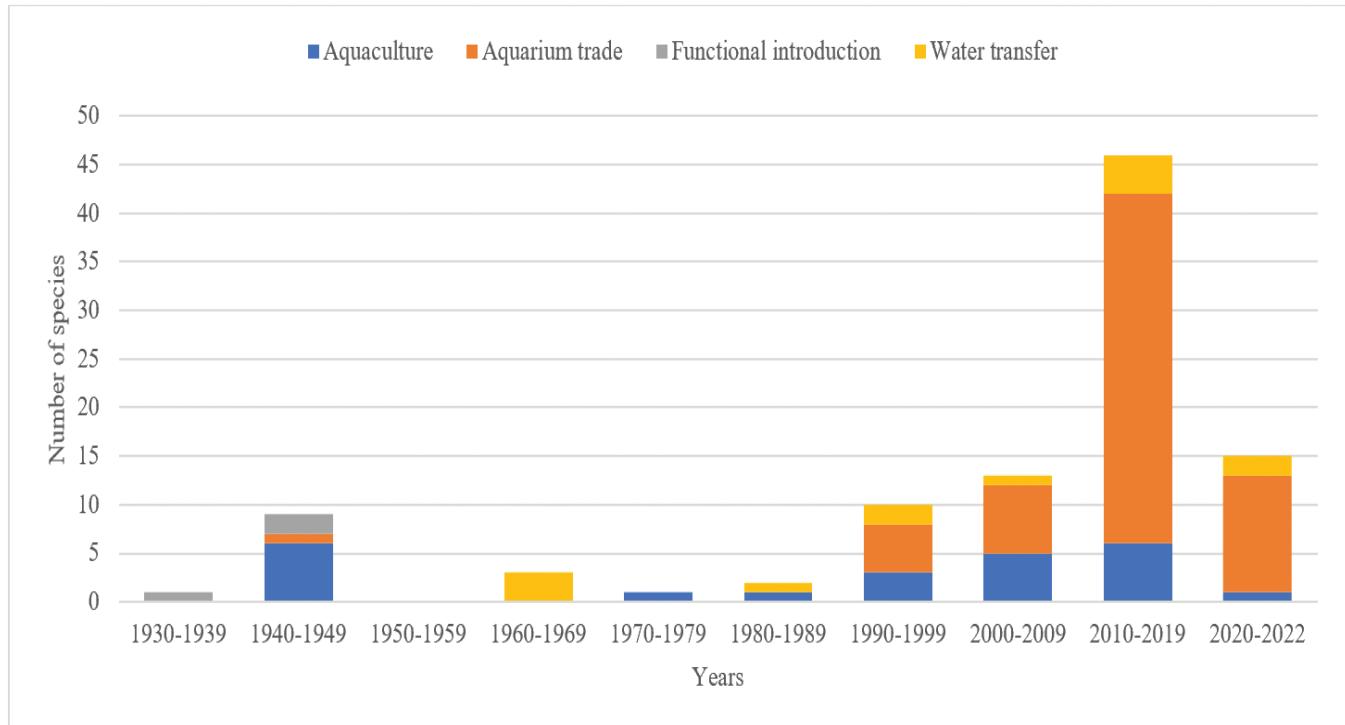


Fig. 52. First records of non-native freshwater fish species from 1930 to 2022 and their suspected introduction sources.

With the exception of five putative hybrids, the non-native fishes originated from: Central or South America (27 species), East Asia (21 species), Southeast Asia (15 species), Africa (15 species), South Asia (10 species), North America (five species), Australasia (one species), and Europe (one species). In addition, the majority of non-native fish in Hong Kong (70%) were from tropical regions, which is lower than in Singapore (82.9%; Tan et al., 2020), but is a likely reflection of the warm climate in both locations.

**Introductions over time.** The number of non-native fish species has risen dramatically in the past 30 years (Fig. 47), with a five-fold increase in the number of non-native species since the previous annotated compilation of freshwater fishes by Chong & Dudgeon (1992). Our results show that non-native freshwater fishes in Hong Kong were introduced mainly through the aquarium trade (64 species), followed by aquaculture (23 species), and water transfer from the Dongjiang in mainland China (13 species). Species introductions from the aquarium trade and aquaculture reflect an increasing trend since the 1990s (Fig. 52), possibly because both industries are increasingly reliant on imported fishes (FHB, 2011; Ho, 2013), given the declining profitability in breeding aquarium/aquaculture species locally. Similarly, increases in species introductions from the Dongjiang mirrors the rising importance of water imports that represent 60–80% of annual supply in 1989–2015 compared to only 20% in the 1960s (ADMCF, 2017). This increase in the volume of imported water increases the likelihood of species establishment (Table 2) as propagule pressure is greater (Simberloff, 2009).

**Aquarium trade.** Sixty-two non-native species traded as aquarium fishes in Hong Kong were recorded in local fresh waters, of which 27 species originated from Central and

Table 2. Freshwater fish species suspected to be introduced into Hong Kong through water transfers from mainland China.

Family	Species
ENGRAULIDAE	<i>Coilia grayii</i>
CYPRINIDAE	<i>Parabramis pekinensis</i>
XENOCYPRIDIDAE	<i>Chanodichthys erythropterus</i> <i>Culter recurvirostris</i> <i>Hemiculter bleekeri</i> <i>Opsariichthys</i> sp. <i>Toxabramis houdeimeri</i>
GOBIONIDAE	<i>Sarcocheilichthys nigripinnis</i>
BAGRIDAЕ	<i>Tachysurus vachellii</i> <i>Tachysurus fulvidraco</i> <i>Tachysurus virgatus</i>
HEMIRAMPHIDAE	<i>Hyporhamphus intermedius</i>

South America, 11 from Southeast Asia, 10 from Africa, six from South Asia, five from North America, two from East Asia, and one from Australasia. In total, 27 of them were associated with breeding populations, indicating that more than 40% of species introduced by way of the aquarium trade have become established in Hong Kong. Propagule pressure from the aquarium trade may have increased over time due to the diversification of introduction pathways. In the past, non-native fishes in aquaria were introduced as escapees from fish farms, mosquito control agents (only Poeciliids), and for angling purposes (Lin, 1949; Dudgeon & Corlett, 2004). At present, fish releases during Buddhist rituals or as unwanted pets are commonplace.

A study on the invasion risk of ornamental freshwater fish in Hong Kong by Ho (2013) using the Fish Invasiveness Screening Kit (FISK) indicated that *Carassius auratus* (FISK score 31), *Cyprinus carpio* (FISK score 26.5), *Pterygoplichthys anisitsi* (FISK score 26), *P. gibbiceps* (FISK score 25), *Xiphophorus hellerii* (FISK score 18), and *Silurus glanis* (FISK score 18), had a high chance of becoming invasive in Hong Kong (Ho, 2013). Of these, *C. auratus*, *C. carpio*, and *X. hellerii* are locally widespread, although the former two may also have native populations. While *P. anisitsi* and *P. gibbiceps* have not been recorded in the wild, it is possible that they have been misidentified, owing to difficulties in differentiating between members of the loricariid genus *Pterygoplichthys* currently in Hong Kong and South China (Wei et al., 2017). This is a potential cause for concern as only 25 species traded through Hong Kong were selected randomly for the study's FISK assessment (of which 20% were found to be high risk), although other species may be equally, or even more invasive (e.g., *Poecilia reticulata* and *Hemichromis guttatus*).

**Hotspots.** Non-native fish species were reported throughout Hong Kong (Fig. 53), with the highest frequencies of occurrence in waterbodies outside of country parks and reservoirs. Country parks were designated in 1977 to protect water catchments. This may have contributed to the preservation of native assemblages in hillstreams above 100 m elevation, as they were relatively insulated from Hong Kong's pollution problem during the late 20<sup>th</sup> century (Binnie & Partners, 1974; Dudgeon, 1996). Conversely, freshwater habitats outside of country parks are mostly low elevation areas that were subject to higher intensity of pollution, habitat degradation, and alteration (Dudgeon, 1996), with mostly compromised native communities, which may have allowed non-native species to establish. Pollutants from farms and tanneries, in particular, are believed to have driven several native fishes (e.g., the white cloud mountain minnow, *Tanichthys albonubes*) to the point of extirpation in lowland (unprotected) streams (Weitzman & Chan, 1966). After the cessation of tannery operations, and restrictions on livestock raising arising from concerns over zoonoses, local streams are now in post-pollution recovery but are yet to reach a state of equilibrium (Tsang & Dudgeon, 2021a). This means that there may be vacant ecological niches in local streams that can be exploited by non-native species (Olden et al., 2006). Moreover, species that become established outside of their native ranges tend to be tolerant of higher levels of habitat degradation and pollution (Karatayev et al., 2009).

Reservoirs, on the other hand, represent a novel freshwater habitat in Hong Kong given the lack of natural lakes or large rivers. In the absence of native species that have evolved in similar environments, Hong Kong's reservoirs are likely to be susceptible to being quickly overtaken by non-native fishes from various sources discussed earlier (Liew et al., 2016; Liew et al., 2018).

**Ecological impacts.** Nearly half (43.4%) of all species-specific location records were dominated by six species: *Gambusia affinis* (119 localities), *Oreochromis mossambicus*

(89 localities), *Oreochromis niloticus* (81 localities), *Coptodon zillii* (50 localities), *Poecilia reticulata* (50 localities), and *Xiphophorus hellerii* (45 localities) (Fig. 54). Of these, we only know about the potential ecological impacts of poeciliids (i.e., *G. affinis*, *P. reticulata*, *X. hellerii*, *X. salvatoris*, *X. variatus*) (Tsang & Dudgeon, 2021a; 2021b; 2021c; 2021d).

The most widespread species, *G. affinis*, can lower the abundance and richness of aquatic invertebrates, although the native *Barbodes fasciolatus* may have similar effects (Tsang & Dudgeon, 2021b). However, *G. affinis* drove greater reductions in the abundance of wetland invertebrates in the United States (e.g., over 70% in Missouri and California; Shulse et al., 2013; Preston et al., 2017) than in Hong Kong (40%; Tsang & Dudgeon, 2021c). Locally, predation by *G. affinis* also reduced the survival of tadpoles from four native amphibian species (Karraker et al., 2010). Moreover, it has also been implicated in the decline of the native *Oryzias curvinotus* through competition with adults and predation on eggs and juveniles, as the latter is known only from a few locations where *G. affinis* does not occur (Chong & Dudgeon, 1992).

In general, *P. reticulata* had weaker effects on aquatic invertebrates in mesocosms compared to *G. affinis*, particularly during the cool dry season (Tsang & Dudgeon, 2021b). This may be because the former has a higher mean critical thermal minimum (CT<sub>min</sub> of *P. reticulata*: 12.4°C–14.6°C; *G. affinis*: 5°C–10°C) (Pyke, 2005; Jourdan et al., 2014). There are limited data on the effects of other poeciliids in Hong Kong. However, *X. hellerii* and *X. salvatoris* were found to have higher feeding rates than *G. affinis*, *P. reticulata*, and three native fish species in laboratory settings, suggesting that the two *Xiphophorus* species may have greater ecological impacts on native prey (Tsang & Dudgeon, 2021d). While this is worrying, *P. reticulata*, *X. hellerii*, and *X. variatus* in lowland streams are mainly herbivorous (Tsang & Dudgeon, 2021a). We nevertheless believe that these species should be closely monitored, as *X. hellerii* are known to alter invertebrate communities and reduce of native fish abundance in invaded streams (Courtenay & Meffe, 1989; Holitzki et al., 2013).

Cichlidae is the most widespread family of non-native fishes in Hong Kong. While members of this family often impact local biodiversity (Canonico et al., 2005; Martin et al., 2010), we lack comprehensive knowledge about potential ecological impacts in Hong Kong. Dudgeon (1983) reported that *O. mossambicus* consumed terrestrial macrophytes in the Plover Cove Reservoir, while *O. niloticus* and *Coptodon zilli* are the most widespread cichlids in river systems near Hong Kong (i.e., Guangdong Province; Gu et al., 2019). Cichlids (i.e., *O. niloticus*) in Guangdong Province have been known to reduce the growth rate of native *Cirrhina molitorella*, and may lower the biomass of native fishes when occurring in high abundances (Gu et al., 2015).

Tsang and Dudgeon (2021a) suggested that the ecological impacts of non-native poeciliids on native fish assemblages

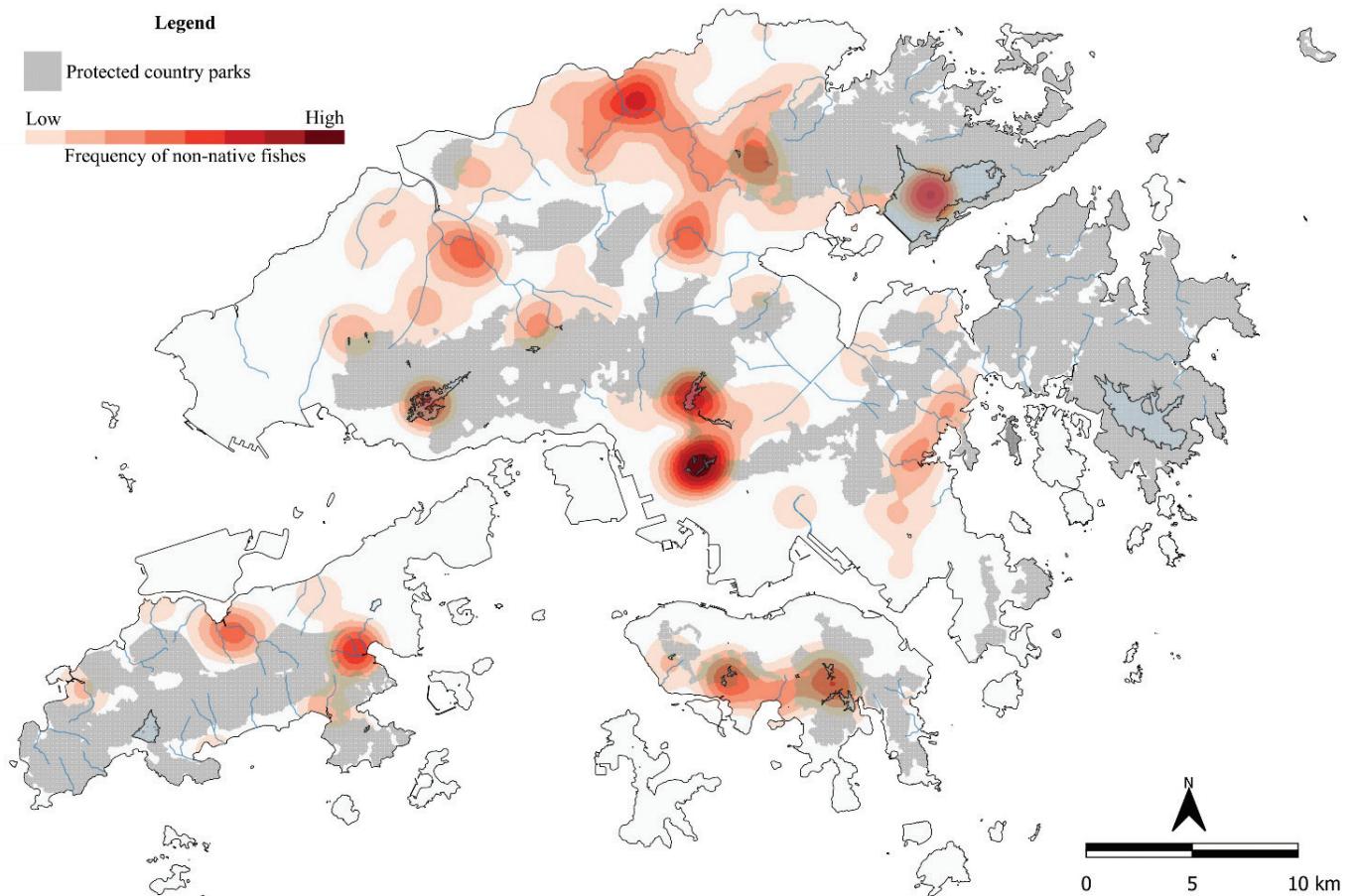


Fig. 53. Distribution of non-native freshwater fish species in Hong Kong. Each record was location and species-specific, which means that multiple records of one species in the same locality were represented only once in the heatmap. In total there are 999 locality records for 93 species (two species have unknown distribution) and five hybrids.

may be difficult to detect as a consequence of the legacy effects of pollution in Hong Kong streams. Specifically, non-native species may avoid competing with extant natives by occupying vacant niches (Cornell, 1999) resulting from historical pollution-driven extirpations. This phenomenon is not unprecedented. For instance, non-native round gobies occupying an empty ecological niche created by an artificial rip-rap have been shown to interact minimally with juvenile native fish that were relatively unimpacted (Janáč et al., 2016). This may not be true for other widespread families of non-native fishes, however. As such, we recommend prioritising the threat assessment of widespread species (e.g., Fig. 54), especially those that co-occur with locally threatened natives including *Acrossocheilus parallens* and *Rhodeus ocellatus* (Tsang & Dudgeon, 2021a).

**Native fishes and hybridisation.** Hong Kong has 65 extant native inland freshwater fish species (Table 3), with at least five locally extinct species: *Aphyocyparis lini*; *Garra orientalis*; *Osteochilus salsburyi*; *Tanichthys albonubes*; and *Cobitis sinensis* (Chong & Dudgeon, 1992; AFCD, 2021a). Based on the findings of the current study, *Misgurnus anguillicaudatus* and *Channa maculata* may hybridise with non-native congeneric species (*M. dabryanus* and *C. argus* respectively). While, the scale and effects of hybridisation in Hong Kong are unclear due to a lack of genetic studies, low rates of introgression were found in natural hybrids of

*M. anguillicaudatus* × *M. dabryanus* in mainland China (You et al., 2009), while *C. maculata* × *C. argus* hybrids crossed in aquaculture had significantly higher growth rates than their parent species (Ou et al., 2018), although the ecological impacts of both hybrids are not well understood.

**Non-native fishes from South China.** A total of 13 non-native species from South China have been recorded in Hong Kong: *Coilia grayii*, *Misgurnus dabryanus*, *Carassius auratus*, *Cirrhinus molitorella*, *Decorus decorus*, *Mylopharyngodon piceus*, *Culter recurvirostris*, *Hemiculter bleekeri*, *Sarcocheilichthys nigripinnis*, *Eugnathogobius siamensis*, *Channa argus*, *Channa striata*, and *Hyporhamphus intermedius*. The majority of them originate in large rivers, such as the Dongjiang, so they have been most frequently found in reservoirs or channelised rivers in the New Territories, with the exception of *M. piceus* and *D. decorus* (with an unknown distribution and stocked in ponds respectively). Given the scarcity of knowledge on species assemblages before the 1940s (Lin, 1949), it is conceivable that some of these southern Chinese species had native populations in Hong Kong that had already been extirpated before ichthyological surveys and recording began.

**Management implications.** The most effective means of non-native species management is mitigating ongoing arrival of propagules (Ruiz & Carlton, 2003) rather than removing

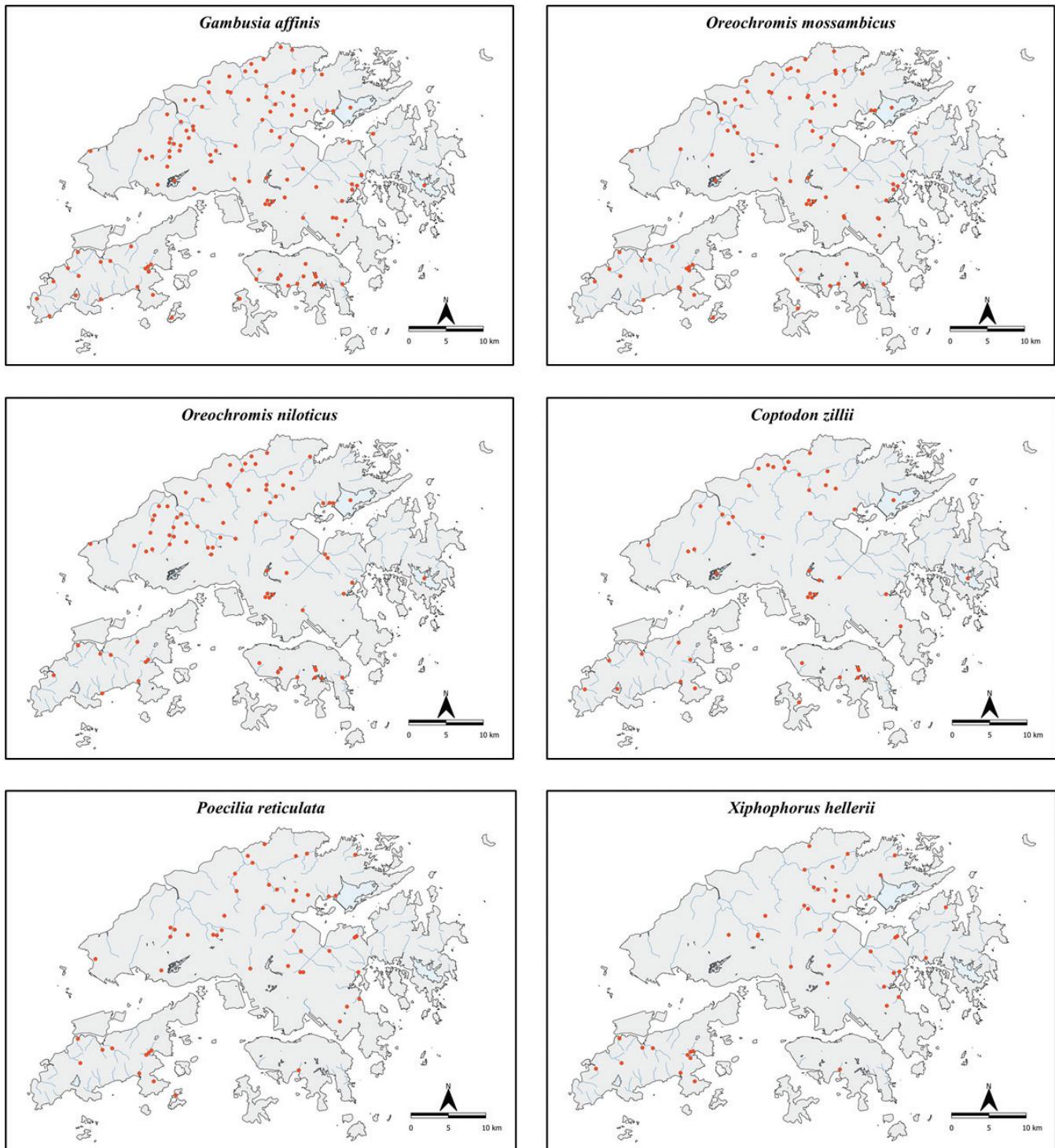


Fig. 54. Distribution of the six most widespread non-native freshwater fish species in Hong Kong.

species once they have established (Simberloff, 2009). This is especially critical to Hong Kong's lowland habitats and unprotected areas, which are dominated by non-native fishes that may hinder re-colonisation by native fishes (Tsang, 2020). Current regulations prohibit the release of animals into reservoirs (Cap. 102) and public parks (Cap. 132BC), but other freshwater bodies remain vulnerable to species introduction. Moreover, species with a history of invasion can still be imported and sold in Hong Kong. These avenues for improved legislation and regulatory efforts may provide achievable options for mitigating and or preventing ecological impacts (Gozlan et al., 2010; Simberloff et al., 2013).

Lesser-understood sources and pathways, such as water transfers and Buddhist ritual releases, require more nuanced approaches and further research due to their societal and sociological implications. In habitats where non-native fishes have become established, direct eradication through removal of fishes using traps or piscicide (rotenone) has been suggested to be an effective method (Cano-Rocabayera et al., 2019). However, trapping can be costly, labour-intensive, and time-consuming for purposes of complete eradication when applied without other forms of management (Francis, 2012); for instance, attempts to eradicate *Gambusia holbrooki* in a Spanish stream required high-intensity hand-netting

Table 3. An updated list of native inland freshwater fishes in Hong Kong (Chong &amp; Dudgeon, 1992; AFCD, 2022).

Family	Species	Family	Species
MEGALOPIDAE	<i>Megalops cyprinoides</i>	GOBIIDAE	<i>Awaous melanocephalus</i>
ANGUILLIDAE	<i>Anguilla japonica</i>		<i>Gobiopterus cf. macrolepis</i>
	<i>Anguilla marmorata</i>		<i>Mugilogobius abei</i>
COBITIDAE	<i>Misgurnus anguillicaudatus</i>		<i>Mugilogobius chulae</i>
GASTROMYZONTIDAE	<i>Linipharhomaloptera disparis</i>		<i>Mugilogobius myxodermus</i>
	<i>Pseudogastromyzon myersi</i>		<i>Redigobius cf. bikolanus</i>
NEMACHEILIDAE	<i>Oreonectes platycephalus</i>		<i>Rhinogobius duospilus</i>
	<i>Schistura fasciolata</i>		<i>Rhinogobius leavelli</i>
	<i>Schistura incerta</i>		<i>Rhinogobius similis</i>
CYPRINIDAE	<i>Acrossocheilus beijiangensis</i>		<i>Sicyopterus longifilis</i>
	<i>Acrossocheilus parallens</i>		<i>Stiphodon atropurpureus</i>
	<i>Barbodes semifasciolatus</i>		<i>Stiphodon imperiorientis</i>
DANIONIDAE	<i>Rasbora steineri</i>		<i>Stiphodon multisquamus</i>
XENOCYPRIDIDAE	<i>Aphyocyparis normalis</i>		<i>Stiphodon palawanensis</i>
	<i>Hemiculter leucisculus</i>		<i>Stiphodon percnopterygionus</i>
	<i>Metzia formosae</i>		<i>Tridentiger trigonocephalus</i>
	<i>Metzia lineata</i>		<i>Glossogobius giuris</i>
	<i>Opsariichthys sp.</i>		<i>Glossogobius olivaceus</i>
	<i>Parazacco spilurus</i>	MASTACEMBELIDAE	<i>Mastacembelus armatus</i>
ACHEILOGNATHIDAE	<i>Rhodeus ocellatus</i>	SYNBRANCHIDAE	<i>Monopterus albus</i>
GOBIONIDAE	<i>Pseudorasbora parva</i>	OSPHRONEMIDAE	<i>Macropodus hongkongensis</i>
BAGRIDAE	<i>Tachysurus trilineatus</i>		<i>Macropodus opercularis</i>
SISORIDAE	<i>Glyptothonax pallozonus</i>	CHANNIDAE	<i>Channa asiatica</i>
SILURIDAE	<i>Pterocryptis anomala</i>		<i>Channa maculata</i>
	<i>Silurus asotus</i>	ADRIANICHTHYIDAE	<i>Oryzias curvinotus</i>
CLARIIDAE	<i>Clarias fuscus</i>	MUGILIDAE	<i>Mugil cephalus</i>
PLECOGLOSSIDAE	<i>Plecoglossus altivelis</i>		<i>Planiliza subviridis</i>
RHYACICHTHYIDAE	<i>Rhyacichthys aspro</i>	LUTJANIDAE	<i>Lutjanus argentimaculatus</i>
ELEOTRIDAE	<i>Eleotris acanthopoma</i>	KUHLIIDAE	<i>Kuhlia marginata</i>
	<i>Eleotris oxycephala</i>		<i>Kuhlia rupestris</i>
	<i>Giuris tolsoni</i>	LATEOLABRACIDAE	<i>Lateolabrax maculatus</i>
	<i>Hypseleotris cyprinoides</i>	TETRAODONTIDAE	<i>Takifugu ocellatus</i>
	<i>Butis humeralis</i>		

and trapping over three years (Ruiz-Navarro et al., 2013). Furthermore, regardless of their effectiveness against non-native fishes, piscicides such as rotenone can be detrimental to native fishes and invertebrates (Schreier et al., 2008; Beaulieu et al., 2021).

This study provides baseline information on the diversity, distribution, and sources of non-native fishes in Hong Kong. With 95 species and five putative hybrids recorded to date, there are clear signs that non-native fishes are widespread and well-established, demanding further action. We recommend investigation of introduction pathways and potential impacts on vulnerable natives using this paper as a basis for prioritising non-native species that may warrant greater concern.

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## APPENDIX

Appendix 1. Names and coordinates of sites sampled during the current study.

Site	Coordinates	Site	Coordinates
Aberdeen Lower Reservoir	22.253322, 114.161966	Sha Lo Tung Stream	22.480089, 114.183792
Aberdeen Upper Reservoir	22.25789, 114.165547	Sha Lo Wan Stream	22.288499, 113.90183
Big Wave Bay Stream	22.246528, 114.245802	Sha Po area	22.452279, 114.051379
Black Hill area	22.304039, 114.244963	Sham Chung area	22.443183, 114.287419
Cheung Chau area	22.202774, 114.023513	Sham Tseng Settlement Basin	22.371024, 114.052793
Cheung Po Stream	22.415439, 114.073976	Sham Wat River	22.266087, 113.888395
Deep Water Bay Stream	22.247207, 114.187269	Shan Pui River	22.454227, 114.030303
Fanling area	22.490255, 114.146584	Shap Long Irrigation Reservoir	22.232474, 113.998911
Fung Yuen Stream	22.466975, 114.179297	Shap Sze Heung area	22.418776, 114.261236
Ha Wo Hang area	22.529698, 114.19875	She Shan River	22.453519, 114.145269
Heung Yuen Wai Stream	22.555504, 114.165461	Shek Kong Stream	22.426685, 114.106617
High Island Reservoir	22.37518, 114.352708	Shek Lei Pui Reservoir	22.355522, 114.14838
Ho Chung River	22.354789, 114.246805	Shek Pik Reservoir	22.231711, 113.898337
Ho Pui Reservoir	22.406282, 114.074923	Sheung Wo Hang Stream	22.523893, 114.194596
Ho Pui River	22.417771, 114.06875	Sheung Yue River	22.511215, 114.111907
Hoi Ha Stream	22.45812, 114.324855	Shing Mun Reservoir	22.385022, 114.147117
Hok Tau Reservoir	22.491702, 114.181359	Shing Mun River	22.384348, 114.196907
Hung Shui Hang Irrigation Reservoir	22.412933, 113.998028	Shuen Wan area	22.500098, 114.240325
Kai Tak River	22.334993, 114.1939	Shui Chuen O Stream	22.371503, 114.196109
Kam Tin River	22.460382, 114.045832	Shui Hau Stream	22.219647, 113.915152
Kau Ling Chung Stream	22.204964, 113.864076	Shui Lo Cho Stream	22.231859, 113.854204
Kau Lung Hang Lo Wai Stream	22.480966, 114.158463	So Kwun Wat Stream	22.376414, 114.008767
Kowloon Byewash Reservoir	22.35028, 114.15068	Tai Chung Hau Stream	22.37317, 114.257404
Kowloon Reception Reservoir	22.350895, 114.145444	Tai Ho River	22.291586, 113.977861
Kowloon Reservoir	22.354392, 114.15522	Tai Lam Chung Reservoir	22.381671, 114.026803
Kwu Tung Reservoir	22.497373, 114.096516	Tai Lung Wo Liu Stream	22.4193, 114.2616
Lai Chi Chong area	22.452089, 114.300826	Tai Mei Tuk area	22.473461, 114.234625
Lai Chi Wo area	22.52572, 114.258824	Tai Mong Tsai Stream	22.392632, 114.299185
Lai King area	22.352973, 114.131668	Tai O River	22.248849, 113.870768
Lam Tei Irrigation Reservoir	22.410179, 113.990084	Tai Po Kau Nature Reserve	22.427919, 114.180707
Lam Tsuen River	22.462016, 114.145906	Tai Po River	22.437604, 114.164404
Lamma Island area	22.214399, 114.133875	Tai Shui Hang area	22.406435, 114.223213
Lau Shui Heung Reservoir	22.496145, 114.168602	Tai Tam Byewash Reservoir	22.25612, 114.211357
Lin Ma Hang Stream	22.550138, 114.18112	Tai Tam Intermediate Reservoir	22.246408, 114.210273
Little Hawaii Stream	22.329063, 114.250074	Tai Tam Reservoir	22.259198, 114.210137
Lohas Park Stream	22.298664, 114.274156	Tai Tam Tuk Reservoir	22.245209, 114.219216
Lok Ma Chau area	22.512653, 114.077514	Tai Tei Tong Stream	22.266916, 113.989179

Site	Coordinates	Site	Coordinates
Long Valley	22.508498, 114.112873	Tai Tong area	22.420122, 114.020509
Lower Shing Mun Reservoir	22.37265, 114.160156	Tai Tung Wo Liu Stream	22.420803, 114.262039
Lung Mei area	22.472595, 114.225824	Tan Shan River	22.50686, 114.178523
Ma Dai Stream	22.407196, 114.225082	Tin Shui Wai River	22.452648, 113.997787
Ma Wat River	22.490276, 114.146558	Ting Kok area	22.472037, 114.221511
Man Hang Stream	22.401612, 114.189804	Tong Fuk River	22.226842, 113.93094
Man Kam To area	22.526459, 114.123081	Tsing Tai Stream	22.418423, 113.938433
Miu Shan Stream	22.503345, 114.266779	Tsing Tam Reservoir	22.416617, 114.087126
Mui Tsz Lam Stream	22.401794, 114.22669	Tsing Tam Tsuen Stream	22.42033, 114.081027
Mui Wo River	22.264577, 113.993878	Tsing Yi area	22.351894, 114.097221
Nam Sang Wai	22.458117, 114.034447	Tsui Keng area	22.479359, 114.106398
Ng Tung River	22.506301, 114.139241	Tung Chung River	22.276705, 113.929556
Ngong Ping Stream	22.257131, 113.902091	Tung Tsz Stream	22.473185, 114.198595
Pak Long Stream	22.3911, 113.9231	Wang Tong River	22.272261, 113.996408
Pak Ngau Shek Stream	22.443536, 114.125523	Waterfall Bay Stream	22.252829, 114.13365
Pak Tam Chung Stream	22.400432, 114.322524	Wetland Park	22.468978, 114.006808
Pak Tin area (Tai Wai)	22.3823, 114.17332	Wo Shang Wai area	22.487068, 114.052276
Ping Kong Stream	22.489778, 114.123683	Wong Lung Hang Stream	22.276656, 113.943454
Plover Cove Reservoir	22.476641, 114.25637	Wong Nai Chung Reservoir	22.256629, 114.195197
Pok Fu Lam Reservoir	22.265317, 114.137704	Wong Nai Tun Irrigation Reservoir	22.399754, 114.017612
Pui O Stream	22.24389, 113.980547	Wu Kau Tang Stream	22.505706, 114.243558
Sai Kung River	22.388401, 114.270825	Yeung Ka Tsuen Stream	22.412253, 114.020578
Sam Dip Tam Stream	22.38064, 114.12429	Yi O Stream	22.227454, 113.847763
San Tau Stream	22.288688, 113.921646	Yuen Long Bypass Floodway	22.449501, 114.043349
San Tin area	22.495814, 114.072531	Yuen Long Town Nullah	22.44144, 114.025743
Sandy Ridge Cemetery	22.524561, 114.116907	Yuen Tun Ha Stream	22.429276, 114.161213
Sha Ling area	22.533585, 114.127443	Yung Shue O Stream	22.426056, 114.292886

**SUPPLEMENTARY MATERIAL**

Supplementary 1. Native species with non-native genetic stock

Table 1. Native freshwater fishes with feral populations in Hong Kong (nine species). Region of origin is based on FishBase (Froese & Pauly, 2021), while introduction pathways have been deduced from ad-hoc surveys, literature, or expert opinions.

<b>Order and Family</b>	<b>Species</b>	<b>Region of Origin</b>	<b>Introduction Pathway</b>	<b>Remarks</b>
<b>ORDER CYPRINIFORMES</b>				
Family Cobitidae	<i>Misgurnus anguillicaudatus</i>	East Asia	Aquarium trade	Established
Family Cyprinidae	<i>Garra orientalis</i>	East Asia	Water transfers	Established
	<i>Osteochilus salsburyi</i>	South Asia	Water transfers	Established
Family Xenocyprididae	<i>Hemiculter leucisculus</i>	East Asia	Water transfers	Established
Family Tanichthyidae	<i>Tanichthys albonubes</i>	East Asia	Aquarium trade	Introduced
<b>ORDER GOBIIFORMES</b>				
Family Gobiidae	<i>Glossogobius olivaceus</i>	East Asia	Water transfers	Established
	<i>Gobiopterus cf. macrolepis</i>	East Asia	Water transfers	Established
	<i>Mugilogobius myxodermus</i>	East Asia	Water transfers	Established
<b>ORDER ANABANTIFORMES</b>				
Family Channidae	<i>Channa maculata</i>	East Asia	Aquaculture	Established

## COMPILED LIST OF NATIVE FRESHWATER FISHES WITH FERAL POPULATIONS

### Order Cypriniformes

#### Family Cobitidae

##### *Misgurnus anguillicaudatus* (Cantor)

**Distribution.** Ho Chung River, Shing Mun Reservoir (current survey).

**Native range.** Russia, Korea, Japan, China and Vietnam (East Asia).

**Remarks.** This species is occasionally sold as live fish food along with *Paramisgurnus dabryanus* in the aquarium trade, and these fishes are often purchased for release in Buddhist rituals.

#### Family Cyprinidae

##### *Garra orientalis* (Nichols)

**Distribution.** Tai Lam Chung Reservoir, Plover Cove Reservoir (A.C. Lam, pers. comm., 2021).

**Native range.** Asia (presumably East Asia).

**Remarks.** Native riverine populations of this species have not been recorded again since Chan (2001) and are suspected to be extirpated as their local habitat has been channelised. It is unlikely this species naturally occurred in feeder streams of the two reservoirs as it usually inhabits tributaries of large rivers (Pan et al., 1991), which are not present within the catchments of Tai Lam Chung and Plover Cove. The populations in the two reservoirs likely arrived through water transfer from mainland China since this species naturally occurs in the Dongjiang river system (Guangdong and Beijiang rivers) (Pan et al., 1991).

##### *Osteochilus salsburyi* (Nichols & Pope)

(Fig. 55, [LU])



Fig. 55. *Osteochilus salsburyi*, 109 mm SL, Lower Aberdeen Reservoir.

**Distribution.** Plover Cove Reservoir (Man & Hodgkiss, 1981; Lai, 2011); Tai Lam Chung Reservoir (Lai, 2011; current study); High Island Reservoir (Lai, 2011; H.T. Cheng, pers. comm., 2021); Shing Mun Reservoir (current survey); Lower Aberdeen Reservoir, Lower Shing Mun Reservoir (GBIF.org, 2021).

**Native range.** Laos, Vietnam, and South China (South Asia).

**Remarks.** Native populations have been historically recorded in the hill streams of Kam Tin (Lin, 1949), but have not been recorded in any such streams since except for those flowing directly into reservoirs. This species is often sold as food in wet markets and releases into reservoirs has been observed.

#### Family Xenocyprididae

##### *Hemiculter leucisculus* (Basilewsky)

(Fig. 56, [LU])



Fig. 56. *Hemiculter leucisculus*, 120.2 mm SL, Tai Lam Chung Reservoir.

**Distribution.** High Island Reservoir, Hok Tau Reservoir, Shing Mun Reservoir, Lau Shui Heung Reservoir, Plover Cove Reservoir, Kowloon Reservoir, Shek Lei Pui Reservoir, Tai Lam Chung Reservoir, Tai Tam Tuk Reservoir (Lai, 2011; current survey); Shek Pik Reservoir (AFCD, 2021c; current survey); Tai Tam Byewash Reservoir (GBIF.org, 2021; current survey).

**Native range.** North and South Korea, China, and Japan (East Asia).

**Remarks.** This species is suspected to have both native and non-native populations in Hong Kong (Chong & Dudgeon, 1992). Reservoir populations are likely to have been introduced by water transfers from mainland China and from local rivers.

**Family Tanichthyidae*****Tanichthys albonubes* (Lin)**  
(Fig. 57.)Fig. 57. *Tanichthys albonubes*, 29.5 mm SL, trade material.**Distribution.** Tai Po Kau Nature Reserve (current survey).**Native range.** China and Vietnam (East Asia).

**Remarks.** This species once had native populations but was extirpated during the 1960s (Chong & Dudgeon, 1992). The individuals observed in the stream at Tai Po Kau Nature Reserve in 2018 do not resemble those of the wild types that have been found in Hainan Island and Guangdong (Chan & Chen, 2009; Zhao et al., 2018), and instead, are identical to those from the aquarium trade. No individuals were observed during surveys in Tai Po Kau Nature Reserve before or after 2018.

**Order Gobiiformes****Family Gobiidae*****Glossogobius olivaceus* (Temminck & Schlegel)**  
(Fig. 58, [LU])Fig. 58. *Glossogobius olivaceus*, 65 mm SL, Plover Cove Reservoir.

**Distribution.** Plover Cove Reservoir (Lai, 2011; GBIF.org, 2021; current survey); Tai Lam Chung Reservoir (Lai, 2011; AFCD, 2021c; GBIF.org, 2021; current survey); Lower Shing Mun Reservoir (current survey); High Island Reservoir (H.T. Cheng, pers. comm., 2021).

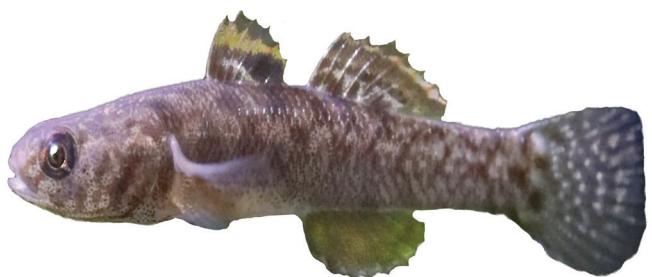
**Native range.** Russia, Japan, China, and Taiwan (East Asia).

**Remarks.** This species has native populations in estuaries and lower reaches of streams locally. Reservoir populations are confined to sites receiving water transfers from mainland China.

***Gobiopterus cf. macrolepis* (Cheng)**  
(Fig. 59, [LU])Fig. 59. *Gobiopterus cf. macrolepis*, non-native specimen (top), Tai Lam Chung Reservoir, native specimen (female with eggs) (bottom), Kam Tin River.**Native range.** Pearl River Delta endemic, South China.

**Distribution.** Kowloon Reception Reservoir (Lai, 2011); Tai Lam Chung Reservoir (Lai, 2011; current study); Plover Cove Reservoir (GBIF.org, 2021).

**Remarks.** Native populations inhabit estuaries and lower courses of streams in the New Territories and Lantau Island. However, there are several non-native reservoir populations that are suspected to have been introduced through water transfers from mainland China (Lai, 2011).

***Mugilogobius myxodermus* (Herre)**  
(Fig. 60, [LU])Fig. 60. *Mugilogobius myxodermus*, Plover Cove Reservoir.

**Distribution.** Kowloon Reception Reservoir (Lai, 2011 as *Mugilogobius* sp.); Tai Lam Chung Reservoir (current survey); Plover Cove Reservoir (GBIF.org, 2021; current survey).

**Native range.** South China.

**Remarks.** Native populations are found in coastal and estuarine areas, but reservoir populations have become established by way of water transfers from mainland China.

**Order Anabantiformes**

**Family Channidae**

***Channa maculata* (Lacepède)**  
(Fig. 22B)

**Distribution.** Kam Tin River (Black & Veatch Hong Kong Limited, 2005; current survey); Mai Po Nature Reserve (WWF, 2006; WWF, 2021); Kong Nga Po area (Mott MacDonald Hong Kong Limited, 2013); Sandy Ridge Cemetery (Ove Arup & Partners Hong Kong Limited, 2016); Lin Fa Tei area (Atkins China Limited, 2020); Shan Pui River (Black & Veatch Hong Kong Limited, 2020b); Ma Wat River, Ho Chung River, Ping Yuen River, Yuen Long Bypass Floodway, Lam Tsuen River, Shek Kong Stream (DSD, 2021); Ting Kok area, Wo Shang Wai area, San Tin area, Sheung Yue River, Ng Tung River, Ping Kong area (GBIF.org, 2021); Sam Dip Tam Stream (Tsang & Dudgeon, 2021d); Lau Shui Heung Reservoir, Shing Mun Reservoir, Kowloon Reservoir, Kowloon Byewash Reservoir, Shing

Mun River, Lower Shing Mun Reservoir, Mui Tsz Lam Stream, Plover Cove Reservoir, Fo Tan Nullah, Tai Lam Chung Reservoir, She Shan River (current survey).

**Native range.** Japan, China, Taiwan, and Vietnam (East Asia).

**Remarks.** As native populations of this species occur in several reservoirs, the distribution records presented above include only obvious feral populations (e.g., including many damaged individuals and/or found in exceptionally high abundances in channelised water courses). Historically, this species has been cultivated in fish ponds since the 1940s (Lin, 1949), and non-native individuals may have been able to breed in local fresh waters or interbreed with native populations. *Channa maculata* differs from *Channa argus* and their hybrids by having a single stroke in the dorsal head pattern in between the eyes (more separated from the eyes, the larger they become) and smaller blotches on its lateral side (for further details, see Ou et al., 2018).