Occurrence of ornamental fishes: a looming danger for Inland fish diversity of India

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India is known for its immense aquatic wealth, in particular freshwater fish resource. But, the ongoing ornamental fish trade and introduction of exotic fishes in the wild pose a serious threat to India's native aquatic diversity. Recent studies from several parts of India have revealed the presence of several ornamental fishes in inland water bodies, including the biologically sensitive areas such as Chalakudy River in the Western Ghats, a biodiversity hotspot which harbours 16 endangered and 4 critically endangered species. So far, 27 ornamental species have been reported in the inland wetlands of India. Among them, 15 have already established a good breeding population and have emerged as a threat to the native species. Awareness among the public, policy makers and researchers about the impacts of ornamental fishes in inland water is the need of the hour. Stringent measures should be taken to monitor the aquarium fish trade and accidental release of exotic species into inland waters. If not, the invasion of ornamental fishes may demolish the inland aquatic diversity of native Indian breeds.

Keywords: Aquatic diversity, exotic species, inland water, ornamental fishes.

GLOBAL aquatic biodiversity is being depleted at an alarming rate due to habitat destruction, pollution, overexploitation of aquatic resources, tourism and the introduction of invasive exotic species along with alien pathogens and parasites[1–7]. In general, the loss is higher in the freshwater ecosystem, which supports 40% of the globally recorded fish species[8]. Studies in the mid-1990s had clearly shown that 20% of the world's freshwater fish fauna is already extinct or is on the verge of extinction[9]. Globally, invasive alien species are considered as one of the major factors for devastation of freshwater ecosystem, and have emerged as a great threat for the existing indigenous aquatic diversity, in particular ichthyo fauna[5,10].

India is one of the regions that supports unique and immense aquatic diversity. In particular, India is endowed with rich fish diversity – 3231 finfish (788 freshwater, 2443 marine species)[11], even though, since independence, it has accorded a relatively low national priority to aquatic health. The country has enacted only a limited number of overt legislations on fisheries[7], in particular, ornamental fish trade and release of fishes in the wild. Due to this lacuna, for the past two decades many alien fish species have been clandestinely brought into India by private aqua-culturists, entrepreneurs, hobbyists and aqua-industrialists for instant economic benefits[12,13]. Such unauthorized activities are causing indiscriminate spread/proliferation of alien species in the wild, which slowly destroys the native diversity and also affects the prolonged ecological services offered by the system. Besides, the exotic species have also paved the way for the entry of new pathogens, which has resulted in the outbreak of new diseases[6,7,12,13].

Recent studies in several parts of India have highlighted the fact that freshwater fish biodiversity is depleting at an alarming rate due to invasion of commercially important and ornamental, exotic fish species[3,6,7,10,14]. Many native species, especially Indian major carps in various riverine systems have been critically depleted due to the introduction of commercially important exotic species such as Nile/red tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Thai pangus (*Pangasiandon hypophthalmus*) and common carp (*Cyprinus carpio*)[3,10,15]. For instance, studies from the Yamuna and Ganga rivers have shown that there is a constant increase in the yield of alien varieties. In Yamuna, the occurrence of tilapia, African catfish, silver carp and *Gambusia* is higher and the yield is spiralling every year[10,15]. Singh *et al.*[15] reported the highest yield of exotic variety of 384.27 kg/km in the Ganga. Likewise, studies from Kerala have shown the high occurrence of tilapia species in inland waters (up to 25%), due to which native species such as *Puntius dubius* and *Labeo kontius* face local extinction[13]. Also, overpopulation of ornamental sucker mouth catfish *Pterygoplichthys multiradiatus* and *Pterygoplichthys pardalis* has resulted in the decline of commercially important inland native fish in Kerala and Tamil Nadu, respectively[15,16].

In India, 31 aquaculture species, 600 ornamental varieties and 2 species of larvicidal fish have been identified as exotic[17,18]. The deleterious role of alien fish species in aquatic diversity and commercial aquaculture has not yet been properly addressed in several parts of India. Most of the available information is in the form of amateur field reports and popular articles[17,18]. The rest of the available papers discusses the economic and ecological

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impacts of commercially important alien invasive aquaculture species (see, for example 10, 13, 15 and 17). A handful of papers are available about the occurrence/impacts of ornamental fishes on native diversity. It is worthwhile to mention here that, one-third of the world's worst aquatic invasive species include exotic ornamental fishes[19], and the introduced alien aquarium fishes represent a major source of ecological destruction[20].

In India, exotic ornamental fishes ranging from the tiny guppy fish (*Poeciliare ticulata*) to the large and aggressive red piranha (*Pygocentrus nattereri*) have been recorded in rivers, lakes, traditional village ponds and other inland freshwater bodies[3,6,7,21]. Ironically, a number of exotic ornamental species have been successfully reproduced in Indian inland wetlands. Table 1 provides a list of such species.

Pathways for ornamental fish entry to the wild

The ever-increasing global trade of ornamental aquarium fishes is one of the most important and yet poorly documented pathways for aquatic invasion[22,23]. Interestingly, ornamental fish trade in India is dominated by several alien fish varieties, such as angel fish, arowana, goldfish, gourami, guppy, koi carp, oscar, pacu, platy, piranha, swordtail and sucker mouth catfish[17]. Besides, more than 200 alien aquarium fish species are now bred in different parts of India by untrained local vendors[7,13,24].

Recently, researchers have identified some of the important pathways for the entry of ornamental fishes into the wild. In most cases, the hobbyists release the healthy ornamental fishes when they tire of them, or when they become too large to be accommodated in their aquaria[25]. Besides, most of the species entered into the wild during monsoon floods from the local breeding sites. Apparently, most of the local breeding sites are in the form of small cement cisterns or earthen ponds, plastic-lined pools, homestead ponds and granite quarries[14,17,25]. Obviously all the sites are not properly protected/fenced and hence the exotic ornamental fishes can easily enter into the adjoining natural ecosystem during monsoon floods[14,17,25]. Some of the ornamental species even enter into the new geographical boundary during the river-linking projects. For instance, *Badis badis*, *Pethia gelius*, *Osteobrama cotio* and *Lepidocephalus guntea* have invaded Chennai lakes only after the river-linking projects[21,26].

Table 1. Exotic ornamental fish species reported from different inland water bodies of India

Species	Common name
Amphilophus trimaculatus	Three spot/Point Cichlid
Badis badis	Blue perch or badis
*Barbonymus gonionotus**	Silver barb
*Carassius auratus auratus**	Gold fish
*Carassius carassius**	Crucian carp
*Cichlasoma trimaculatum**	Three spot cichlid
*Cyprinus carpio**	Common carp
*Gambusia affinis**	Western mosquito fish
*Gambusia holbrooki**	Eastern mosquito fish
Lepidocephalus guntea	Gutum
Macropodus opercularis	Paradise fish
*Oreochromis mossambicus**	Mozambique tilapia
*Osphronemus goramy**	Giant gourami
Osteobrama cotio	Cotio
Pethia gelius	Golden barb
Pethia phutunio	Spotted sail barb
Piaractus brachypomus	Red-bellied pacu
*Poecilia reticulate**	Guppy
*Pterygoplichthys disjunctivus**	Vermiculated sailfin catfish
*Pterygoplichthys multiradiatus**	Sucker mouth armored catfish
*Pterygoplichthys pardalis**	Amazon sailfin catfish
*Pygocentrus natterei**	Red Piranha
*Tinca tinca**	Tench
*Trichogaster trichopterus**	Three-spot gourami
Trichopsis vittata	Croaking gourami
*Xiphophorus hellerii**	Green swordtail
*Xiphophorus maculatus**	Platy

*Indicates breeding population in the wild. Sources: Refs 3, 6, 21, 25, 26, 49–51.

Impacts of ornamental fishes on aquatic system

Several studies have clearly emphasized that alien fishes frequently alter the aquatic ecology by changing water quality (e.g. increase in nitrogen and phosphorus concentration) and also cause the extinction of native fishes by predation (destroying the eggs, larvae, sub adults and adults), damaging the aquatic vegetation and exploiting the food resources[7,27,28]. Besides, a number of alien fish species also hybridize with indigenous species in the wild, diluting the wild genetic stock leading to long-term introgression of gene pools[27].

Mostly, the invasion of aquarium fishes triggers the native species decline and ecological destruction of the native system[20]. However, in India, there is no detailed study which discusses the impacts of ornamental fishes in every tropic level. Majority of the Indian studies reported about the occurrence of the species in the inland water rather than its detailed impacts on the system. Besides, it is worth mentioning here that the decline of native fish variety will affect the livelihood, health and general well-being of the rural and indigenous community[28].

In order to create awareness among different groups about the deleterious role of aquarium fishes in the wild, this article discusses some of the important impacts (biological/ecological) of ornamental species reported in several parts of the world and in India as well.

Goldfish (*Carassius auratus auratus*)

Goldfish is identified as a potential pest and the ecological impacts of this species in freshwater bodies have been reported in several parts of the world. It is a bottom-feeder,

due to which it frequently resuspends the nutrients settled in the bottom and accelerates the blooming of blue-green algae which results in large-scale aquatic devastation, including fish mortality[29]. Moreover, its feeding behaviour increases turbidity level in the water which affects the aquatic vegetation, due to which some of the native fish species will lose their breeding sites. It was also reported that goldfish feeds on the eggs, larvae, subadults and adults of some native fishes[30,31]. Besides, it is a live carrier of several pathogens and parasites (bacteria, viruses, protozoan and metazoan) and smoothly transmits them into the natural aquatic system. This leads to the outbreak of exotic aquatic diseases resulting in huge economic and biodiversity losses[7,32].

Platy (*Xiphophorus maculatus*)

Platy is an insectivorous species. Due to its foraging nature it acts as a potential food competitor for indigenous fishes including *Haludaria fasciata*, *Pethia ticto Puntius vittatus*, *Aplocheilus lineatus*, *Aplocheilus panchax* and *Aplocheilus dayi*. Moreover, it attains sexual maturity within 3–4 months and will become a potential pest within a short span in a new habitat (see Krishnakumar *et al.*[25]).

Gutum (*Lepidocephalus guntea*)

L. guntea, alien to Chembarampakkam Lake of Chennai, outnumbered the native *Lepidocephalus thermalis* from this lake[26]. The other impacts are yet to be studied.

Three-spot gourami (*Trichogaster trichopterus*)

Gourami is an air-breather, bubble-nest brooder and an opportunistic carnivore which aggressively protects its territory and rapidly establishes itself in stagnant waters[33]. This species was strongly suspected to be the reason for decline of Chinese barb (*Puntius semifasciolatus*) in Taiwan[34].

Guppy (*Poecilia reticulate*)

Poecilia reticulate is reported to destroy the egg and larval forms of native fish species in USA. Further, it emerged as a direct food competitor to cyprinids, killifishes and damselflies in USA and Africa[35,36]. Besides, it effectively transmits iridoviruses, trematode and nematode parasites[37–39].

Suckermouth armoured catfish (*Pterygoplichthys multiradiatus*)

Suckermouth catfish has been identified as a great threat to global freshwater diversity. Occurrence of the species in the wild is reported to alter the entire system and change the physico-chemical nature of water. Furthermore, it will outcompete the native algae consumers and aggressively drive them away from the system[40]. It also creates serious negative impacts on periphyton-feeding and bottom-spawning fishes. Besides, it consumes the eggs of native species, which leads to local extinction of indigenous varieties[16]. A study by Bijukumar *et al.*[16] in the drainages of Thiruvananthapuram city, Kerala, revealed a constant declining trend in native species yield due to high invasion of suckermouth fishes (Figure 1). The number of fishes collected by the cast net each time varied from 3 to 27 throughout the study period, which indicates the dominant biomass of the species in the system[16].

Interestingly, another species of suckermouth catfish *Pterygoplichthys pardalis* was reported to cause huge damage to the native species diversity of Vandiyur Lake, Madurai, southern India. The biomass of *Pterygoplichthys pardalis* was statistically significant compared to the indigenous varieties, which clearly shows the negative impacts of this exotic aquarium fish on inland aquaculture in terms of diminished production of edible fishes[14]. Further, *Pterygoplichthys pardalis* does not hold any market value. So after harvest people discard the species on the banks of the lake, where it is not even scavenged (Figure 2)[14].

Besides, the suckermouth catfish has also been reported to affect other biota in the aquatic system. For instance, the physical cover and food for aquatic insects are destroyed by the suckermouth fish. The strong dorsal and pectoral spines of the catfish cause death of piscivorous birds such as brown pelican (*Pelecanus occidentalis*)[40,41]. Furthermore, the bottom-plowing behaviour of the suckermouth affects the composition of the aquatic vegetation[40]. The nesting behaviour of this species also leads to small-scale bank/bund erosion (Figures 3 and 4)[40]. The suckermouth is also known to cause economic losses by damaging fishing gears, especially cast and gill nets[7,25].

Figure 1. Harvested suckermouth catfish from drainage in Thiruvananthapuram, Kerala. (Photo courtesy: A. Bijukumar.)

Role of ornamental fishes on disseminating exotic pathogens and parasites

Aquatic species trade has been identified as a potential pathway for exotic pathogens and parasites. Introduction of these alien organisms with parasites and pathogens often leads to outbreak of diseases, resulting in huge biodiversity and economic losses[7]. Several such outbreaks of exotic diseases in aquaculture industry have already been reported in different parts of India[7]. For example, in the 1990, the aquaculture industry collapsed due to outbreak of white spot syndrome virus which entered through imported brood stocks[7].

Figure 2. Discarded *Pterygoplichthys pardalis* on the banks of Vandiyur Lake, Madurai. (Photo courtesy: S. Chandrasekaran.)

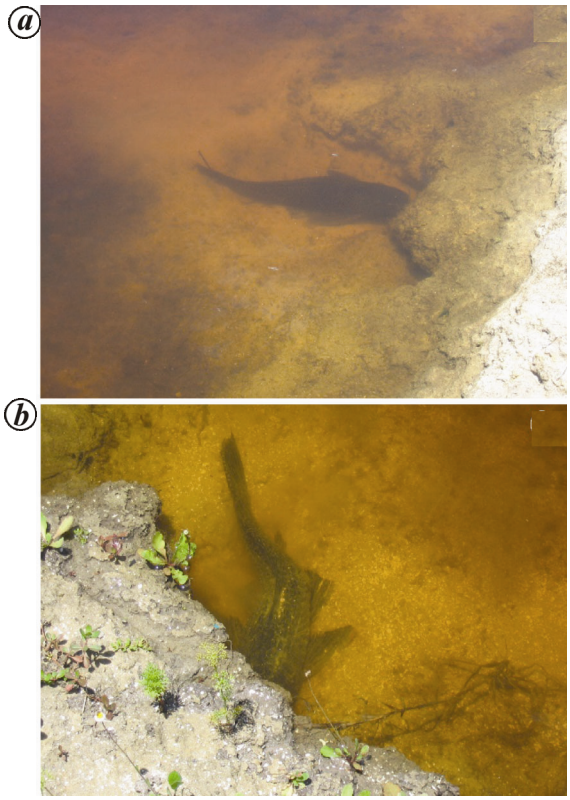

Figure 3 ***a***, ***b***. Suckermouth catfishes recorded during construction of burrows on riverbanks in USA. (Photo courtesy: Oliver Van Den Ende.)

A recent study in the aquarium markets of Arunachal Pradesh and Uttar Pradesh revealed the existence of *Gussevia spiralocirra*, a monogenoid Neotropical Platyhelminthes parasite. *G. spiralocirra* has been reported in angelfish *Pterophyllum scalare* which was collected from the post-quarantine populations in local aquarium markets of Lucknow and Itanagar[7]. Fortunately there is no report of the parasite in the wild till date. Once the species invades into the wild, it can pose a serious threat to native diversity[6,7] and also affect the livelihood, health and regional GDP. So far 13 species of exotic monogenoids (Platyhelminthes) have been reported in India (Table 2)[7].

Conclusion

In the recent past, the global ornamental fish trade has emerged as a multibillion dollar business. Exports have increased at an average rate of approximately 14% per

Table 2. Monogenoid species reported from exotic ornamental fishes in India

Species	Host ornamental fish
Diplozoon nipponicum	*Cyprinus carpio carpio*
Gyrodactylus medius	*Cyprinus carpio carpio, Carassius auratus*
Dactylogyrus sp.	*Carassius auratus*
Pellucidhaptor kritskyia	*Carassius* sp.
Heteropriapulus heterotylus	*Hypostomus* sp.
Diaphorocleidus armillatus	*Gymnocormbus ternetzi*
Urocleidoides vaginoclaustrum	*Xiphophorus helleri*
Sciadicleithrumi phthimum	*Pterophyllum scalare*
Gussevia spiralocirra	*Pterophyllum scalare*
Silurodescoides exotica	*Corydoras melanistius*
Silurodiscoides vistulensis	*Pangasianodon hypophthalmus*
Thaparocleidus siamensis	*Pangasianodon hypophthalmus*
Thaparocleidus caecus	*Pangasianodon hypophthalmus*

Source: Tripathi[6].

Figure 4. Burrows made by Suckermouth catfishes in the San Antonio River, Texas, USA. (Photo courtesy: Jan Jeffrey Hoover.)

year. India's overall ornamental fish trade was about US$ 1.06 million during 2009 (refs 42, 43). On the other hand, alien ornamental fishes introduced into the wild pose a serious threat to Indian aquatic diversity. Several studies have disclosed the occurrence of exotic ornamental fishes in many inland aquatic system, including the biodiversity-sensitive areas of India. For instance, Raghavan *et al.*[44] have shown the presence of five alien ornamental fishes (*Gambusia affinis*, *Oreochromis mossambicus*, *Osphronemus goramy*, *Poecilia reticulate*, *X. maculates*) from the Chalakudy River in the Western Ghats, a biodiversity hotspot which harbours 16 endangered and 4 critically endangered species. Further, the study highlighted that *Poecilia reticulate* species have established a breeding population in this hotspot. However, till date, there has been no detailed and in-depth study in India to quantify the economic and biodiversity losses due to invasion of ornamental fishes in inland waters. On the other hand, several developed countries contribute major research in biological invasions of ornamental fishes in the wild[45]. India should also learn from them in this regard and strengthen legal measures on ornamental fish trade and release of fishes in the wild[46]. For instance, in England, the Salmon and Freshwater Fisheries Act of 1975 clearly states that transport of native and non-native fishes within the political boundaries without proper procedure is illegal[7]. Further, the European Union (EU) has banned the trade, possession and transport of 37 (likely to extend to 350) invasive species. People who export or possess invasive species such as grey squirrels, ruddy ducks and water hyacinth in the EU face penalty[47].

The National Committee on Introduction of Aquatic Species is entitled to screen the entry of exotic aquatic species before they are introduced into India. Besides, the Ministry of Agriculture, Government of India has enacted guidelines for the import of ornamental fishes, which clearly states the importance of pre-quarantine certificate from the competent authority of the exporting countries. Moreover, the guidelines also point out the post-quarantine follow-up[7]. However, traders and hobbyists frequently breach the rules in India and introduce several ornamental fish species, including the notorious carnivorous piranha[3]. India is highly prone to additional invasion of ornamental fishes and their pathogens and other parasites in the future[7]. Unless stringent measures are taken to monitor the aquarium fish trade and accidental release of exotic species into inland waters, our water bodies will soon emerge as breeding grounds for exotic ornamental fishes which will eventually drive out India's native, indigenous freshwater fishes[48].

To resolve these issues, strict implementation of the guidelines of CBD 2014X II/16 and immediate investigation related to the management/eradication of the invaded exotic ornamental fishes in the wild should be carried out[25]. We need to establish a regulatory authority to deal with IAS issues under MOEF & CC. Further, establishment of a national institute with special branches for IAS management is also needed. Such an institute should concentrate on adherence to the guidelines by traders and other stakeholders, creating awareness among public and policy makers, and encouraging research in the management aspects.

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