



Alien fish species in open waters of India: Appearance, establishment and impacts

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ABSTRACT

The diverse germplasms pool already available in the vast and varied water resources of India has potential to cater to the need of the fisheries and aquaculture sector, but introduction of fish species for different purposes is still continuing. The exotic fishes introduced into India for different purposes covers nearly 13.6% of total fish diversity. Due to wider tolerance limit and generalist nature, some alien fish species have acclimatised to diverse eco-climatic conditions. Some of these introduced fishes are now established in the open water bodies including rivers, wetlands and reservoirs and some others are in the process of establishment. Degraded open waters and wanton destruction of fishery resources in the rivers have resulted in depletion of the sensitive fish species and appearance of exotic fishes. The potential risk areas for appearance of the alien species are mushrooming fish culture units in different parts of the country, porous boundaries, farming of alien fishes in flood prone areas, rapid expansion of aquaculture and ornamental fish trade. Eradication of an introduced species is usually difficult or impossible once it is established in open water bodies. Therefore, there is an urgent need to regulate the import of alien fish species, based on their merit and likely impacts on open waters.

Keywords: Alien fish species, Establishment, History, Implications, Risks

Trans-boundary movement of goods is an age old practice, which intensified during few decades ago with the advent of globalisation. There has been regular addition of new import items over the period, including live plants, animals and fish. Owing to multiple utilities, transportation of live fish and its juveniles started in the country since long time. The globalization and increase in free trade and tourism, render more chances for fish species to spread either intentionally or non-intentionally (Welcomme 1984, Jenkins 1996, Cohen and Carlton 1998, Casal 2006, Sampson *et al.* 2009). The movement of living organisms across the globe by humans has led to intense change in the ecology of relocated species and the communities to which they have been introduced (Callaway and Maron 2006). Though the introductions are aimed to ease the human life, but in many instances, the introduced organism cause severe impacts on recipient ecosystems and biodiversity. Moreover, due to broad environmental tolerance capacity and generalist nature, some alien fish species gets acclimatised to diverse eco-climatic conditions and out of which few turned into invasive. The invasive species have some specific traits which allow them to establish and outcompete native species such as fast growth rate; ability to reproduce

in the broad range of environmental conditions; fast reproduction rate; high dispersal rate; phenotypic plasticity; tolerance to a broad range of environmental conditions; survive on wide range of food items; and association with human beings.

Once alien species are introduced accidentally or intentionally may become invasive and can cause considerable harm to natural ecosystems, biodiversity, human health and economy (Pimentel *et al.* 2005, Oreska and Aldridge 2011). Nyman (1991) also highlighted that alien fish introduction may lead to irreversible changes in the aquatic ecosystems, habitat loss which could result in extinction of indigenous species. Decline in water volume and increased water temperature due to massive river modifications in the Himalayan rivers are resulting in range extension of brown trout in some upstream rivers and tributaries. In general, the altered river habitats are suitable for the invasion by some of the resilient fish species.

Aichi Target 9 of the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011–2020, seeks to identify, prioritise, and manage invasive alien species and their invasive pathways (UNEP 2011). As a signatory to the Convention, India is obliged to act on this target, however, managing introduced species in freshwater ecosystems while balancing public perceptions and economic imperatives is a complex issue (Woodford *et al.* 2016). This calls for focused research on different facets of introduced species in order to facilitate species management

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and aid in the development of effective legislation. Hence, there is a stringent need to record appearance, establishment and invasion of alien fish species with the objective to control on import and likely expansion of indiscriminate and unregulated introduction of fish species from across the borders. The present review highlights the need to assess the likely impacts of all such introductions to minimise consequences of introductions on ecology and native fish diversity.

Native and alien fish species in India

The enormous geographical area with varied topographical features of India, supports diverse aquatic resources, which offer immense opportunities for livelihood support, besides maintaining its ecological integrity and valuable gene pool. A vast network of criss-crossing rivers, rivulets and streams of different orders; connected floodplain wetlands and estuaries are the valuable aquatic resources existing in the country. Among the available aquatic resources the rivers, floodplain wetlands and reservoirs are highly prone to anthropogenic stressors because of diverse drainages traversing through varied catchments, highly populated banks and area of maximum developmental activities. India possesses rich aquatic diversity spread across different ecosystems, owing to its vast and varied geographical features. The updated list of fin fishes comprise of total 3,157 species, including 1,545 marine, 892 freshwater, 391 brackish water-marine, 115 freshwater-brackish water, 197 freshwater-brackish water-marine and 17 brackish water species. While approximately 35,797 fish species have been recorded throughout the globe.

During the last few decades, the exotic fishes have been brought into India for different purposes which form about 13.6% additional diversity. Besides this, there are reports of clandestine introduction of some risk bearing fishes. Several of these introduced fishes are now established in the natural water bodies including rivers, wetlands and reservoirs and some others are in the process of establishment. Though the diverse germplasms pool already available in the vast and varied water resources of the country has potential to cater to the need of the fisheries and aquaculture sector, but the introductions are still continuing mostly without proper assessment of merits and demerits of the introduced species.

Pathways for appearance and range extension

Though a number of precautionary measures are already in vogue to control and check the spread of alien fish species in Indian open waters, still, there has been some instances indicating abrupt appearance and extension of aliens in open waters. The potential risk areas for appearance of the alien species in inland open waters are mushrooming fish culture units in different parts of the country, porous boundaries, farming of alien fishes in flood prone areas, rapid expansion of aquaculture and ornamental fish trade. The invasion pressure to open water bodies intensified under depleted

habitat conditions. The reasons attributed for establishment of alien species into our open water resources could be attributed to their hardy, resilient, eurythermal, omnivorous nature; amenable for breeding in all aquatic conditions, strong adaptability to new environments, diverse habitat, altered ecological conditions.

History of introduction

Introduction of any desired species in diversity poor countries seems justifiable, but indiscriminate introduction in a country like India having rich biotic wealth, is highly debatable. Despite the abundant fish diversity available in India, sizeable number of alien fish species have also been introduced intentionally or un-intentionally to fulfil the need of diversification of species for aquaculture; stocking in lakes and reservoirs; diversification of sport fishery base; augmentation of varieties in aquarium trade and larval control.

Introduction of alien fish species started during 1863 in India, when Sir Francis Day made an unsuccessful attempt to import brown trout eggs to Nilgiri hills. Later Mr F J Mitchel successfully introduced brown trout eggs from Scotland to Harwan (Jammu & Kashmir) in 1900 (Mitchell 1918). *Tinca tinca* was imported in India in 1870 for aquaculture. Thereafter number of carps, tilapia, trout and ornamental fishes were introduced in the country (Sehgal 1999). A total of 9 fish species had been introduced in India during pre-independence (1870–1947) period. The introduced species were temperate food fishes such as *T. tinca*, *Carassius carassius*, *Cyprinus carpio*; the salmonid game fishes, *Salmo trutta fario*, *Salmo gairdneri*; larvicidal *Gambusia affinis*, *Lebistes reticulatus* and the tropical osphronemid, *Osphronemus goramy* (Natarajan and Menon 1988). The post-Independence India witnessed introduction of number of food and ornamental fishes including carps (Chinese strain of *C. carpio*, *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, *Puntius javanicus*), cichlid (*Oreochromis mossambicus* and *O. niloticus*), salmonids (*Salvelinus fontinalis*, *Salmo salar*, *Oncorhynchus mykiss*, *O. nerka*). In general, the present list of introduced fish species in India comprised about 500 species including food fishes (29), sport (2), mosquito control (3) and the rest are ornamental fishes. However, many of these fish were introduced without assessment of their likely impacts on ecology and fish diversity (Table 1). Moreover, several exotic species are now established in the natural waters of India.

Besides the existing proper import regulatory channel, there has been number of un-authorised introductions in the country without study of its risk assessment. Moreover, some of the introductions are posing serious threat to indigenous fish species and its ecosystems. Introduction of African catfish (*Clarias gariepinus*), tilapia (*Oreochromis niloticus*), pangasius (*Pangasionodon hypophthalmus*), big head (*Hypophthalmichthys nobilis*), pacu (*Piaractus brachypomus*), suckermouth catfish (*Pterygoplichthys* spp.), and mosquito fish (*G. affinis*) are introduced in the

Table 1. Introduction of major fish species in Indian waters

Species	Common name	Year	Source	Place of introduction	Aim	Remarks
<i>Salmo trutta fario</i>	Brown trout	1863–1908	England Japan	Nilgiri, Harwan	Stocking in lakes, reservoirs	Established
<i>Salmo lavensis</i>	Loach leven trout	1863	England	Nilgiri	Stocking in lakes, reservoirs	Almost disappeared
<i>Onchorhynchus mykiss</i>	Rainbow trout	1909 onwards	Sri Lanka Germany New Zealand	Nilgiri	Stocking in lakes, reservoirs	Exist
<i>Salmo gairdneri irideus</i>	Steelhead trout	1867, 1940	Europe, England, Sri Lanka England	Nilgiri	Stocking in lakes, reservoirs in Kashmir	Almost disappeared
<i>Salmo gairdneri shasta</i>	Steelhead trout	1941	England	Kerala	Stocking in lakes, reservoirs	Almost disappeared
<i>Salvelinus fontinalis</i>	Brook trout	1959	Canada	Kerala	Stocking in lakes, reservoirs	Almost disappeared
<i>Salvelinus namaycush</i>	Splake trout	1968	Japan	Nilgiri	Stocking in lakes, reservoirs	Almost disappeared
<i>Oncorhynchus nerka</i>	Sockeye salmon	1968, 1970	Canada	Nilgiri	Stocking in lakes, reservoirs	Almost disappeared
<i>Salmo salar</i>	Atlantic salmon	1968	North America	Kashmir	Stocking in lakes, reservoirs	Almost disappeared
<i>Carassius carassius</i>	Gold fish	1974	England	Nilgiri	Culture	Exist
<i>Tinca tinca</i>	Tench	1873	England	Nilgiri	Culture	–
<i>Osphronemus gourami</i>	Gourami	1856	Java	Kolkata	Culture	Exist
<i>Barbonymus gonionotus</i>	Silver barb	1972	Indonesia	West Bengal	Culture	Exist
<i>Oreochromis mossambicus</i>	Mozambique tilapia	1952, 1962, 1985	Indonesia, Bangladesh, Bangkok, Nepal	West Bengal, Tamil Nadu, Rajasthan	Culture	Established
<i>Oreochromis niloticus</i>	Nile tilapia	–	Thailand, Israel	Rajasthan	Culture	Established
<i>Oreochromis zilli</i>	Tilapia	1986	Thailand	Rajasthan	Weed control	–
<i>Oreochromis urolepis</i>	Tilapia	–	–	Coastal Andaman Nicobar	Culture	–
Hybrid <i>O. niloticus</i>	Red tilapia	1980	Philippines, Israel	Chennai, Kolkata	Culture	–
<i>Cyprinus carpio communis</i>	Common carp, Scale carp	1939, 1957	Sri Lanka, Bangkok	Cuttak	Culture	Established
<i>Cyprinus carpio specularis</i>	Mirror carp	1939, 1957	Sri Lanka, Bangkok	Cuttak	Culture	Established
<i>Cyprinus carpio nudus</i>	Leather carp	1939, 1957	Sri Lanka, Bangkok	Cuttak	Culture	Established
<i>Ctenopharyngodon idella</i>	Grass carp	1959	Japan, Hong Kong	Cuttak	Culture	Established
<i>Hypophthalmichthys molitrix</i>	Silver carp	1959	Japan, Hong Kong	Cuttak	Culture	Established
<i>Hypophthalmichthys nobilis</i>	Bighead	1980	Probably Hong Kong, Bangladesh, Nepal	West Bengal	Culture	Established
<i>Ictalurus punctatus</i>	Channel catfish	1990	–	Tamil Nadu, West Bengal	Culture	–
<i>Clarias gariepinus</i>	Thai magur	–	–	West Bengal	Culture	Exist in different regions

Table 1. contd...

Species	Common name	Year	Source	Place of introduction	Aim	Remarks
<i>Pangasianodon hypophthalmus</i>	Payasi	-	-	Tamil Nadu, Andhra Pradesh	Culture	Exist
<i>Puntius javanicus</i>	Tawes	1972	Indonesia	-	Culture	Exist
<i>Poecilia reticulata</i>	Guppy	1908	South America	-	Mosquito larval control	Exist
<i>Gambusia affinis</i>	Top minnows	1928	Italy	-	Mosquito larval control	Exist
<i>Gambusia holbrooki</i>	Top minnows	-	-	-	Mosquito larval control	-
<i>Piaractus brachipoma</i>	Pacu	2003-2004	-	West Bengal	Ornamental	Exist
<i>Pterygoplichthys anisitsi</i>	Suckermouth catfish	-	-	Bihar	Ornamental but accessed in open waters	-
<i>Pterygoplichthys multiradiatus</i>	Suckermouth catfish	-	-	Kerala, Tamil Nadu	Ornamental but accessed in open waters	Established
<i>Pterygoplichthys disjunctivus</i>	Suckermouth catfish	-	-	Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu	Ornamental but accessed in open waters	Established
<i>Pterygoplichthys pardalis</i>	-	-	-	Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu	Ornamental but accessed in open waters	Established
<i>Litopenaeus vannamei</i>	White leg shrimp	2001	-	Andhra Pradesh, Tamil Nadu	Culture	-

Source: (Modified after Ajithkumar *et al.* 1998, Acosta and Gupta 2001; Daniels 2006; Krishnakumar *et al.* 2009; Knight 2010, Murlidharan *et al.* 2015, Biju Kumar 2000; Biju Kumar *et al.* 2015; Singh 2014; Sinha *et al.* 2010, Hussan *et al.* 2019 and Suresh *et al.* 2019).

country for immediate gains and without evaluating their ecological consequences.

Impacts of alien fish species

The introduction of alien fishes has been observed to brought about a huge problems including destruction of native species (Kumar 2000). These alien species compete with the indigenous species for food, habitat and may even prey upon them. They facilitate in the introduction of new parasites or diseases and moreover can result in the production of hybrids which could cause genetic 'erosion' of indigenous species. The potential risks which not only affect the aquatic biodiversity, but also the socio-economic conditions of the rural communities that depend on aquatic ecosystem for their livelihood. The introduction of the Nile perch, *Lates nilotica*, to Lake Victoria may have caused, or contributed to, the extinction of nearly 200 species (Barel *et al.* 1985, Gophen *et al.* 1995). Epizootic ulcerative syndrome has expanded its range through Southeast Asia with fish movements and poor quarantine controls, and may be introduced elsewhere with further aquaculture species movements or aquarium fishes and caused serious loss of cultured fish production through most of Asia (Roberts *et al.* 1994). Eradication of an introduced species once it is established is usually difficult or impossible (Carlton and Mann 1981). FAO (1980) identified following four possible implications of introduction of exotic species:

- Extinction of ecological homologues
- Hybridization with concomitant profound effects on the genetics of the original fish populations
- Failure of introduction, in part, because of competition from established resident species,
- Co-existence, which means that the introduced species has found vacant niche in the community with an interactive niche segregation as an obvious result.

The impacts of indiscriminate introductions of alien species resulted in the disappearance of native species which has been recorded in many countries. It is very interesting to know that out of 160 species of freshwater fishes introduced in 120 countries, only 10% were reported to found satisfactory indicating futility of indiscriminate introductions (Courtenay and Stauffer 1984). Due to extreme change in the habitat of the river from lotic to lentic, obstruction of the continuous flow and meagre downstream discharge, the composition and structure of fish assemblages, ecology and fish diversity of the river has been affected. Further, it has been reported that fish diversity and fishery of the systems shifted enormous in the potamon zone due to severe change in physico-chemical parameters (Joshi *et al.* 2014a and b). The deteriorated riverine habitats and depleted waters are reportedly invaded by alien fish species (Joshi *et al.* 2014a and b, Laxmappa *et al.* 2015, Joshi *et al.* 2016

Table 2. Impacts of alien fish species in open waters of India

Introduced species	Environmental impacts	References
<i>Oreochromis mossambicus</i>	Displaced Gangetic carps, <i>Puntius dubius</i> , <i>Labeo kontius</i> and posing threat to <i>Etroplus suratensis</i> from reservoirs of Southern states	Sreenivasan 1967, Murthy <i>et al.</i> 1986, Natrajan and Menon 1988
<i>Oreochromis niloticus</i>	Occupied riverine habitats of Indian major carps (IMC)	Joshi <i>et al.</i> 2014a, 2014b, 2017
<i>Osphronemus goramy</i>	Established with least impacts to ecology	Shetty <i>et al.</i> 1989
<i>Hypophthalmichthys nobilis</i>	Compete for food with Catla and silver carp	Singh and Ponniah 2001
<i>Cyprinus carpio</i>	Displacement of IMC from riverine habitats, <i>Schizothorax richardsonii</i> , <i>Osteobrama belangeri</i> , <i>Tor putitora</i> etc.	Joshi <i>et al.</i> 2014a, 2014b, 2017; Shetty <i>et al.</i> 1989
<i>Clarias gariepinus</i>	Risk of establishment	Singh and Ponniah 2001, Krishna Kumar <i>et al.</i> 2011
<i>Carassius auratus</i>	Hybridization with common carp	Shetty <i>et al.</i> 1989
<i>Hypophthalmichthys molitrix</i>	Established in certain reservoirs and displaced Catla	Kaushal 1991, Pandey 1997
<i>Salmo truttafario</i>	Feeds on local species	Sehgal 1989
<i>Pterygoplichthys</i> spp.	Occupy habitats of native species and compete for food with native species	Murlidharan <i>et al.</i> 2015, Biju <i>et al.</i> 2015, Hussan <i>et al.</i> 2019, Suresh <i>et al.</i> 2019

and 2017) (Table 2). If the deterioration of riverine resources persist as per present momentum, the Indian rivers will probably lose their valuable fish germplasm, which is required for sustenance of ecological balance; and commercial importance as protein rich food, cater the need of ornamental and fish based sport sectors.

Degraded open waters owing to large scale river modifications, abstraction, excessive drawl of riparian groundwater; over-exploitation and wanton destruction of fishery resources in the rivers are resulting in depletion of the sensitive fish species and appearance of exotic fishes (Kolar and Lodge 2002, Arts and Nienhuis 2003, Joshi *et al.* 2014a, 2014b, 2017). The invasion of alien fish species in various inland open water resources of India has been

adequately reported (Singh *et al.* 2010, Joshi *et al.* 2014a and b, 2017; Joshi 2017). The reasons for establishment could be attributed to decreasing water volume, velocity and higher pollution load, which proved uncongenial for sensitive native species but amiable for the highly resilient alien species like common carp (*C. carpio*), tilapia (*O. mossambicus* and *O. niloticus*), and suckermouth catfish (*Pterygoplichthys* spp.).

The Ganga River system is a glaring example of the above situation (Joshi 2017) where cumulative effect of hydrological degradations has resulted in severe decline of fisheries in the river Ganges and its tributaries (Vass *et al.* 2010, Sinha *et al.* 1999). Further, the resultant vacant habitat/niche has been occupied by hardy, resilient exotic fishes like common carp and Nile tilapia, which probably made access in the river from the prevailing culture systems on the basins (Joshi *et al.* 2014b).

Conclusion

The reasons attributed for establishment of alien species into open water resources could be attributed to their hardy, resilient, eurythermal, omnivorous nature; amenable for breeding in all aquatic conditions, strong adaptability to new environments and above all our diverse aquatic habitats and altered ecological conditions. Keeping the risk of escape from the culture system and possibilities of spread in open waters, there is earnest need to control the import of alien fish species, based on their merit and likely impacts on open waters.

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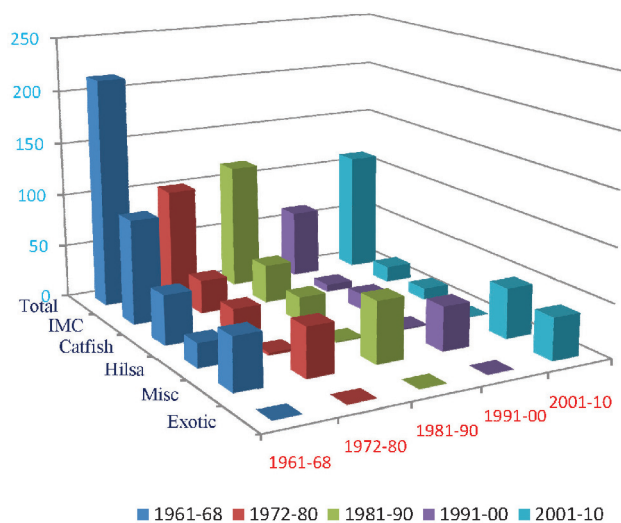


Fig. 1. Emergence of alien fishes in the rivers at Allahabad during 1961–2010 (Joshi 2017).

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