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The recent occurrence of exotic freshwater fishes in the tributaries of river Ganga basin: abundance, distribution, risk, and conservation issues

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Abstract We record here the recent occurrence, abundance and distribution of six exotic fish species, viz. *Oreochromis mossambicus*, *Cyprinus carpio*, *Hypopthalmicthys molitrix*, *Ctenopharyngodon idellus*, *Clarias gariepinus,* and *Pterygoplichthys disjunctivus* (a new exotic in India) distributed through the four important tributaries of river Ganga basin in India. From the total catch, the abundance index of all exotic species in different rivers ranged from 1.1 to 14.5 % with highest value in River Gomti. The relative abundance of the exotic species in all the four tributaries demonstrated that a single species *C. carpio* contributed a considerable abundance (43.3–83 %) than that of the remaining exotic fishes. The Common Carp, *C. carpio,* was ubiquitous in all the four tributaries of Ganges basin studied and had the highest local distribution (52.63 %). Smaller size groups of endangered (*Chagunius chagunio*, *Chitala chitala,* and *Tor tor*) and migratory species (*Bagarius bagarius, Ompok pabda, Wallago attu,* and *Sperata aor*) in the four tributaries were recorded, and the increasing appearance of Common Carp and other exotic fishes is signaling biological invasion. Possible threats to the indigenous fish fauna, as a result of the invasion and proliferation of these exotics, are discussed.

Keywords Exotic fish · Abundance · Distribution · Ganga basin · India

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1 Introduction

The aquatic biodiversity of the world is changing and getting depleted alarmingly fast as a result of extinction caused by habitat loss, pollution, introduction of exotic species, over exploitation, and other anthropogenic activities (Moyle and Moyle 1995; Duncan and Lockwood 2001). The indiscriminate transfer of aquatic organism, particularly fishes, brought about a worldwide concern as it resulted in a wide array of problems including extirpation of indigenous species (García-Berthou 2007; Rowe 2007). The exotics are a competition to indigenous fishes for food and habitat. They may prey upon native fishes, introduce new disease and parasites, involve in the production of hybrids, and cause genetic erosion of indigenous species and degradation of physiochemical nature of aquatic ecosystem. The potential risk not only affect the quality or level of biodiversity but also the socio-economic aspects of the human community that depends on aquatic ecosystem for their sustenance (Philipp et al. 1995). Worldwide, exotic fish introductions have been reported to impact the fish biodiversity and have provided significant warnings of the various effects on environment posing threats to the community trophic structure disrupting biological integrity (Casal 2006; Lakra et al. 2008).

In India, during the last several decades, over 300 species of exotics fishes have been brought into India for experimental aquaculture, sport fishing, and mosquito control (Biju Kumar 2000). Apart from these, innumerable ornamental fishes have also been introduced into the country at different times. Though, these introductions have helped to widen the species spectrum, their impact on indigenous fish in capture and culture fisheries has not been properly evaluated until now, even though it has been realized that some of the introduced fishes have adversely

affected the indigenous species. The Ganga River (Ganges) is known to harbor rich fish diversity (Bilgrami 1991; Rao 2001; De Silva et al. 2007; Sarkar et al. 2012); however, environmental integrity of this largest freshwater river systems is being increasingly threatened due to several anthropogenic activities and also through exotic fish introductions (Sarkar and Bain 2006; Sarkar et al. 2008; Singh et al. 2010). The reported impacts of alien fish species emphasized biodiversity threats and conservation of the large rivers (Singh and Lakra 2006; De Silva et al. 2007; Lakra et al. 2008; Sarkar et al. 2012). However, unfortunately, the statuses of exotic species in the tributaries of Ganga have not been addressed although they support a rich biodiversity and offer ideal habitat for breeding and spawning of many indigenous species.

It has been well reported that the fish fauna of Indian rivers are threatened due to various natural and anthropogenic activities. The lack of definite information on the various threats faced by the fish due to exotic introductions in these rivers has hampered the appropriate conservation and management tactics. Therefore, to plan successful management and conservation strategies for the native and indigenous fish biodiversity of these major tributaries of River Ganga, an assessment on the abundance and distribution pattern of these invasive fish species is urgently needed. The present investigations based on the distribution pattern, abundance, and impacts of the exotic fishes serves as a basis for the conservation of native fish fauna. Also, our assessment based on the potential threats of exotic fishes especially on the threatened fishes inhabiting in these rivers invites attention to conserve the fishes of regional conservation concern.

2 Materials and methods

2.1 Study area

The details of the Ganga basin showing studied tributaries have been shown in Fig. 1. The Gomti and Ghaghara rivers are the major tributaries of the Ganga River system in northern India. River Gomti originates from a natural lake

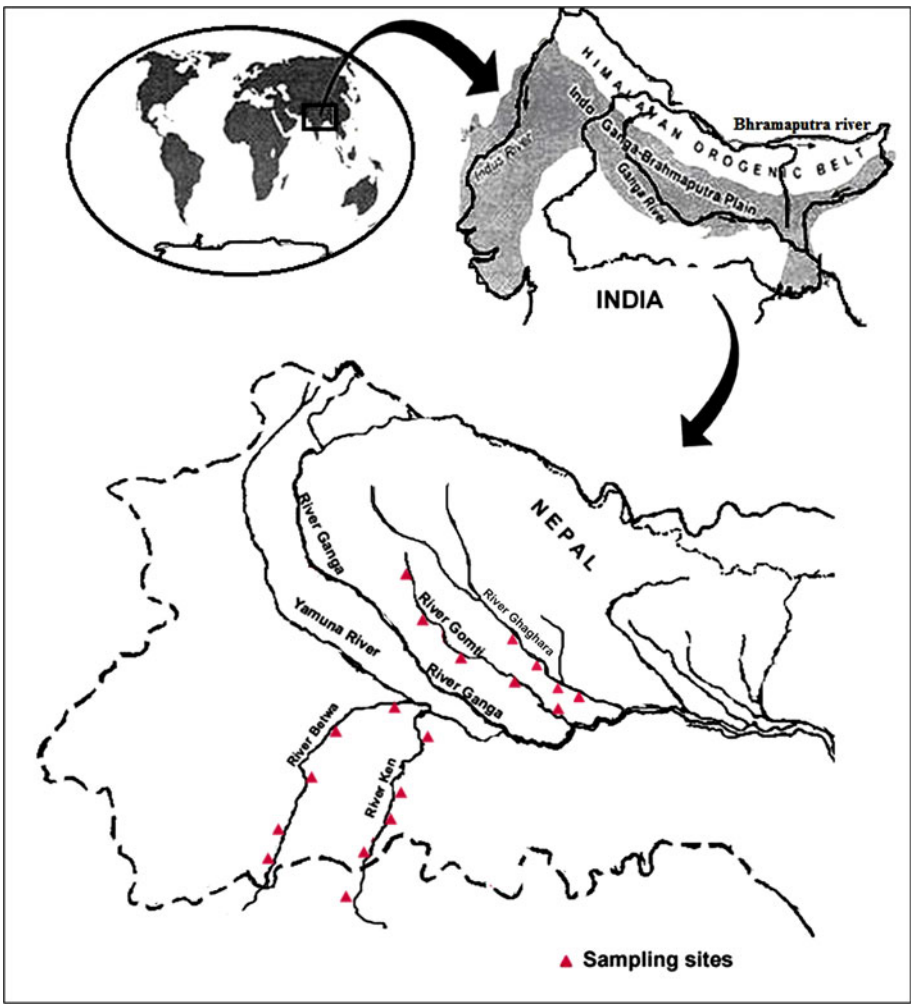

Fig. 1 Map of the river Ganga basin showing the study area and sampling sites

in the forested area near Pilibhit town in Uttar Pradesh, about 50 km south of the Himalayan foothills (Singh et al. 2004). The river flowing through the central and eastern part of Uttar Pradesh traverses a total distance of about 730 km before finally merging with the Ganga River near Varanasi. The river drains a catchments area of about 25,800 km^2 and also serves as a major source of domestic water supply of the Lucknow city, the state capital of Uttar Pradesh. Subsequently, the river receives back the untreated domestic wastewater from Lucknow city (Singh et al. 2005) and effluents from a few industries (distilleries, sugar mills, chemical, and others) directly during its course. The Ghaghara is a river in Nepal and northern India, one of the largest affluent of the Ganges. It rises in the southern slopes of the Himalayas in Tibet, at an altitude of about 13,000 feet (3962 m) above sea level. The river flows south through Nepal, where it is known as the Karnali River. In Uttar Pradesh state, the Ghaghara flows in a southeast direction to the town of Chapra, where, after a course of 570 miles (917 km), it joins the Ganges. The river also is one of the most important commercial waterways of Uttar Pradesh.

The Betwa and Ken rivers are the major tributaries of River Yamuna that is a major tributary river of the Ganges (Ganga) in northern India. River Betwa, with a total length of around 1,370 km, is the largest tributary of the Ganges. The Betwa originates in the Raisen district in Madhya Pradesh at an elevation of 475 m above mean sea level and joins River Yamuna near Hamirpur in Uttar Pradesh, traveling a total distance of about 590 km. Annual discharge rate of River Betwa is 10000 million cum, the total area of about 43,319 sq. km. The river is regulated by 3 large dams (Rajghat, Matatila, and Paricha) and 2 small dam/weirs in the middle and upper stretch of the river. The Ken River has its origin from the Ahirgawan village on the northwest slopes of the Kaimur hills in the Jabalpur district of Madhya Pradesh at an elevation of about 550 meters above mean sea level. Like the Betwa River, it is also an interstate river between Uttar Pradesh and Madhya Pradesh that flows with a discharge rate of 11,300 million cubic m. The total length of the river from its origin to confluence with the River Yamuna is 427 km, out of which 292 km lies in Madhya Pradesh, 84 km in Uttar Pradesh, and 51 km forms the common boundary between Uttar Pradesh and Madhya Pradesh. The river joins the Yamuna River near village Chilla in Uttar Pradesh at an elevation of about 95 m. The river is the last tributary of Yamuna before the Yamuna joins the Ganga.

2.2 Selection of the sampling sites

The sampling sites in four rivers were selected based on the representative habitat type present and accessibility during the study period. The study was carried out during 2007 through 2010. In our study, four sites were selected along the entire stretch of Ghaghara river whereas five study sites were selected along the entire stretches of Gomti, Betwa, and Ken rivers. The details of the different study sites and locations, altitude, and land use pattern have been presented in Table 1.

2.3 Fish sampling and data collection

The fishes were collected by experimental fishing in the selected sites cast nets, gill nets, and drag nets, during 2007

Table 1 Details of the sampling sites in river Ganga basin

Site no	Sampling sites	Name of tributary	Altitude (ft)	Land use pattern/ detrimental factors
1.	Girijapuri barrage	Ghaghara	385	Forest cover, agriculture, irrigation barrage
2.	Elgin Bridge	Ghaghara	284	Agriculture
3.	Chahlari ghat	Ghaghara	281	Agriculture
4.	Faizabad	Ghaghara	234	Agriculture, temple in river bank
5.	Pilibhit	Gomti	575	Forest cover, agriculture
6.	Sitapur	Gomti	435	Agriculture, domestic sewage
7.	Lucknow	Gomti	368	Domestic sewage, beverage distillery, industry, temple in the river bank
8.	Sultanpur	Gomti	228	Agriculture, domestic sewage, sugar mills, small scale industries
9.	Jaunpur	Gomti	183	Agriculture, domestic sewage
10.	Bhojpur	Betwa	1430	Agriculture, industries, and lifting of boulders
11.	Ganjbasoda	Betwa	1314	Agriculture, irrigation dam/weir and barriers
12.	Rajghat	Betwa	1162	Agriculture, dams with large reservoir
13.	Orcha	Betwa	659	Power plant, dams, temple and industrial pollution
14.	Hamirpur	Betwa	260	Agriculture, sand mining, discharge of sewage
15.	Amanganj	Ken	985	Agriculture, fragmented river channel
16.	Patan	Ken	607	Reserve forest
17.	Mandla	Ken	638	Reserve forest
18.	Banda	Ken	722	Agriculture, domestic pollution
19.	Chilla	Ken	240	Agriculture

through 2010. From commercial catches, fishes were collected at the landing centers of the respective sampling sites. The single specimen of newly reported *Pterygoplichthys disjunctivus* was collected during experimental fishing in river Gomti (geographical coordinates of N 36° 53.221′ and E 080° 54.027′) in November 2009 and identified according to methods by Page and Robins (2006) and Hoover et al. (2004). The representative specimens of the collected fishes were fixed in 10 % formaldehyde in plastic bottles and transferred to the laboratory, where they were identified using standard literature (Jayaram 1999; Talwar and Jhingran 1991). The fish catches were sorted by species by fishermen for marketing and sale. The data from such segregated fish groups were then collected to work out the species contribution. From the catch, the exotic fish species was separately counted. From the total catch, the abundance index of exotic fish was calculated. The diet and feeding habits of exotic fish were determined based on the contents of the digestive tract and was examined using microscope. Data regarding threats faced by the fish fauna were obtained from direct observations and interactions with local stakeholders and fishermen. The conservation status of the indigenous fish was adapted from Lakra et al. (2010).

2.4 Analysis of biological indices

a: Relative abundance (RA)

$$RA = N/S$$

where N = total number of individuals of species, S = total number of fishes

b: Local distribution (D)

$$D = \text{Ni.st}/\text{Ni.st} \times 100\ \%$$

where D = local distribution, Ni.st = total No. of locations where fishes were found, N.st = total sampling sites

c: Abundance index (AI)

$$AI = n(k) \times 100/N$$

where AI = abundance index, $n(k)$ = number of exotic fish caught at each study site, N = number of all the fish species caught at that site

2.5 Analysis of trophic niche

Various members of exotic fish are classified into trophic groups based on feeding habits (Karr et al. 1986; OPEA 1987). Analyzing the gut content, we found three types of trophic niche (planktivore = PL, omnivore = OM, herbivore = HR) in the tributaries. Based on the habitat orientation, the exotic species were classified into two general groups: pelagic (P) and benthic (B) (Jhingran 1997).

3 Results

3.1 Abundance and distribution pattern

Based on the extensive explorations, a total of six exotic fish, viz. *Oreochromis mossambicus* (Peters), *Cyprinus carpio* (Linnaeus), *Hypopthalmicthys molitrix* (Valenciennes), *Ctenopharyngodon idellus* (Valenciennes), *Clarias gariepinus* (Burchell), and *P. disjunctivus* (Weber) representing four families, six genera, and four orders, were recorded from the various sampling sites (Table 2). From

Table 2 List of the freshwater exotic species sampled in the tributaries of Ganga basin

Family/species	Ghagara				Gomti					Betwa					Ken					Habitat	Trophic guild	Length range (cm)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
Cyprinidae																						
Cyprinus carpio	+		+		+	+	+	+	+					+			+		+	P	OM	4.4–58.2
Hypopthalmicthys molitrix		+	+	+			+	+												P	PL	12.0–47.4
Ctenopharyngodon idellus			+	+			+	+												P	HR	19.5–37.8
Cichlidae																						
Orechromis mossambicus				+										+			+			B	OM	10.0–37.8
Clariidae																						
Clarias gariepinus							+				+									B	OM	20.0–39.2
Loricariidae																						
Pterygoplichthys disjunctivus							+													B	OM	36.0

PL planktivores, *HR* herbivore, *OM* omnivore, *P* pelagic, *B* benthic (1–19 are the different locations of the respective rivers)

the total catch, the abundance index of all the six exotic species in different rivers ranged from 1.1 to 14.5 % and with highest value in River Gomti as shown in Fig. 1. We found that out of five species, two species *C. carpio* and *H. molitrix* had an abundance of more than 100 individuals out of 1000 individuals collected in all the 19 sampling sites. The Common Carp, *C. carpio,* had the highest relative abundance (67.5 %) with size range of 4.4–58.2 cm followed by *H. molitrix* (12.3 %), *C. idellus* (9.9 %), *O. mossambicus* (6.8 %), *C. gariepinus* (3.0 %), and *P. disjunctivus* (0.5 %) (Figs. 2, 3). The Loricariid catfish *P. disjunctivus* (Figs. 4, 5) in rivers of India were not previously reported and this being the first record from the River Gomti in the Indian subcontinent.

In our study, the distribution pattern of exotic fishes suggests that only one species, *C. carpio,* was ubiquitous in all the four tributaries of Ganges basin studied and had the highest local distribution (52.63 %) (Fig. 4). The highest distributional range of this species was recorded in River Gomti that spread along the downstream/upstream gradient. The fish was also recorded from the downstream of the rivers Betwa and Ken. Samples of Silver Carp, *H. molitrix,* with local distribution of 26.32 % were collected from the middle segment of river Ghaghra and Gomti. The Thai magur, *C. gariepinus,* was recorded from the two sampling sites located midstream of Gomti and upstream of Betwa rivers while Tilapia (*Orechromis mossambicus*) was recorded from three sampling sites located in three rivers, that is, downstream of the Ghaghra, Betwa, and Midstream of Ken. The local distribution of Grass Carp (*C. idellus*) recorded 21.05 %, which was distributed in the downstream and midstream segments of Ghaghara and Gomti, respectively. The lowest local distribution (5.2 %) was recorded in Sailfin catfish (*P. disjunctivus)*, which was collected for the first time from one sampling site located in the midstream of Gomti River. From the total catch, presence and absence of native fish species in sampling sites of the rivers were also recorded and grouped as Indian Major Carps (IMCs), Minor Carps, Catfishes, and

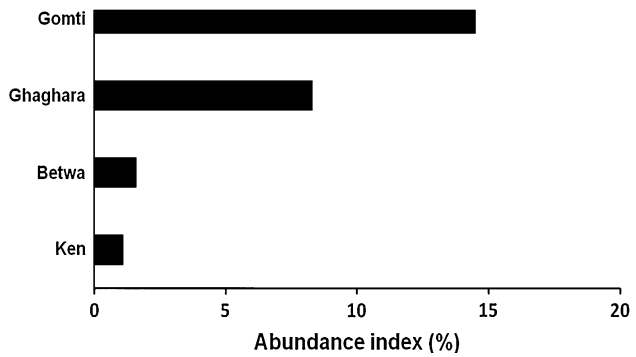

Fig. 2 Abundance index (AI %) of exotic fish species in different rivers

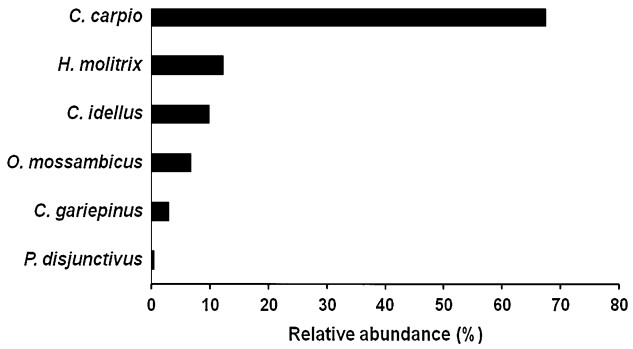

Fig. 3 Relative abundance (%) of exotic fish species in the tributaries of Ganga basin

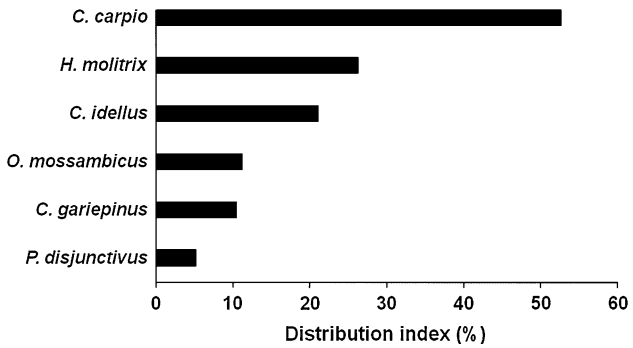

Fig. 4 Distribution index (%) of exotic fish species in the tributaries of Ganga basin

miscellaneous fish. The Indian Major Carps comprising of *Catla catla, Cirrhinus mrigala,* and *Labeo rohita* were distributed in at least two-to-three sampling locations in all of the four rivers, and their size ranged from 212 to 550 mm in length and 400 to 9000 gm in weight. We also recorded four native fish species from different sampling sites of the rivers having regional importance and listed as endangered (EN) as per Lakra et al. (2010). Only some samples (6–20 nos) of *Chagunius chagunio* (EN) were recorded from the downstream of Gomti, Ghaghara, Ken, and upstream of the Betwa rivers whereas *Chitala chitala* in substantial abundance (10–50 nos) were recorded from almost all the sampling sites of Betwa, midstream of Ken, Gomti, and Ghaghara rivers, respectively. Endangered mahseer (*Tor tor*) were recorded in good abundance (70 nos) from the midstream of Ken and few samples (1 no) from upstream of Betwa. Samples of (2 nos) *Ompok pabo* (EN) were only recorded from the downstream of Ghaghara river.

3.2 Habitat orientation and trophic indices

The analysis of trophic niches of the exotic fish species in different sampling sites in the tributaries indicated that

Fig. 5 *Pterygoplichthys disjunctivus* from Gomti river (tributary of Ganga basin) India (total length = 36 cm, collected by B. K. Gupta)

among six of the exotic species, four species were of omnivorous in nature followed by one species as planktivore and herbivore, respectively. The data on habitat orientation of described exotic species reveal the dominance of pelagic exotic fishes in all the tributaries followed by benthic fish species (Table 2).

4 Discussion

The present study made in the tributaries of river Ganga basin demonstrated that out of 27.8–61.8 % of exotic fishes captured in River Ghaghara and Gomti, only one species, *C. carpio,* contributed 43.3–83 % than that of the remaining exotic fish. Although the dominance of Common Carp (*C. carpio*) in the main stream of River Ganga was reported in a recent study by Singh et al. (2010), its pattern of occurrence and distribution in the tributaries of the river Ganga basin has been described here for the first time. Its occasional occurrences were subsequently reported from open waters gravitating Jhelum, Mahanadi, and Yamuna rivers (Singh and Lakra 2006; Singh et al. 2008). This data confirmed that Common Carp has already established breeding populations and contribute a large percent of the exploited stock in those rivers. Samples of early life stages collected from all the sampling sites of Gomti River indicate the reproductive potential of this fish. Since Common Carp, *C. carpio*, is known to exhibit early sexual maturity, rapid colonization, and wide environmental tolerances (Koehn 2004; Singh and Lakra 2006), these attributes have been considered to help this exotic fish to successfully invade into new environment of River Gomti and also toward the other tributaries of River Ganga and other rivers of India. A comprehensive list of 15 freshwater exotic species with details of date of introduction, origin, first records if any, and purpose of introduction in Indian rivers has been presented in Table 3.

Introduced Common Carp has been reported to implicate environmental changes principally eutrophication through an increase in turbidity and mobilization of nutrients to the water column from the benthos through its habit of rooting or digging in the bottom (Britton et al. 2007; Khanna et al. 2007; Rowe 2007). The invasion of Common Carp, *C. carpio*, in Australia, has already been reported to quickly spread and dominate fish communities (Koehn 2004). Significant negative effects of Common Carp on the piscine diversity have been reported (Lakra et al. 2008; Ross et al. 2008). Common Carp in India has already been reported to cause sharp decline in the catches of endemic schizothoracids (Singh and Lakra 2006; Lakra et al. 2008). Due to introduction of Common Carp in the lakes of Kumaon, the catches of schizothoracids were found to decline drastically (Singh and Lakra 2006) and the production of Common Carp increased since 1985 (Shyam Sunder 1998). In our study, smaller size groups of endangered (*C. chagunio*, *C. chitala,* and *T. tor*) and migratory species (*Bagarius bagarius, Ompok pabda, Walago attu,* and *Sperata aor*) in the four studied rivers were recorded and the increasing appearance of Common Carp in the fishery is signaling biological invasion and threatening the ecological integrity.

In addition to the impending risk due to the Common Carp coupled with the growing population and distribution of other exotic fishes like Silver Carp (*H. molitrix*) and Grass Carp (*C. idellus*) particularly in mid-to-down streams of River Gomti and Ghaghara, native fish diversity in riverine ecosystem is under threat. These exotic species have already created adverse effects on important indigenous fishes in India and also in other countries (Menon 1989; Laird and Page 1996; Pflieger 1997; Fuller et al. 1999). In India, the depleted population of Catla and Mahseer in Govind Sagar reservoir after the introduction of Silver Carp is well known (Menon 1989; Molur and Walker 1998). The ability of Silver Carp to consume

Table 3 Status of exotics reported in Indian rivers

Name of the species	Date of introduction/first record	Home country	Purpose	Current distribution in Indian rivers
Oreochromis mossambicus	1952	Africa	Experimental culture	River Ganga[a], Gomti[b], Churni[c], Chalakudy[d], Kali[e], Sharavati[f], and Bharathapuza[g]
Cyprinus carpio	1939	Sri Lanka	Experimental culture	River Ganga[a], Gomti[b], Churni[c] Kali[e], Sharavati[f], Achenkoil[h], Jhelum[i], Mahanadi[j], Yamuna[k], and Gerua[l]
Hypopthalmicthys molitrix	1959	Hong Kong	Experimental culture	River Ganga[a], Gomti[b], and Churni[c]
Ctenopharyngodon idellus	1957	Japan	Experimental culture	River Ganga[a], Gomti[b], and Churni[c]
Pangasius sutchi	1994	Thailand	Experimental culture	River Churni[c]
Osphronemus goramy	1916	Java and Mauritius	Experimental culture	River Chalakudy[d]
Poecilia reticulata	1908	South America	Mosquito control	River Chalakudy[d] and Meenachil
Xiphophorus maculatus	2008	North America	Aquarium trade	River Chalakudy[d]
Gambusia affinis	1928	Italy	Mosquito control	River Chalakudy[d]
Oncorhynchus mykiss	1920	North America	Aquarium trade	River Ganga[a]
Lebestis reticulates	2003	South America	Aquarium trade	River Kali[e] and Sharavati[f]
Pterygoplichthys anisitsi	2010	South America	Aquarium trade	River Ganga[a]
Oreochromis niloticus	Unauthorized introduction			River Ganga[a], Churni[c]
Clarias gariepinus	Unauthorized introduction			River Ganga[a], Gomti[b] Churni[c]
Aristichthys nobilis	Unauthorized introduction			River Ganga[a], Churni[c]

[a] Anonymous (2010); [b] Sarkar et al. (2010); [c] Bhakta et al. (2007); [d] Raghavan et al. (2008); [e, f] Bhat (2003); [g] Biju Kumar (2000); [h] Kurup et al. (2003); [i, j, k] Singh and Lakra (2006); [l] Sarkar et al. (2008)

detritus, phytoplankton, and zooplankton, combined with its high-consumptive capacity, may negatively affect other aquatic organisms of both the rivers. Further, the Indian Major Carps *Cirrhinus mrigala* and *Catla catla* important omnivorous fishes recorded in both the rivers share approximately the same resources as that of Silver Carp. Consequently, the proliferation of the Silver Carp will invariably harm the stocks of both the indigenous carps. Correspondingly, if the Grass Carp populations in both the rivers continue to increase, the entire riverine ecosystem, as well as native herbivores, could be adversely affected. It is evident that plants serve as biotic mediation in river floodplain ecosystems, reducing sediment resuspension and turbidity by damping waves with their leaves and anchoring the bottom with their roots, and also serve as spawning sites and refugia for aquatic invertebrate and small fish, thus contributing to the dissolved and particulate organic matter that fuels the detritus-based food webs in riverine ecosystems (Sparks et al. 1990; Raibley et al. 1995).

Several cases of fish species decline from various water bodies in India including reservoirs and rivers due to proliferation of tilapia have been documented (Jhingran 1984). The presence of tilapia in Ghaghara, Betwa, and Ken rivers will invariably cause negative effects on the native fish fauna of the region. Taking into consideration the trophic status of *O. mossambicus*, we believe that an immediate threat to a native species would be to the endangered mahseer (*T. tor*) recorded from the midstream of River Ken. An important resident and endangered fish of the River Ken *T. tor* shares the same food resources as that of *O. mossambicus* that will later can be produced a predator overlap between the two fish species and ultimately results in the decline of indigenous stock of mahseer in River Ken. Furthermore, one of the exotic species *C. gariepinus* (Thai magur) recorded from the midstream of Gomti and upstream of Betwa rivers is a voracious carnivore that may proliferate in near future and affect the native fish fauna specially endangered *C. chagunio* and *C. chitala* inhabiting in Gomti and Betwa rivers in considerable abundance. This exotic catfish is reported to have had a clandestine entry into India from Bangladesh, first into West Bengal and later spread to other parts of the country (Thakur 1996). It is also known to be found in the rivers of Yamuna, Sutlej, Godavari, and several other rivers of India (Sugunan 2000). Due to its highly voracious feeding habits across niche, the Government of India decided to ban its culture in this country. Despite the ban, it has been gaining popularity among the farmers in India as an economically alternative species to Indian Major Carps.

Interestingly, in this study, a single specimen of armored Southern Sailfin catfish (Loricariidae) *P. disjunctivus* was reported for the first time in River Gomti in the Indian subcontinent. It is not known that the population of *P. disjunctivus* is well established in this river. However, several studies have proved that it can become abundant within a short period of time due to rapid growth and high fecundity (Hoover et al. 2004). Most importantly, in a recent study, occurrence of another Southern Sailfin catfish species (*Pterygoplichthys anisitsi*) has been reported by Sinha et al. (2010) from the main channel of River Ganga

near Patna, India. A large population of the fish in near future can significantly alter and reduce food and ecology of aquatic insects and other arthropods, subsequently negatively affecting many native fishes that depend on these food sources (Inger and Chin 2002; Kottelat et al. 1993).

In addition, with varying degree of threat from exotic fish mentioned in this study, we also identified an assortment of anthropogenic and natural threats faced by local fish species in different studied rivers. River Gomti and Ghaghara were subjected to the threats of pollution by sewage and industrial wastes, deforestation, excessive use of fertilizers, pesticides, and water abstraction, which have affected the overall fish diversity to large extent. The Betwa River is subjected to the fragmentation in the upper stretch, due to construction of many irrigation dams and barriers (a horizontal bundh in the river bed to store river water). The mid-to-down segments of the river were subjected to thermal pollution, soil erosion, and siltation. However, the Ken River showed less anthropogenic disturbance due to presence of protected area, dense forest cover, and low water pollution (Dubey et al. 2012). At some of the upper stretches, we observed some natural disturbances like low rain fall and draught that address the need for conservation and management of fish and their habitat.

5 Conclusion

Our results presented here provided for the first time an assessment of the exotic fish species along with new findings, distributed throughout the tributaries of river Ganga basin. Previous literature indicates that at least five among the six exotic species that we have collected from those tributaries have the status of "potential pests". Their occurrence and possible spread through the river system could spell disaster for the many endangered fishes mentioned in different rivers in our study. Our findings on the occurrence and abundance of exotic fish species in those sampling locations of the rivers that harbor substantial amount of endangered species, early life stages, and smaller size groups of many migratory fish are of critical concern. The results based on the natural and anthropogenic threats faced by Gomti and Ghaghara rivers indicate that the ecological conditions of those rivers were homogenizing by the increasing population of exotic fish like Common Carp, Silver Carp, and Grass Carp that could be a great threat to the ecological integrity of those rivers. Since degraded ecosystems are often more susceptible to successful invasion of exotic fish species, other introduced exotic fishes may also find access and then negatively impact the biodiversity. Overall, the impacts of exotic fish in the tributaries of river Ganga basin have been found to be mild at present, but it may cause habitat alteration, trophic structure alteration, and hybridization in due course of time. Therefore, detailed investigations should be planned and carried out into aspects of species interactions (native–exotic and exotic–exotic), habitat alterations, genetic deterioration as well as introduction of parasites and diseases. The results of our study on the distribution and abundance of exotic fish species in the tributaries of river Ganga basin invites attention to conserve indigenous germplasm facing threats of shifting from their natural habitats.

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