Indian Journal of Animal Sciences **92** (2): 268–271, February 2022/Short communication
https://doi.org/10.56093/ijans.v92i2.122109

Mounting threat of invasive alien fish species in Ganga river system and open water resources of the basin

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Received: 18 September 2021; Accepted: 29 October 2021

Keywords: Alien fish, *Clarias gariepinus, Cyprinus carpio*, Ganga river, *Oreochromis niloticus*

The import of commodities has been an age-old practice and attraction in India. There have been regular additions of newly imported items over the period, which include live plants, animals, and fish. For multiple utilities, the import of live fish started in the year 1863, and for the first time, brown trout eggs were successfully introduced in 1900 from Scotland to Harwan, Kashmir (Mitchell 1918). The introduction efforts have gradually intensified during the last few decades. The introductions of fish in India were primarily meant for the diversification of species in aquaculture, stocking in lakes and reservoirs, diversification of the sport fishery base, larval control, and augmentation of fancy ornamental fishes. Besides, there have been some clandestine introductions of risk-bearing fishes through unauthorized channels. The introduction of alien species may be an earnest need of diversity poor countries but India endowed with rich fish diversity, has the potential to cater to the needs of the sector from its germplasm pool. The vast geographical area and varied topographical regions of India possess copious fish diversity. A total of 3,157 native species are reported from the cold-water, freshwater, brackish water, and marine resources of India (NBFGR 2020). Irrespective of the facts, introductions are still underway in India. Despite the abundant fish diversity available in the country, considerable alien fish species (13.67%) have also been introduced in India over the years. A total of 500 introduced fish species/strains were listed in India, including food fishes (29), sport (2), mosquito control (3), and the rest, ornamental fishes. In general, the alien fish species have been introduced and cultured in captivity, even though a few escaped into adjoining inland water bodies and subsequently made access to different rivers and connected water bodies. Among these, most of the escapees were unable to breed and establish in new habitats, while some other highly resilient fishes like common carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambicus, O. niloticus*), and silver carp (*Hypophthalmichthys molitrix*) have been established in several rivers, wetlands, and reservoirs in India (Shetty *et al*. 1989, Vass *et al*. 2010, Singh *et al*. 2013, Joshi *et al*. 2014a, 2017a, 2017b). Increasing expansion and establishment of alien fishes in open waters resources of the country is a matter of serious concern, which is often discussed in a different forum and it was also thoroughly discussed by senior fisheries and environmental experts assembled in a joint Consultation (Joshi *et al*. 2019) organized by ICAR-NBFGR, Lucknow, and WWF-India, at WWF-India New Delhi on 19th December 2018. Keeping its ecological and socio-economic importance in view, there is an urgent need to keep a constant vigil on this highly important issue and accordingly sensitize the stakeholders and policymakers. To assess the influence of alien fishes in open water bodies, we conducted sampling at selected sites of the Ganga river system and other water bodies from April 2017 to March 2020, to unravel the state of occurrence, dominance, and establishment of alien fish located on the basin.

The present study revealed the occurrence of 9 alien fish species from studied stretches of the Ganga river system and other water bodies comprising common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus, O. mossambicus*), African magur (*Clarias gariepinus*), Amazon sailfin catfish or suckermouth catfish (*Pterygloplichthys anisitsi, P. pardalis*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*) and grass carp (*Ctenopharyngodon idella*). Among these, all 9 species were observed in the river Yamuna, which is an extremely impaired river due to the construction of barrages and multiple perturbations along its course (Joshi *et al.* 2016). Among aliens, *O. niloticus* and *C. carpio* formed a sizeable fishery round the year comprising fishes of all size groups, while the rest were observed occasionally as stray samples. Common carp and Nile tilapia were recorded in 35% of total catch at Varanasi, 41% at Prayagraj, 67% at Etawah, 61% Agra, and 63% at Mathura, however, it was dominated by tilapia at all these sites except Prayagraj (Table 1). Analysis of different length classes of *C. carpio* and *O. niloticus* reveals the availability of all sized samples and fully established populations of both species (Figs 1, 2). The occurrence of large-sized samples from the rivers

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Table 1. Occurrence, dominance and percent composition of alien fishes in different water resources

River/ wetland	Number of alien species observed	Sampling site	Geographical coordinates (Lat. (N); Long. (E))	Percent composition (aliens)	Dominant species (Among aliens)
Ganga	*Cyprinus carpio* *Oreochromis niloticus*	Varanasi	25°19′45.42″N 83° 9′15.26″E	35	*O. niloticus*
	*O. mossambicus** *Hypophthalmichthys molitrix**	Prayagraj	25°30′8.59″N 81°51′20.12″E	38	*C. carpio*
	*H. nobilis** *Ctenopharyngodon idella**	Dalmau	26° 3′53.60″N 81° 1′37.13″E	30	*C. carpio*
	*Pterygoplichthys anisitsi**	Kanpur	26°28′2.48″N 80°22′26.51″E	46	*O. niloticus*
Yamuna	*C. carpio* *O. niloticus*	Prayagraj	25°25′24.18″N 81°52′30.24″E	41	*C. carpio*
	*O. mossambicus** *Clarias gariepinus*	Etawah	26°45′10.11″N 79° 1′11.01″E	67	*O. niloticus*
	*Pterygoplichthys pardalis** *P. anisitsi**	Agra	27°10′37.56″N 78° 2′31.40″E	61	*O. niloticus*
	*H. molitrix** *H. nobilis** *C. idellus**	Mathura	27°20′5.04″N 77°46′54.27″E	63	*O. niloticus*
Tons/ Tamsa	*C. carpio* *O. niloticus* *H. molitrix**	Chakghat, Prayagraj	25° 2′10.22″N 81°43′48.61″E	26	*C. carpio*
Gomti	*C. carpio* *O. niloticus* *Clarias gariepinus** *H. molitrix** *H. nobilis** *C. idellus**	Lalpul, Lucknow	26°52′23.58″N 80°54′53.95″E	31	*C. carpio*
Soor Sarovar Bird Sanctuary	*O. niloticus* *C. carpio* *H. molitrix**	Keetham, Agra	27°15′10.54″N 77°51′8.03″E	53	*O. niloticus*
Sujan Ganga	*O. niloticus* *C. carpio*	Bharatpur	27°13′2.04″N 77°29′44.87″E	88	*O. niloticus*
Nahar (Lohagarh fort moat), Bharatpur, Rajasthan	*C. gariepinus**				

*Collected stray specimens occasionally.

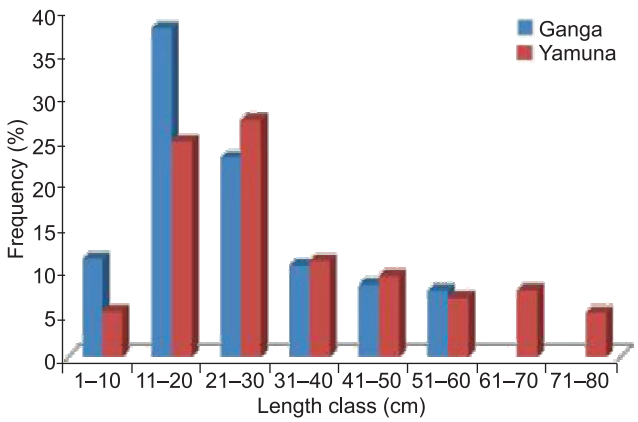

Fig. 1. Distribution of different length class (cm) of common carp in the rivers Ganga and Yamuna at Prayagraj.

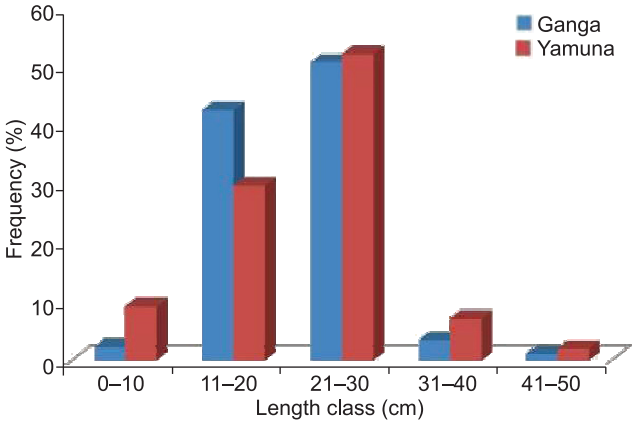

Fig. 2. Distribution of different length class (cm) of Nile tilapia in the rivers Ganga and Yamuna at Prayagraj.

further evidence the establishment of an alien population. Due to comparatively larger volume and depth, the river Yamuna holds larger fish specimens in comparison to river Ganga at Prayagraj.

Recent experimental fishing operations conducted in the river Yamuna at Prayagraj using dragnet (3 attempts) and

cast nets (15 castings) revealed an alarming state of the dominance of alien fishes over indigenous species. The relative abundance depicted the highest percentage of *O. niloticus* (65.85%), followed by *C. carpio* (26.83%) and the rest (7.31%) small fraction comprised of indigenous fishes including *Sperata aor* and *Cirrhinus mrigala*. In a previous study, extreme invasion of alien fishes was recorded from the highly polluted stretch of river Yamuna at Etawah, in which alien fishes (*C. carpio* and *O. niloticus*) formed 93% of the total catch (Joshi *et al.* 2016). It appears that the degraded Yamuna river is highly invaded by these two alien fishes and is responsible for the spread of alien fishes in the entire Ganga river system and other tributaries.

Occurrence and gradual expansion of African magur, *Clarias gariepinus* has also been noticed in the river Yamuna in general and highly impaired Mathura and Etawah stretch in particular. Experimental fishing conducted in the Mathura-Etawah stretch using gill and cast nets yielded a relative abundance of African magur between 2.32 and 7.14% and the size range of the collected samples comprised 265 to 630 mm with a corresponding weight of 136 to 1,620 g, respectively. Both the parameters indicated the establishment risk of the ecologically dangerous fish.

Besides fully established aliens (*C. carpio* and *O. niloticus*), the occurrence of some other aliens comprising *O. mossambicus, C. gariepinus, P. pardalis, P. anisitsi, H. molitrix, H. nobilis,* and *C. idellus* was recorded from the sampling sites of the rivers Ganga, Yamuna, Gomti and their tributaries, occasionally as stray specimens. But Soor Sarovar Bird Sanctuary, Agra and Lohagarh Fort Moat, Bharatpur hold sizeable alien populations dominated by tilapia (Table 1). The reasons for the spread of these aliens could be escapees from aquaculture ponds situated on the catchments during the flood or deliberately released by the hobbyist.

The majority of the rivers of India supported flourishing populations of Indian major carps (IMC), other carps, and catfishes in the past due to their pristine, unregulated, pollution-free, and dynamic nature. Hence, the Ganga river system is known as the original abode of IMC and other indigenous fishes (Joshi *et al.* 2019). But owing to continuous ongoing anthropogenic pressure since the last few decades, the rivers are losing their unique river characteristics and biota (Joshi 2017a, Joshi *et al*. 2019). Multifarious factors like large scale river modifications, water abstraction, excessive drawl of riparian groundwater, alterations on substratum conditions, loss of deep pools, and connected wetlands are resulting in alterations of river waters and drastic depletion of the sensitive indigenous fish species and appearance of exotic fishes (Kollar and lodge 2002, Vass *et al*. 2010, Singh *et al.* 2013, Joshi *et al*. 2014a, 2016, 2019; Joshi 2017a, b). As a result, the impaired river systems, connected wetlands and other derelict and polluted open water bodies are gradually turning uncongenial for prized IMC and other native species and becoming abode to some hardy and opportunist aliens. The occurrence and expansion of alien fish species gradually increase in many such open water resources. Further, a few notorious invasive species such as *Clarias gariepinus* and *Pterygloplichthys* spp. are spreading rapidly in open water bodies of North-Eastern and Peninsular India (Krishnakumar *et al*. 2011, Muralidharan *et al.* 2015, Sandilyan 2016, Hussan *et al*. 2019, Kumar *et al*. 2019, Suresh *et al*. 2019).

The potential risk factors responsible for the spread of the alien in open water bodies may be attributed to our porous boundaries, farming of alien fishes in flood-prone areas, rapid expansion of aquaculture, and ornamental fish trade activities throughout the country. Occasional release of fish seed in the rivers and open water resources with religious sentiments and disposal of aquarium fish to a nearby drain or water bodies by the hobbyist is another serious way by which alien fishes can make access to open waters. The degraded open water resources owing to water abstraction and pollution load are facilitating the expansion and establishment of resilient alien fishes in these waters. Hence, there is an earnest need to strictly control the import of alien fish species, based on their merit and likely impacts on open waters of the country.

The study revealed the dominance of *C. carpio* and *O. niloticus* in most of the river stretches of the Ganga river system and some other open water bodies located in the basin. Besides the gradual appearance of the notorious African catfish, *C. gariepinus* in some stretches of river Yamuna and the occasional appearance of another resilient fish of Amazon basin, *Pterygloplichthys* spp. in some stretches of Ganga river basin. Stray samples of *O. mossambicus, C. gariepinus, P. pardalis, P. anisitsi, H. molitrix, H. nobilis,* and *C. idellus* were observed rarely in some stretches of the system.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, ICAR-National Bureau of Fish Genetic Resources, Lucknow for the continuous guidance and encouragement to carry out the research work. We also extend sincere thanks to Dr G Rathore, Head, FHM&E Division, ICAR-NBFGR, Lucknow for the facilities and support to carry out this study. The research work is carried out under Institute based project on 'Risk and benefit assessment modelling for exotic fishes'.

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