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Invasion of the Mozambique tilapia, *Oreochromis mossambicus* (Pisces: Cichlidae; Peters, 1852) in the Yamuna river, Uttar Pradesh, India

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Oreochromis mossambicus **(Peters, 1852) is a highly successful invader of aquatic ecosystems due to its adaptable life history, tropic flexibility, ability to tolerate extreme and often unfavourable environmental conditions, rapid reproduction and maternal care of offsprings. Upon introduction to areas outside its natural range, these characteristics often give *O. mossambicus* a competitive advantage over indigenous fishes. The present study investigated the population characteristics of non-indigenous Mossambique Tilapia, *O. mossambicus*, for a period of 12-months from August 2009 to July 2010 in the lower stretch of Yamuna River in India. The Mossambique Tilapia, *O. mossambicus,* formed the most abundant fish species in all the catches from the Yamuna River at all the sampling stations. The gonado-somatic index (GSI) and the presence of all six gonadal stages confirmed that *O. mossambicus* has established a breeding population. The GSI for females indicated year-round reproduction with increased spawning intensity in spring (March to April) and monsoon (July to August). Males ranged from 142-280.0 mm total length (TL) and females from 130-265.0 mm TL. Small juvenile fish were collected every month of the year and multiple size classes present in sampling catches suggest successful recruitment of young. Adult *O. mossambicus* consumed primarily detritus and vegetal matter, though the diet of juveniles, collected from the Yamuna River, was found to be carnivorous. We expected Mozambique tilapia to further invade the Yamuna River due to natural dispersal. There is a need for more detailed studies of tilapia abundance, recruitment and local environmental conditions across the country to fully understand the invasion potential and consequences for the endemic aquatic biodiversity.**

Key words: Exotic fish, *Oreochromis mossambicus*, invasion, colonization, Yamuna River, U.P.

INTRODUCTION

India is a vast country in terms of natural resources and considered one of the mega-biodiversity countries in the world (Lakra et al., 2011). The indian mainland is drained by 15 major, 45 medium and over 120 minor rivers, besides numerous ephemeral streams (Rao, 1975). The diverse river system in India harbour one of the richest fish germplasm resources in the world (Vass et al., 2009), characterized by many rare and endemic fish species

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and as much as 166 indigenous fish species have so far been recorded from the rivers of Central India (Sarkar and Lakra, 2007).

Unfortunately, over the last few decades riverine ecosystems of India has suffered from intense human intervention resulting in habitat loss and degradation and as a consequence, many fresh water fish species have become highly endangered, particular in Yamuna basin where heavy demand is placed on fresh waters. A new and potentially serious threat to the indigenous fish faunais the invasion of alien fishes (Singh and Lakra, 2011). Although the negative effects of introduced species are widely recognized (Canonico et al., 2005; Lakra et al., 2008; Singh and Lakra 2006, 2011), many of them are still being released into the aquatic ecosystems of India for production enhancement, without consideration of their potential impact on native fish and fisheries.

The African mouth-brooder cichlid, *Oreochromis mossambicus* (Peters 1852), or the Mozambique tilapia, is native to the eastward flowing rivers of central and southern Africa (Philippart and Ruwet, 1982; Trewavas, 1982). Due to their perceived utility as an aquaculture species, *O. mossambicus* are now widely distributed around the world (Arthington et al., 1984; Philippart and Ruwet, 1982). However, *O. mossambicus* have now fallen out of favour as a preferred aquaculture species because of their propensity to 'stunt' and their general poor quality due to the small size of founder stocks (Pullin, 1988). Invasive populations are now causing environmental and ecological problems in many countries (Canonico et al., 2005) and as such, *O. mossambicus* is listed in the Global Invasive Species Database (2006) as being in the top 100 invasive alien species on the planet.

The species has been described as a 'model invader' due to a number of key biological characteristics including tolerance to wide ranging ecological conditions, generalist dietary requirements, rapid reproduction with maternal care, and the ability to successfully compete with native fish through aggressive behaviour (Pe´rez et al., 2006b). Therefore, given suitable environmental conditions, *O*. *mossambicus* have become successfully established in almost every region in which they have been cultured or imported (Costa-Pierce, 2003; Cucherousset and Olden, 2011; Diana, 2009; Strecker et al., 2011). Official records show that *O*. *mossambicus* was first introduced to India from Srilanka in 1952 and thereafter stocked in several reservoirs of southern India for production enhancement (Sugunan, 1995). Tilapia now forms a part of fish fauna in the Godavari, Krishna, Cauvery, Yamuna and Ganga Rivers (Lakra et al., 2008).

In earlier studies, tilapia attracted the attention of scientific communities due to its mouth brooding behaviour (Perez et al., 2006; Russell et al., 2012). Tilapia has remained an objective of astonishment to ethnologists for years but its present behaviour, that is, prolific feeder and prolific breeder changed the scenario.

Tilapia is now known for its invasion to the non-native water bodies and destruction of their flora and fauna. The reported high incidence of *O. mossambicus* in the catches of artisanal fisheries prompted us to study the population characteristics, that is, the abundance, size range, food and feeding, gonado-somatic index (GSI), maturity and breeding so as to ascertain the abundance and establishment of *O. mossambicus* in the Yamuna River flowing along Etawa to Hamirpur in the state of Uttar Pradesh.

MATERIALS AND METHODS

Study area

Uttar Pradesh (U.P.) is one of the largest states in India, located between 23°52'-31°28'N latitude and 77°04'-84°38'E longitude. Being land-locked, it is endowed with an abundant supply of inland water resources (1165 million ha) that are ideal for fisheries and aquaculture. The availability of 0.72 million ha of running water in the form of rivers and canals enriches the state with plenty of ichthyofaunal diversity (Bilgrami, 1991; Kapoor et al., 2002). Yamuna River, one of the most important Rivers of Indogangetic plains, originates from Yamnotri glacier near Banderpuch peaks of lower Himalayas (38° 59° 78° 27°) in the Mussorie range at an elevation of about 6320 m above mean sea level in the Uttarkashi district of Uttrakhand. It is the sub-basin of the Ganga River system. It is 1376 sq. km long basin, covering an area of 320 lakh sq. km of which 61750 sq. Km. lies in U.P.

The study area covered approximately 250 km of the river stretch of the lower Yamuna flowing along the districts of Etawa, Jaluan and Hamirpur in the state of Uttar Pradesh. Etawa (S1), Kalpi (S2) in Jaluan and Hamirpur town (S3) in Hamirpur district were the study sites as demarcated in Figure 1. These landing sites were chosen because they are some of the most active, with high artisanal fisheries landings for the Yamuna stretch in the three districts. Landings from the study sites were therefore considered more appropriate and more representative**.**

Collection and identification of fish

The data for this study were collected from the commercial catches at the fisheries landing sites of three districts viz, Etawa, Jalaun (Kalpi) and Hamirpur of Uttar-Pradesh state during the period August 2009 to July 2010 on fortnightly basis. The sampling from the selected landing sites was conducted for two consecutive days twice a month in every fifteen days interval in a month from each landing site. Therefore, the monthly sampling frequency represents four days at each landing site. Sampling was conducted in the early mornings or evenings because in these hours all the fresh fish were brought to the landing sites for marketing. Fishermen generally used multi-meshed gill nets of mesh size 8.5 to 50 mm as well as dragnets for fishing. From commercial catches, fishes collected at the landing centres were measured (total length, TL nearest mm), and body mass determined (weighed to the nearest gram) using portable digital balance. Fish identification was confirmed using reference literature (Jayaram, 1981, 1999; Talwar and Jhingran, 1991). In addition data were also collected from fisheries market Jhansi and Lucknow because harvests from all these landing sites (Etawa, Kalpi and Hamirpur) are sold in fish market Jhansi and Lucknow, which maintain landing records (numbers and body mass).

Relative abundance

From the catch, sorting of fish species was done by fishermen for

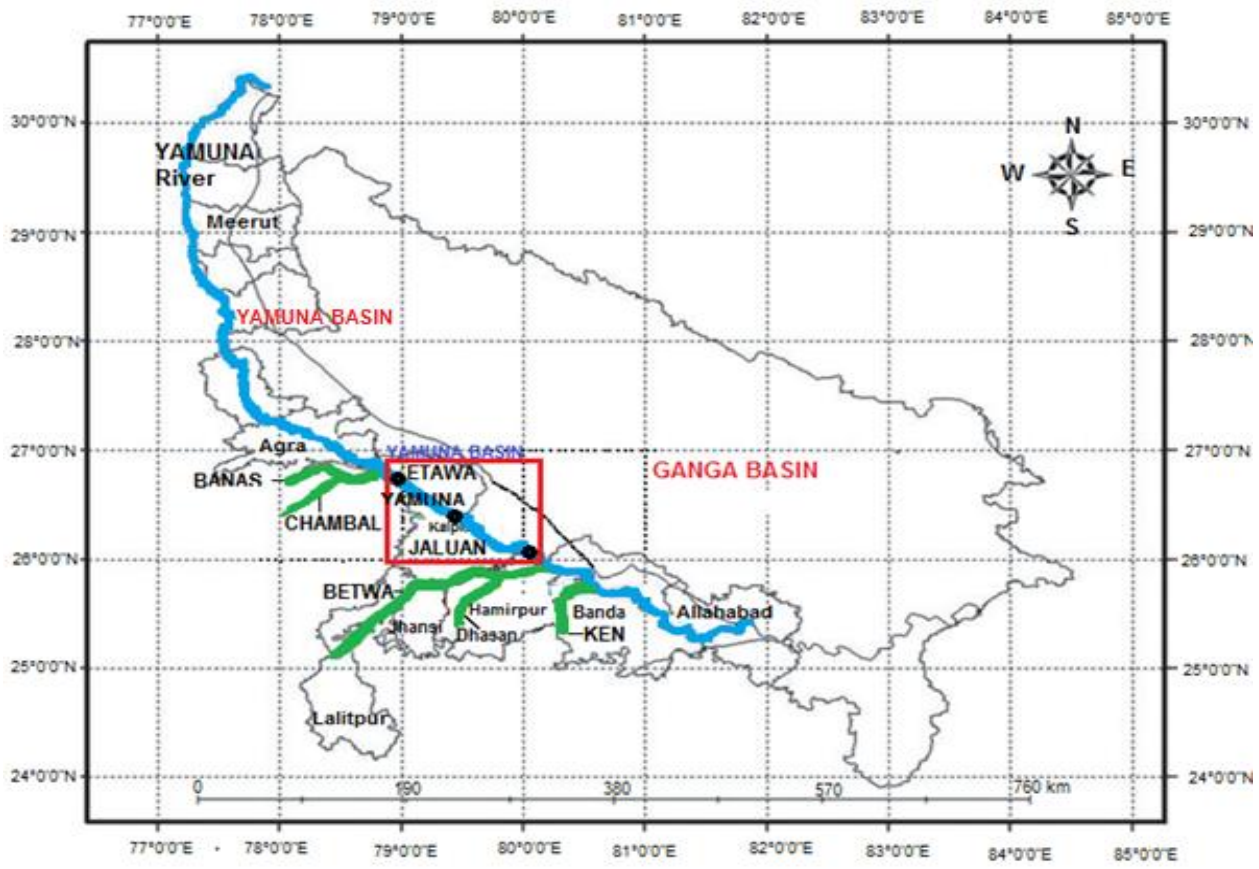

Figure 1. Map of the Yamuna River and the portion of the river in the present study.

marketing and sale. The data from such segregated fish groups were then collected to work out the species contribution. From the total catch, relative abundance (RA) of a individual fish species at each study site was estimated following the formula adopted by Lakra et al. 2010:

$$RA\ (\%) = \frac{\textit{Number of samples of particular fish species}}{\textit{Total number of samples}} \times 100$$

Gonado-somatic index (GSI)

From the catch, *O. mossambicus* was separately counted, sexed as male and female and the gonads of immature, maturing, mature and spent fish were dissected out, weighed and fixed in 10% formalin for microscopic examinations. The GSI was calculated using the formula GSI = GW/EBW x100, With GW = gonad mass/weight (g) and EBW = eviscerated body mass/weight (g). The fecundity of individual females was determined gravimetrically (to the nearest gram), and the gonad maturity stages were determined visually according to reference literature (Nagelkerke and Sibbing, 1996).

Food and feeding habits

The intestines of 150 collected specimens from different sampling sites were cut and fixed in 4% formalin for gut content analysis. The diet and feeding habits of *O. mossambicus* were determined based on the contents of the digestive tract and was examined using Binocular Magnus MXL-Bi stereomicroscope. Different taxa of the food items were identified, and counted by numerical methods adopted by Hyslop (1980) and Costal et al. (1992). In the numerical method, the number of each food item was expressed as the percentage of the total number of food items found in the stomach.

RESULTS

Biodiversity of fish species and catch composition

The results of present study showed the occurrence of 21 freshwater fish species belonging to 9 Families (Table 1). The Indian major carps comprising of *Catla catla*, *Cirrhinus mrigala* and *Labeo rohita* constituted 1.10 to 2.15% of total catch and their size ranged from 80 to 500 mm in length and 500 to 7500 g in body mass (Table 2). The minor carps in the total catch were mainly represented by *Labeo calbasu*, *Cirrhinus reba*, *Puntius sophore*, *Puntius ticto* and *Puntius ranga*. They constituted 15.23–18.65% with size range of 50 to 350 mm in length and 200–1500 g in body mass (Table 2). Catfishes in general were represented by *Channa striatus, Mystus tengra, Rita rita, Notopterus notopterus* and constituted 07–10%

Figure 2. Specimen of *O. mossambicus* collected from Yamuna River.

Table 1. Diversity of fish species*, total mean length (TL) and relative abundance (RA) of fish collected from the Yamuna River at three study sites (S1, S2, S3).

Specie	Family	Total length (mm)		RA (%)		
		Max	Min	S1	S2	S3
Oreochromis mossambicus (Peters)	Cichlidae	220	130	24.51	26.24	24.50
Gadusa chapra (Hamilton–Buchanan)	Clupeidae	140	60	8.09	8.87	11.52
Cirrhinus mrigala (Hamilton–Buchanan)	Cyprinidae	450	160	0.15	0.39	0.18
Cirrhinus reba (Hamilton–Buchanan)	Cyprinidae	220	150	4.01	3.61	4.98
Cyprinus carpio	Cyprinidae	400	230	8.32	7.95	7.86
Catla catla (Hamilton)	Cyprinidae	460	280	0.52	0.66	0.35
Labeo rohita (Hamilton–Buchanan)	Cyprinidae	500	80	1.12	0.62	0.61
Labeo calbasu (Hamilton–Buchanan)	Cyprinidae	350	140	0.81	0.93	0.26
Puntius ticto (Hamilton–Buchanan)	Cyprinidae	90	45	6.65	6.34	7.84
Puntius sophore (Hamilton–Buchanan)	Cyprinidae	90	60	1.04	0.93	1.76
Puntius ranga (Hamilton–Buchanan)	Cyprinidae	100	70	7.73	7.60	7.55
Mystus tengra ((Hamilton–Buchanan)	Cyprinidae	180	125	1.66	2.14	1.88
Rita rita (Hamilton–Buchanan)	Bagridae	260	80	2.95	3.91	3.62
Oreochromis niloticus	Cichlidae	260	190	10.37	9.80	4.48
Notopterus notopterus (Pallas)	Notopteridae	300	150	0.89	1.07	0.48
Chitala chitala (Hamilton–Buchanan)	Notopteridae	800	250	1.12	0.78	0.64
Channa striatus (Bloch)	Chandadae	150	100	3.51	3.20	2.60
Mastacembalis armatus (Lacepede)	Mastacembelidae	540	160	2.08	1.66	1.88
Glossogobius giuris(Hamilton-Buchanan)	Gobiidae	160	95	4.10	4.64	4.97
Chanda nama (Hamilton–Buchanan)	Ambissidae	100	40	5.56	4.48	6.64
Parambassis ranga (Hamilton-Buchanan)	Ambissidae	50	40	4.51	4.17	5.43

*Taxonomic status adapted from Talwar and Jhingran (1991).

of the total catch having body mass range of 500 to 2300 g. Other less abundant catches included *Gadusia chapra, Chitala chitala, Chanda nama, Glossogobius giuris, Parambassis ranga, Mastacembelus armatus* representing 23-30% of total catch (Table 2).

A persual of the present data showed that *O. mossambicus*

Table 2. Important fish species and their contribution in commercial fishery of the Yamuna River.

Fish group	Fish specie	Total length range [mm]	Body mass range [kg]	Catch contribution [%] range
Indian Major Carps	*Labeo rohita, Catla catla, Cirrhinus mrigala*	80 - 500	0.5-7.5	1.10 – 2.15
Minor Carps	*Labeo calbasu, Cirrhinus reba, Puntius sophore, P. ticto, Puntius ranga*	50 - 350	0.2-1.5	15.23 – 18.65
Cat Fishes	*Channa striatus, Mystus tengra, Rita rita,, Notopterus notopterus*	80 - 260	0.5- 2.3	7.69 - 10.45
Miscellaneous	*Mastacembelus armatus,Gadusia chapra, Chitala chitala, Chanda nama, Glossogobius giuris, Parambassis ranga*	50 - 800	0.030 – 1.2	23.14 – 30.68
Exotic	*O. mossambicus,*	180 - 220	0.003 -1.4	24.51 – 26.24
	O. niloticus	190 - 260	0.005 – 1.0	4.48 --10.37
	Cyprinus carpio	230 - 430	0.25 – 8.5	7.82 – 8.32
	C garipinus	250-780	0.35 – 2.5	Stray catch

(Mossambique Tilapia) (Figure 2) formed the most dominant fish species in all the catches from the Yamuna River at all the sampling stations throughout the sampling period (Table 1). The relative abundance (RA) of *O. mossambicus* ranged from 24.5 to 26.24 % from S1 to S3 (Table 1).

Reproductive activity

Gonadal examination of *O. mossambicus* in different catches revealed that immature, maturing, and mature fishes were sampled. Mature females were found at smaller size (130-265 mm TL) while mature males were larger in size (142-280 mm TL). Gonads of 120 examined specimens from different stations of the river showed that mature female represented all reproductive stages (1–6) with varying gonado-somatic index (*GSI* : 0.2 to 6%). In general, the highest *GSI* percentage was recorded during March-April and July–August (Table 3). A consistent pattern of spawning in *O. mossambicus* was also found during July–August when spawning of Indian major carps (*C. catla, L. rohita*, and *C. mrigala*) occured.

Food and feeding

Gut content of tilapia sampled in the present study showed that they consume a variety of food items ranging from macrophytes and algae to plankton and detritus. Trophic spectra of 150 examined specimens of *O. mossambicus* showed that there was similarity in the ingested food at different sites. The analyzed gut contents were *Detritus* (50.62%), *Macrophytes* (21.72%), *Filamentous Algae* (7.83%), cellular algae (14.42%), zooplankton (3.60%), fish (1.73%) and insect parts (0.26%) (Figure 3). Juvenile were found to consume fry.

DISCUSSION

O. mossambicus was introduced into India during 1952 for aquaculture purpose and the utilization of *O. mossambicus* gradually expanded for enhancing reservoir fishery production (Suguan, 1995; Sugunan, 2000). After the expansion of the use of *O. mossambicus* for enhancement of aquaculture production, tilapia now form part of the fish fauna in the Godavari, Krishna, Cauvery, Yamuna and Ganga Rivers (Lakra et al., 2008). Unfortunately, the characteristics (including tolerance to wide ranging ecological conditions, generalist dietary requirements, rapid reproduction with maternal care, and the ability to successfully compete with native fish through aggressive behaviour) that make *O. mossambicus* desirable as an aquaculture species also predispose it for success as an invasive species (Canonico et al., 2005). Invasive populations are now causing environmental and ecological problems in many countries (Canonico et al., 2005) and as such, *O. mossambicus* is listed in the Global Invasive Species Database (2006) as being in the top 100 invasive alien species on the planet.

Results of this study showed abundance of *O. mossambicus* in the fishery and the presence of all reproductive stages (1–6) in the river-caught *O. mossambicus*. This data implied that *O. mossambicus* has established breeding populations in the lower stretch of Yamuna River and the so colonized fishes constituted the bulk of the catches by commercial fisherman. Similar findings were obtained from parts of Yamuna (Singh et al., 2010b) and Jaisamand Lake, Rajasthan (Lakra et al., 2008). Reproductive activity of *O. mossambicus* has been reported to be continuous (non seasonal) in females (De Silva and Chandrasoma, 1980) and the results of the present study provided first evidence of wild spawning of *O. mossambicus* in the Yamuna River forming feral populations. Since Tilapia mossambicus, *O. mossambicus*, is known to exhibit early sexual maturity, maternal care of offsprings, rapid colonization, wide environmental tolerances (Perez et al., 2006; Russell et al., 2012); these attributes have been considered to be important for facilitating successful invasion of this fish in the Yamuna

Table 3. Degree of maturation, gonado-somatic index (GSI) the gonad maturity stage and morphology of ovary in different stages of maturity of *O. mossambicus* of the Yamuna River.

Stage	Degree of maturation	GSI	n	Months of Availability	Ova diameter (mm)	Description
1	Immature or virgin and resting adult	0.2-0.8	12	Throughout the year	0.044 -0.055	Ovaries very small, thin, thread like pale in colour, occupying a small part of the body cavity.
2	Early maturing	0.4-2.2	20	March to September	0.053 -0.085	Ovaries slightly larger and increase in weight and volume with minute opaque whitish eggs occupied about half of the body cavity.
3	Developing	3-5	40	March to October	0.078-0.85	Ovaries occupied about 2/3 of abdominal cavity with large pale yellow eggs.
4	Developed / Prespawning	4-6	20	March to October	0.84- 0.96	Ovary more enlarged occupying almost entire body cavity, with large number of big, turgid, spherical, translucent, deep yellow ripe ova
5	Spawning	3-5.5	18	April to October	1.0- 1.4	Ovary walls thin almost transparent. Riped eggs are visible through the ovarian wall and some riped eggs are present in the oviduct.
6	Spent	2-3	10	April to Late October	0.050 - 0.16	Ovaries are flaccid, shrinked and sac like, reduced in volume. Ovary contains ripped unspawned darkened eggs and a large number of small ova.

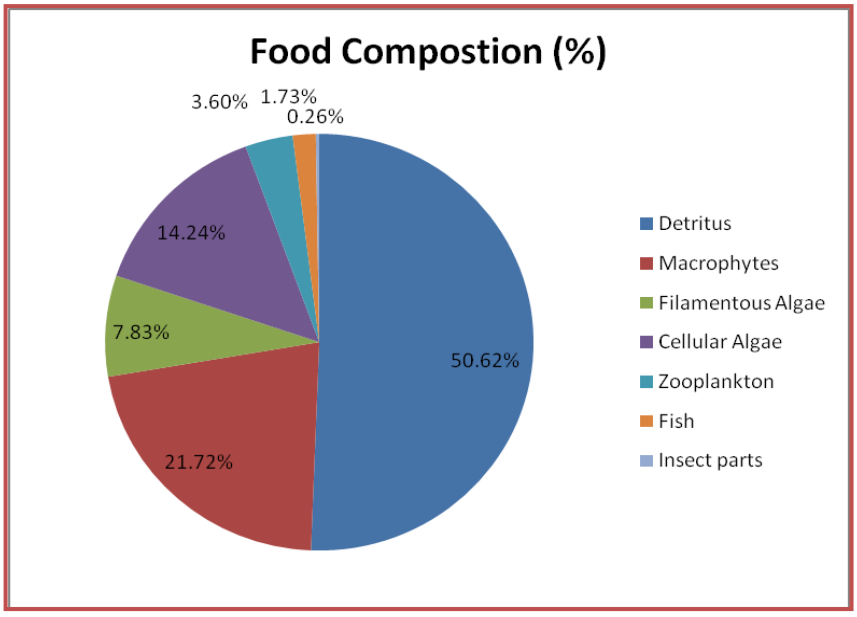

Figure 3. Major food items [%] in the gut of *O. mossambicus* collected (n = 150) from the Yamuna River.

River. The low GSI values observed in the present study are consistent with year-round spawning and are similar to GSI values reported by De silva (1986). The GSI data coupled with the year round presence of mature females, occurring in all months except winter months (December to February), and recruitment of young fish into larger size classes strongly suggest that Mossambiqan Tilapia is spawning year round and is established in river Yamuna.

The gut content analysis showed presence of mainly detritus, plant material, insect parts, algae of similar kind and small fish, which is in agreement with the findings of De Moor et al. (1986), Laundau 1992). Juveniles are carnivorous and eat fry Luna (2012). Gut content analysis showed similar pattern at all the sampling stations. The results indicated that ecological conditions in the Yamuna were homogenizing by the increasing population of *O. mossambicus*, which could be a great threat to the ecological integrity for this mighty river sustaining rich fish biodiversity.

Conclusion

The invasion of *O. mossambicus* has increasingly taken-over at all sites of Yamuna River contributing substantially to the fishery of this river, which is considered serious in view of sustainability of indigenous fish diversity. Further investigations should be carried out to determine the extent of spread of *O. mossambicus* in Yamuna River and to understand its impact on native fish and fisheries. Suitable control and management methods should be found. Such information could contribute to the development of management plans aimed at minimizing possible impacts of this potential invasive species. Moreover, awareness of the implications concerning this invasive species should be generated among scientists, farmers, fishermen, legislators and the general public to provide for the rigorous application of such regulatory measures.

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