Indian Journal of Animal Sciences **86** (8): 957–963, August 2016/Article

Fish diversity, composition and invasion of exotic fishes in river Yamuna under altered water quality conditions

K D JOSHI[1], A ALAM[2], D N JHA[3], S K SRIVASTAVA[4] and V KUMAR[5]

ICAR-Central Inland Fisheries Research Institute, Allahabad, Uttar Pradesh 211 002 India

Received: 9 November 2015; Accepted: 11 January 2016

ABSTRACT

Impacts of water quality parameters on the fish diversity of the river Yamuna were studied from January 2010 to December 2011 at 11 sampling sites from uppermost Badwala to Allahabad. Certain key water quality parameters were showing considerable increase in their values from Badwala to Etawah. The highest value of chloride was observed at Mathura (217.4 ppm). The fish diversity of the river Yamuna were investigated for the first time and 112 fish species belonging to 10 orders, 29 families and 73 genera were identified. Indian major carp fishery has considerably declined in the system while exotics, especially *Cyprinus carpio* and *Oreochromis niloticus*, are increasing at an alarming rate in the middle and downstream stretches. The exotic common carp was observed at all sampling sites except the uppermost, almost pristine Badwala and formed a maximum 27.0% of the total fish catch at Arail (Allahabad), Tilapia was recorded between the Panipat to Allahabad stretch, and formed a maximum 84.8 % population at highly polluted Etawah. The population of exotics comprised 93.0% of the total fish catch at Etawah.

Key words: Common carp, Composition, Fish diversity, Pollution, Tilapia, Water quality

The Indian subcontinent is endowed with rich piscine diversity comprising 2,500 fish species, 930 belong to freshwaters (Talwar and Jhingran 1991). The Ganga river system supports copious fish diversity (Sinha and Khan 2001, Talwar and Jhingran 1991), owing to large catchment area and vast habitat variability extending from cold-water, warm water and estuarine zones. Recent studies reported 143 fish species from the river Ganga (Sarkar *et al*. 2011, Das *et al*. 2014) including coldwater, freshwater and estuarine fishes. The Yamuna river is a major tributary of the river Ganga, which passes through vast catchments spread over 345,848 km^2. The Yamuna river traverses 1,376 km distance till debouch into the river Ganga at Allahabad. The water discharge of the river is obstructed at Dak Patthar in Uttarakhand (regulated through a weir and diverted into a canal) and Hathnikund in Haryana (the major part of river water is diverted again into eastern and western Yamuna canals). In dry season, virtually no water is allowed to flow in the river, downstream to Hathnikund barrage.

The river regains some water from groundwater accrual and contributions of feeding canals and small tributaries downstream of Hathnikund. Among the sampling sites, the uppermost Badwala is located in lower Himalayan region and in almost pristine condition. While the downstream river stretch between Lalauli and Arail (Allahabad) is in moderately modified state and Delhi to Etawah stretch is highly degraded state. Since the river Yamuna has witnessed maximum obstructions due to construction of barrages and weirs, abstraction by a number of canals and addition of pollution load including industrial effluents and sewage from the cities along the basin make the river an extreme example of over-exploitation for human use. Out of the total river length, about a 580 km stretch between Wazirabad barrage and Etawah is highly polluted and has resulted in a drastic decline in the fishery, both in respect to quality and quantity. The river condition is revived downstream to Etawah after receiving considerable flow from Chambal.

The fish fauna of certain tributaries of the Ganga river system, viz. Ken (Joshi and Biswas 2010, Sarkar *et al*. 2013), Sone (Joshi *et al*. 2014a), Betwa (Joshi *et al*. 2009, Lakra *et al*. 2010) and Ganga rivers (Sarkar *et al*. 2011, Das *et al*. 2014) were studied by different workers.

Ongoing multiple developmental activities in the catchments are resulting in obstructions of the rivers and tributaries, abstractions of the river water and addition of arrays of pollutants from different sources. In general, most of the rivers in the country are facing similar situation, as a result there is sharp alterations in the physico-chemical parameters of the rivers, aquatic biota and fisheries in the downstream. The river Yamuna is a critical example of habitat alterations due to massive anthropogenic activities.

Present address: [1]Principal Scientist (kdjoshi.cifri @gmail.com), [2,3]Scientist (absar_alam@rediffmail.com, dharmnath.jha@gmail.com), [4]Assistant Chief Technical Officer (saketsrivastava46@gmail.com), [5]Technical Assistant (cifavijay@rediffmail.com), Regional Centre.

Barring a few scattered information on some ecological, hydrological and fishery parameters of the river Yamuna (Jhingran and Joshi 1987, Jhingran 1991, Mishra and Moza 1997, 2001, Sinha and Khan 2001, Moza and Mishra 2003, Vass *et al*. 2010, Pathak *et al*. 2014, Sharma *et al.* 2014, Soni *et al.* 2014), there is complete dearth of literature on fish diversity in relation to water quality parameters of the entire river. Therefore, the present study was carried out to unravel the fish diversity, distribution pattern and invasion of exotic fishes in the entire river under the influence of altered hydro-ecological conditions to formulate appropriate measures for its restoration and conservation. The above scattered information on the river Yamuna was viewed to compare and ascertain time scale changes.

MATERIALS AND METHODS

Investigations were undertaken at 11 centers along the river Yamuna. Seasonal sampling during winter, summer and monsoon were done from January 2010 to December 2011 in the stretches from Badwala near Dehradun to Allahabad, upstream to the confluence with river Ganga. Global positioning system (GPS) was used to locate the sampling site. The sampling centers from up to downstream were Badwala near Dehradun, Yamunanagar, Panipat, Delhi, Mathura, Agra, Etawah, Hamirpur, Lalauli, Mau and Arail (Allahabad) (Fig. 1).

Water and sediment were collected at three points across the width of the river (one-fourth, one-half and three-fourths from one bank side of the river) and analyzed following standard methods (APHA 2005). River water quality was statistically analyzed using Duncan's multiple range test (SPSS 16.0 vers.). The information on piscine diversity and composition was collected through experimental fishing conducted at the selected sites using cast net (1.5 m diameter and 2.0 × 2.0 mm mesh), gill nets (10-40 mm) and drag nets (different mesh sizes and lengths), fishes caught by the local fishers and market survey at fish landing sites along the river banks. The experimental fishing was conducted during day (06:00–18:00 h) and night (20:00–05:00 h.). Fishing at upstream site- Badwala was conducted by using cast nets, gill nets, hook and lines and local traps. After sampling, captured fish specimens were identified up to species level. Most of the individuals were released and some samples were preserved in 10% formaldehyde, brought to the laboratory and identified with the help of standard texts (Talwar and Jhingran 1991). Fish species name adhere to Fish Base (Froese and Pauly 2011). Biodiversity status of fish species were assessed following IUCN criteria (IUCN 2013). Fish composition was estimated based on average fish catch at the sampling sites.

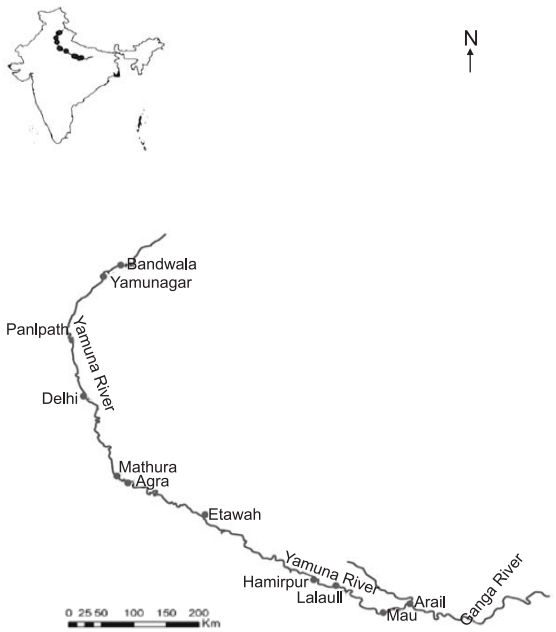

Fig. 1. Map showing the sampling areas in the river Yamuna.

RESULTS AND DISCUSSION

Water quality: The transparency of the river water was the lowest in Delhi-Etawah stretch (26.9 to 39.7 cm), lower in the Yamunanagar-Panipat stretch (30.3 to 38.4 cm), higher in the Delhi-Etawah stretch (35.4 to 49.2 cm) and almost transparent at Badwala. The Yamuna water has strong buffering capacity and as a result there was little fluctuation in pH in the entire stretch. The key water quality parameters like total alkalinity, specific conductance, total dissolved solids (TDS), total hardness, chloride and dissolved organic matter were statistically significant showing considerable increase in the values from Badwala to Etawah. Thereafter, the above water quality parameters showed a considerable improvement in their values which may be attributed to drainages of Chambal, Sind, Betwa and Ken rivers (Figs 2, 3). The range of chemical parameters, viz. total alkalinity, total dissolved solids, specific conductance, total hardness, chloride and dissolved organic matter between Etawah and Delhi stretch were 157.6 to 242 ppm, 359.5 to 490.1 ppm, 698.8 to 976.5 µmhos/cm, 233 to 266 ppm, 122 to 217.4 ppm and 3.5 to 4.6 ppm, respectively, indicating polluted stretch due to draining of domestic sewage and industrial effluents along the banks.

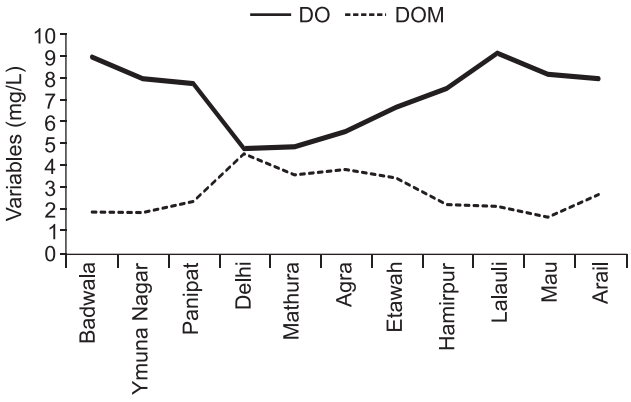

Fig. 2. Key water quality parameters and percentage composition (secondary axis) of exotic fishes at various sampling sites in the river Yamuna.

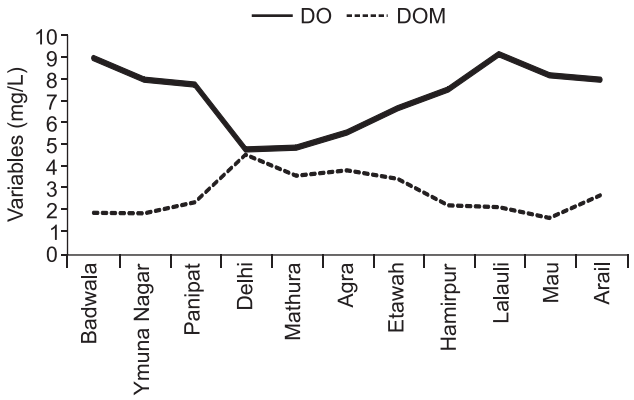

Fig. 3. Graphical representation of dissolved oxygen (DO) and dissolved organic matter (DOM) at various sampling sites in the river Yamuna.

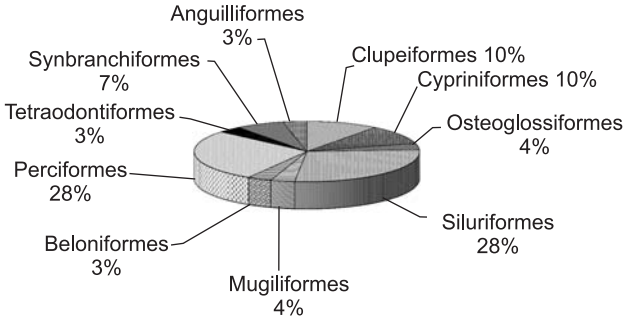

Fig. 4. Diagrammatic representation of the number of fish species and genera occurring in each family and order in the river Yamuna.

Fish diversity, composition and distribution pattern: Fish diversity of the river Yamuna investigated for the first time and 112 species belonging to 10 orders, 29 families and 73 genera (Table 1; Fig. 4) were recorded. Fish species richness at Badwala, Yamunanagar, Panipat, Delhi (Wazirabad), Mathura, Agra, Etawah and Allahabad was 29, 90, 87, 76, 68, 71, 69 and 92, respectively. Fish species like *Psylorhynchus balitora, Puntius stigma, Puntius punjabensis, Nemacheilus corica, N. scaturigina, Para schistura montana, Ompok pabo, Eutropiichthys goongwaree, Pseudambassis baculis, Clupisoma montana* and an exotic *Gambusia affinis* were reported in earlier studies (Prakash *et al*. 1978). Among the 112 species recorded from the river, 6 were exotics viz. *Oreochromis niloticus, Cyprinus carpio, Clarias gariepinus, Hypophthalmichthys molitrix, Hypophthalmichthys nobilis* and *Ctenopharyngo donidella.* Two strains of common carp viz. *Cyprinus carpio* var. *communis* and *Cyprinus carpio* var *specularis* were observed from different stretches of the river. Maximum 6 exotic fish species were encountered from Yamunanagar, Panipat, Delhi, Mathura, Agra, Etawah, Hamirpur and Lalauli sites, and 5 from the Mau and Allahabad sites (Table 1). Besides the sizeable populations of *Cyprinus carpio*(common carp) and *Oreochromis niloticus* (tilapia), stray specimens of 4 other species were occasionally observed throughout the river. Due to almost pristine conditions and torrential flow, no exotic fishes were recorded from uppermost Badwala site. The estimated annual fish catch at different sampling sites during the study period was observed as 0.32, 2.7, 3.54, 5.32, 23.4, 49.6, 34.2, 57.3 and 159.4 tonnes at Badwala, Yamunanagar, Panipat, Delhi, Mathura, Agra, Etawah, Lalauli, Allahabad respectively comprising different fishery groups. Among the exotics, *Cyprinus carpio* and *Oreochromis niloticus* dominated the fishery between Delhi and Allahabad stretches (Fig. 2). The exotic fish species start appearing in the catches from Yamunanagar to downward of the river and maximum contribution (93.0 %) was observed at Etawah, followed by Agra (91.0 %), Mathura (88.0 %), Delhi (86.0 %). Minimum contribution (10.6 %) of exotic fishes in the upstream stretch was recorded at Yamunanagar and at Mau (37.0 %) in the downstream stretch. Mishra and Moza (2001) observed dominance of exotic common carp (12.21%) at Delhi, while its contribution was meagre (0.25%) between Etawah to Delhi stretch. Vass *et al.* (2010) also reported that the increase in fish landing at Allahabad was mainly due to the contribution of the exotic fishes, *Cyprinus carpio* and *Oreochromis niloticus*. In the present study, among the exotic fishes, tilapia dominated over common carp in the catches in highly polluted stretch between Delhi to Etawah (Fig. 2). *Cyprinus carpio* was observed in all the sampling sites except uppermost Badwala and formed 8.2 to 27.0 % of total fish catch with the lowest population at highly polluted Etawah stretch and highest at Arail (Allahabad). *Oreochromis niloticus* population was recorded between Panipat to Allahabad stretch and comprised 1.8 % of the population at Panipat and 84.8 % in the highly polluted Etawah stretch. Moza and Mishra (2003) observed that exotic, *C. carpio* contributed nearly 17.95% with no reports of tilapia in upper stretch of the river Yamuna between Panipat and Yamunanagar. Sharma *et al*. (2014) reported both *Cyprinus carpio* and *Oreochromis niloticus* between Allahabad and Paniapat stretch of the river with mean relative abundance of 0.6 to 9.9%. Appearance and increasing trends of the exotic fishes reported in the earlier studies, showed further expansion in the river stretches and intensification of the populations. This suggested that both the species have fully adapted in the altered river and are reproducing profusely (Alam *et al*. 2015).

On evaluation of fish diversity of the river as per IUCN categorization, 15 species are considered threatened (1 endangered (EN), 5 vulnerable (VU) and 10 near threatened (NT)), warrant urgent attention for their conservation and maintenance of habitats (Table 1).

The river Yamuna is an extreme example of the water quality degradation and over exploitation of the resources through anthropogenic interventions. Drastic decrease in water discharge coupled with incursion of domestic and industrial effluents in the river Yamuna has resulted in degraded water quality from Yamunanagar downward. The key water quality parameters like total alkalinity, specific conductance, total dissolved solids, total hardness, chloride and dissolved organic matter indicated grossly polluted

Table 1. List of fishes collected from the river Yamuna depicting biodiversity status and qualitative abundance

S.no.	Name of species	IUCN status	Badwada	Yamuna Nagar	Panipat	Delhi	Mathura	Agra	Etawah	Allahabad
	Order-Anguilliformes Family-Anguillidae									
1	*Anguilla bengalensis* (Gray, 1831)	LC	-	-	-	-	-	-	-	X
	Order-Clupeiformes Family-Pristigasteridae									
2	*Ilisha megaloptera* (Swainson, 1839)	NE	-	-	-	-	X	X	X	XX
	Family-Clupeidae									
3	*Gudusia chapra* (Hamilton, 1822)	LC	-	X	X	X	XX	XX	XX	XXX
4	*Gonialosa manmina* (Hamilton, 1822)	LC	-	XX	XX	X	XX X	X	X	XXX
	Family-Engraulidae									
5	*Setipinna phasa* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	XX
	Order- Cypriniformes Family-Cyprinidae									
6	*Catla catla* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	XX
7	*Cyprinus carpio* Linnaeus, 1758	EX	-	XX	XX	X	XX	XX	XX	XXX
8	*Cirrhinus mrigala* (Hamilton, 1822)	VU	-	X	X	X	XX	XX	XXX	XXX
9	*Cirrhinus reba* (Hamilton, 1822)	LC	-	XXX	XXX	XX	XXX	XXX	XXX	XXX
10	*Chagunius chagunio* (Hamilton, 1822)	LC	-	XX	XX	X	X	X	X	X
11	*Tor tor* (Hamilton, 1822)	NT	X	-	-	-	-	-	-	
12	*Tor putitora* (Hamilton, 1822)***	EN	XX	X	X	-	-	-	-	-
13	*Osteobrama cotio cotio* (Hamilton, 1822)	LC	-	XXX	XXX	XXX	XXX	XXX	XXX	XXX
14	*Crossocheilus latius* (Hamilton, 1822)	LC	XX	XXX	XX	X	X	X	X	XX
15	*Labeo rohita* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	XX
16	*Labeo calbasu* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	X
17	*Labeo gonius* (Hamilton, 1822)	LC	XX	X	X	X	X	X	X	X
18	*Labeo angra* (Hamilton, 1822)	LC	-	X	X	XX	-	-	-	X
19	*Labeo boga* (Hamilton, 1822)	LC	-	X	X	-	-	-	-	X
20	*Labeo boggut* (Sykes, 1839)	LC	X	X	-	-	-	-	-	-
21	*Labeo pangusia* (Hamilton, 1822)	NT	X	X	X	X	-	-	-	-
22	*Labeo dyocheilus* (McClelland, 1839)	LC	XX	X	X	X	-	-	-	-
23	*Labeo bata* (Hamilton, 1822)	LC	-	XX	XX	XX	XX	XX	XX	XXX
24	*Bangana dero* (Hamilton, 1822)	LC	XX	X	X	X	-	-	-	-
25	*Garra annandalei* Hora, 1921	LC	XX	X	X	-	-	-	-	-
26	*Garra gotyla gotyla* (Gray, 1830)	LC	XX	-	-	-	-	-	-	-
27	*Ctenopharyngodon idella* (Valenciennes, 1844)	EX	-	X	X	X	X	X	X	X
28	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	EX	-	X	X	X	X	X	X	X
29	*Hypophthalmichthy snobilis* (Richardson, 1845)	EX	-	X	X	X	X	X	X	-
30	*Puntius sophore* (Hamilton, 1822)	LC	-	XX	XX	XX	XX	XX	XX	XXX
31	*Pethia conchonius* (Hamilton, 1822)	LC	-	XX	XX	X	X	XX	X	XX
32	*Pethia ticto* (Hamilton, 1822)	LC	-	XX	XX	X	X	X	X	XX
33	*Puntius chola* (Hamilton, 1822)	LC	-	-	-	-	-	-	-	X
34	*Systomus sarana* (Hamilton, 1822)	LC	-	XX	XX	X	X	X	X	X
35	*Puntius chelynoides* (McClelland, 1839)	VU	X	-	-	-	-	-	-	-
36	*Schizothorax richardsonii* (Gray, 1832)	VU	XX	-	-	-	-	-	-	-
37	*Salmophasia bacaila* (Hamilton, 1822)	LC	-	XXX	XXX	XXX	XX	XX	XX	XXX
38	*Salmophasiaphulo* (Hamilton, 1822)	LC	-	-	-	-	-	-	-	XX
39	*Amblypharyngodon mola* (Hamilton, 1822)	LC	-	XXX	XXX	XX	XX	XX	XX	XXX
40	*Cabdio morar* (Hamilton, 1822)	LC	-	XXX	XX	XX	XX	XX	XX	XXX
41	*Aspidoparia jaya* (Hamilton, 1822)	LC	-	XX	XX	XX	XX	XX	XX	XXX
42	*Rasbora daniconius* (Hamilton, 1822)	LC	-	XX	XXX	XXX	X	XX	XXX	XXX
43	*Devario devario* (Hamilton, 1822)	LC	-	XX	XX	-	-	-	-	XXX
44	*Esomus danricus* (Hamilton, 1822)	LC	-	-	-	XX	X	XXX	XXX	XXX
45	*Chela cachius* (Hamilton, 1822)	LC	-	XX	XX	-	-	-	-	XXX
46	*Laubuca fasciata* (Silas, 1958)	VU	-	XXX	XX	-	-	X	-	-
47	*Laubuka laubuca* (Hamilton, 1822)	LC	-	XXX	XXX	-	-	-	-	-
48	*Raiamas bola* (Hamilton, 1822)	LC	XX	X	X	X	X	X	X	X
49	*Barilius barila* (Hamilton, 1822)	LC	XXX	XX	XX	XX	X	X	XX	3X
50	*Barilius bendelisis* (Hamilton, 1807)	LC	XX	XX	XX	-	-	-	-	X
51	*Barilius vagra* (Hamilton, 1822)	LC	X	X	-	-	-	-	-	-

(Contd...)

S.no.	Name of species	IUCN status	Badwada	Yamuna Nagar	Panipat	Delhi	Mathura	Agra	Etawah	Allahabad
52	*Securicula gora* (Hamilton, 1822) Family-Cobitidae	LC	-	XX	XX	X	X	X	X	X
53	*Lepidocephalichthys guntea* (Hamilton, 1822)	LC	-	XX	XX	-	-	-	-	X
54	*Botia lohachata* Chaudhuri, 1912	LC	-	XX	XX	X	-	-	-	X
55	*Botia Dario* Hora, 1932 Family-Nemacheilidae	LC	-	X	X	-	-	-	-	X
56	*Aborichthys elongates* Hora, 1921	LC	-	XX	XX	-	-	-	-	X
57	*Schistura rupecula* McClelland, 1838	LC	XX	-	-	-	-	-	-	-
58	*Acanthocobitis botia* (Hamilton, 1822) Order-OsteoglossiformesFamily-Notopteridae	LC	XX	XX	XX	XX	X	X	X	XX
59	*Notopterus notopterus* (Pallas, 1769)	LC	-	X	X	X	X	X	X	X
60	*Chitala chitala* (Hamilton, 1822) Order-Siluriformes Family-Amblycipitidae	NT	-	X	X	X	X	X	X	X
61	*Amblyceps mangois* (Hamilton, 1822) Family-Sisoridae	LC	X	X	-	-	-	-	-	-
62	*Bagarius bagarius* (Hamilton, 1822)	NT	X	X	X	X	X	X	X	XX
63	*Bagarius yarrelli* (Sykes, 1839)	NT	-	-	-	-	-	X	-	-
64	*Gogangra viridescens* (Hamilton, 1822)	LC	-	XX	XX	XX	X	X	X	XXX
65	*Nangra nangra* (Hamilton, 1822)	LC	-	-	-	-	-	-	-	X
66	*Gagata cenia* (Hamilton, 1822)	LC	-	-	-	XX	XX	XX	XX	XX
67	*Sisorrabdophorus* Hamilton, 1822	LC	XX	XX	XX	-	-	-	-	X
68	*Glyptothorax telchitta* (Hamilton, 1822)	LC	X	X	X	-	-	-	-	X
69	*Glyptothorax pectinopterus* (McClelland 1873) Family-Siluridae	LC	X	-	-	-	-	-	-	-
70	*Wallago attu* (Bloch & Schneider, 1801)	NT	-	X	X	X	XX	XX	XX	XX
71	*Ompok bimaculatus* (Bloch, 1794)	NT	-	X	X	X	-	-	-	X
72	*Ompok pabda* (Hamilton, 1822) Family-Bagridae	NT	-	X	X	X	-	-	-	X
73	*Sperata aor* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	XX
74	*Sperata seenghala* (Hamilton, 1822)	LC	-	X	X	X	XX	XX	XX	XXX
75	*Mystus cavasius* (Hamilton, 1822)	LC	-	3X	3X	X	XX	XX	XX	XX
76	*Mystus bleekeri* (Day, 1877)	LC	X	XX	XX	X	X	X	X	X
77	*Mystus vittatus* (Bloch, 1794)	LC	XX	XXX	XXX	XXX	XXX	XXX	XX	X
78	*Mystus tengara* (Hamilton, 1822)	LC	-	XXX	XXX	XX	XX	XX	XX	X
79	*Rita rita* (Hamilton, 1822) Family –Claridae	LC	-	X	X	X	X	X	X	XXX
80	*Clarias magur* (Hamilton, 1822)	EN	-	-	-	-	-	-	-	X
81	*Clarias gariepinus**(Burchell, 1822) Family-*Heteropneustidae*	EX	-	X	X	X	X	X	X	X
82	*Heteropneustes fossilis* (Bloch, 1794) Family-Schilbeidae	LC	-	X	X	X	X	X	X	X
83	*Ailia coila* (Hamilton, 1822)	NT	-	XXX	XXX	XXX	XXX	XXX	XXX	XXX
84	*Ailiichthys punctata* Day, 1872	DD	-	-	-	-	-	-	-	XX
85	*Clupisoma garua* (Hamilton, 1822)	LC	-	XX	XX	XX	XX	X	XX	XXX
86	*Eutropiichthys vacha* (Hamilton, 1822)	LC	-	XX	XX	XX	XX	XX	XX	XXX
87	*Eutropiichthys murius* (Hamilton, 1822)	LC	-	XX	XX	X	X	X	X	XX
88	*Neotropius atherinoides* (Bloch, 1794)	LC	-	XX	X	X	XX	XX	XX	X
89	*Silonia silondia* (Hamilton, 1822) Family- Pangasiidae	LC	-	-	-	X	X	X	X	X
90	*Pangasius pangasius* (Hamilton, 1822) Order- MugiliformesFamily- Mugilidae	LC	-	-	-	-	X	X	X	X
91	*Rhinomugil corsula* (Hamilton, 1822)	LC	-	XX	XX	XX	XX	XX	XX	XXX
92	*Sicamugil cascasia* (Hamilton, 1822) Order-BeloniformesFamily- Belonidae	LC	-	XX	XX	X	XXX	XX	XX	XXX
93	*Xenentodon cancila* (Hamilton, 1822) Order- PerciformesFamily-Ambassidae	LC	X	XX	XX	X	X	X	X	XX
94	*Chanda nama* Hamilton, 1822	LC	-	XXX	XXX	XXX	XXX	XX	XXX	XXX
95	*Parambassis ranga* (Hamilton, 1822)	LC	-	XXX	XXX	XXX	XXX	XX	XXX	XXX
96	*Parambassis lala* (Hamilton, 1822)	NT	-	X	X	-	-	-	-	X

(Contd...)

S.no.	Name of species	IUCN status	Badwada	Yamuna Nagar	Panipat	Delhi	Mathura	Agra	Etawah	Allahabad
	Family-Sciaenidae									
97	*Johnius coitor* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	XX
	Family-Nandidae									
98	*Nandus nandus* (Hamilton, 1822)	LC	-	XX	XX	-	-	-	-	-
99	*Oreochromis niloticus* (Linnaeus, 1758)	EX	-	X	XX	XXX	XXX	XXX	XXX	XXX
	Family- Anabantidae									
100	*Anabas testudineus* (Bloch, 1792)	DD	-	-	-	-	-	-	-	X
	Family-Osphronemidae									
101	*Trichogaster fasciata* Bloch & Schneider, 1801	LC	-	XXX	X	XXX	XXX	XXX	XXX	XX
102	*Trichogaster lalius* (Hamilton, 1822)	LC	-	XX	XX	X	-	-	-	X
	Family-Channidae									
103	*Channa marulius* (Hamilton, 1822)	LC	-	X	X	X	X	X	X	X
104	*Channa striata* (Bloch, 1793)	LC	X	X	X	X	X	X	X	X
105	*Channa punctata* (Bloch, 1793)	LC	-	XX	XX	XX	XX	XX	XX	XX
106	*Channa gachua* (Hamilton, 1822)	NE	-	-	-	-	-	-	-	X
	Family-Gobiidae									
107	*Glossogobius giuris* (Hamilton, 1822)	NE	-	XX	XX	X	X	X	X	X
	Order-TetraodontiformesFamily- Tetraodontidae									
108	*Leiodon cutcutia* Hamilton, 1822	LC	-	X	X	X	X	X	X	X
	Order-SynbranchiformesFamily-Mastacembelidae									
109	*Mastacembelus armatus* (Lacepede, 1800)	LC	XX	XX	XX	XX	XX	XX	XX	XX X
110	*Macrognathus pancalus* Hamilton, 1822	LC	-	X	X	X	X	X	X	XX
111	*Macrognathus aral* (Bloch &) Schneider,1801	LC	-	-	-	-	-	-	-	X
	Family-Synbranchidae									
112	*Monopterus scuchia* (Hamilton, 1822)	LC	-	-	-	-	-	-	-	X
	Order-Anguilliformes Family-Anguillidae									

Abundance: XXX, Very common; XX, Common; X, Rare. Biodiversity status: DD, Data Deficient; NE, Not Evaluated; LC, Least concern; EN, Endangered; VU, Vulnerable; NT, Near Threatened;*, Exotic.

condition of river stretches due to discharge of untreated domestic and industrial effluents, which were fairly higher than that of the Gomti river, another tributary of the river Ganga (Singh *et al*. 2005).

The uppermost Badwala site revealed an almost pristine state of hydrology and water quality parameters upon which degradation begins from Yamunanagar downward. In comparison to an earlier investigation conducted in the river Yamuna, the chloride level at Mathura has increased 4.4 times, specific conductance 2.3 times and total hardness and total alkalinity levels have increased 2.9 times (Jhingran and Joshi 1987). At Agra, chloride and conductance have raised three fold, specific conductance increased almost two times and alkalinity by 2.4 times. Delhi also registered an increase in above values with noticeable increase in chloride values by 3.8 times and total hardness by three folds, respectively (Jhingran and Joshi 1987). The values depicted in Figs 2 and 3 indicated moderately polluted upper stretches from Badwala downstream to Delhi and the lower stretches between Etawah to Allahabad; a grossly polluted middle stretch from Delhi to Etawah. Accordingly the fish diversity and biomass in the middle stretch was comparatively less due to the impact of the degraded water quality or habitat loss and intensive invasion of exotics.

In the river Ganga, dominant catch of exotics in the commercial landing have adversely impacted the Indian major carps (IMC) i.e. *Labeo rohita,Catla catla* and *Cirrhinus mrigala* (Pathak *et al*. 2014, Singh *et al*. 2010). The contribution of tilapia to the fishery showed an almost increasing trend from lower to middle stretches. Abundance of *Cyprinus carpio* and *Oreochromis niloticus* in different stretches of the river registered an inverse relationship. *Cyprinus carpio* dominated at Allahabad which is moderately polluted while Nile tilapia dominated in the middle stretches which were grossly polluted. Year round availability of different size groups of common carp and tilapia in the river Ganga also indicate successful recruitment of fishes (Joshi *et al*. 2014b, Alam *et al*. 2015). A recent study (Pathak *et al.* 2014) conducted at Allahabad stretch of the river Yamuna also corroborates the establishment of common carp in the river. The river Yamuna has faced extreme degradation of water quality and scarcity of fresh water (Gopal 2013), which caused silt loading river bed, algal choking, extermination of sensitive native fish species and invasion of exotic fishes. Therefore, environmental flow of about 50-60% of the total discharge were suggested (Soni *et al*. 2014) to provide efficient soil transport and avoid algal choking in the river Yamuna. The suggested flow could also be helpful to restore the river water and its native fishery in particular. Establishment of resilient exotic fishes was also observed in river Sone due to low discharge driven altered river habitats (Joshi *et al*.

2014a). Invasion and establishment of hardy, resilient exotic fishes could be attributed to their greater adaptability to polluted and stagnant waters.

Regulation of Yamuna river flow by the construction of barrages at Dak Patthar in Uttrakhand, Tajewala in Haryana, Wazirbad and Okhla in Delhi and Mathura in Uttar Pradesh have converted the Yamunanagar - Etawah stretch into localized impoundment. As a result, the voluminous river continuum was changed into a narrow, shallow, semi running, stagnant and discontinued channel. The shallow and sluggish flow concentrated with effluent load has drastically altered pristine feeding and breeding grounds and has eliminated the valuable native species. The altered flow regime, river habitats and physico-chemical parameters turned adverse to the sensitive native fishes including IMC and large catfishes. As a result, the vacant habitats have been occupied by hardy exotic fishes - *O. niloticus* and *C. carpio*, which contributed sizeable catches in the total fish landings and maximum (93.0 %) from Etawah stretch.

ACKNOWLEDGEMENT

The authors are grateful to the Director, Central Inland Fisheries Research Institute (ICAR), Barrackpore, Kolkata for the guidance and facilities provided during the course of study.

REFERENCES

Alam A, Chadha N K, Joshi K D, Chakraborty S K, Kumar T and Sharma A P. 2015. Maturation profile and fecundity of the exotic *Oreochromis niloticus* in the river Yamuna, India. *Journal of Environmental Biology* **36**: 927-31.

APHA. 2005. *Standard Methods for Examination of Water and Wastewater*. 21st edn. APHA AWWA, WPCF, Washington DC, USA.

Das M K, Sharma A P, Vass K K, Tyagi R K, Suresh V R, Naskar M and Akolkar A B. 2014. Fish diversity, community structure and ecological integrity of the tropical River Ganges, India. *Aquatic Ecosystem Health and Management* **16** (4): 395–407.

Froese R and Pauly D. 2011. *FishBase*. World Wide Web electronic publication. http://www.Wshbase.org (accessed April 2014).

Gopal B. 2013. *Environmental flows: The South Asian Experience*. Environmental flow – An introduction for Water Resource Managers. Boon P J, Davies B R and Pelts G E. National Institute of Ecology, New Delhi. p. 183–97.

IUCN. 2013. *The IUCN Red List of Threatened Species*. Version 2013.1 http://www. Iucnredlist.org (accessed on August 2014).

Jhingran A G and Joshi H C. 1987. Heavy metals in water, sediments and fish in the river Yamuna. *Journal of Inland Fish Society of India* **19**: 13–23.

Jhingran V G. 1991. *Fish and Fisheries of India*. Hindustan publishing Corporation, New Delhi.

Joshi K D and Biswas B K. 2010. Piscine diversity and fisheries in the river Ken, proposed for inter-river-linking. *Journal of Inland Fish Society of India* **42** (2): 25–31.

Joshi K D, Biswas B K, Lal S and Vass K K. 2009. Piscine diversity in the river Betwa. *Journal of Inland Fish Society of India* **41** (1): 61–64.

Joshi K D, Jha D N, Alam A, Srivastava S K, Kumar V and Sharma A P. 2014a. Environmental Flow requirements of river Sone: Impacts of low discharge on fisheries. *Current Science* **107** (3): 478–88.

Joshi K D, Jha D N, Alam M A, Das S C S, Srivastava S K and Kumar V. 2014b. Massive invasion of resilient exotic fishes in the river Ganga: a case study at Allahabad stretch. *Journal of Inland Fish Society of India* **46** (1): 92–95.

Lakra W S, Sarkar U K, Kumar R S, Pandey A, Dubey V K and Gusain O P. 2010. Fish diversity, habitat ecology and their conservation and management issues of a tropical river in Ganga basin, India. *Environmentalist* **30**: 306–19.

Mishra D N and Moza U. 1997. *Changing scenario of fish and fisheries of River Yamuna-II*. Proceedings of National Seminar "Inland Fisheries". Pp. 57–62. 16–17 March. Kolkata, India.

Mishra D N and Moza U. 2001. Evaluation of fish biomass and community structure in the context of environmental modifications in upper stretch of river Yamuna-Part-11. *Applied fisheries and Aquaculture* **1** (1): 17–21.

Moza U and Mishra D N. 2003. Ecodynamics and fishery status of upper stretch of river Yamuna and associated canals. Pp 1–51. Bulletin No 123. CIFRI pub.

Pathak R K, Gopesh A, Dwivedi A C and Joshi K D. 2014. Age and growth of alien fish species *Cyprinus carpio* var. *communis* (common carp) in the lower stretch of Yamuna River at Allahabad, India. *National Academy of Science Letters* **37**(5): 419–22.

Prakash C, Rawat D C, Grover P P. 1978. Ecological study of the river Yamuna. *Indian Association for Water Pollution Control Technical Annual* **5**: 32–45.

Sarkar U K, Pathak A K, Sinha R K, Sivakumar K, Pandian A K, Pandey A, Dubey V K and Lakra W S. 2011. Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats and conservation perspectives. *Reviews in Fish Biology and Fisheries* **22**: 251–72.

Sarkar U K, Lakra W S, Dubey V K, Pandey A, Madhu T, Sani R and Awasthi A. 2013. Freshwater fish diversity in the river Ken in Ganga basin: Abundance, threats and their management. *Proceedings of National Academy of Sciences, India Section B: Biological Sciences* **84** (4): 1043–51.

Sharma A P, Das M K, Samanta S, Paul S K and Bhowmick S. 2014.The ecology and fishery status of river Yamuna. Pp 1–32. Bulletin No 184. CIFRI pub.

Singh A K, Pathak A K and Lakra W S. 2010. Invasion of an exotic fish—common carp, *Cyprinus carpio* L. (Actinopterygii: Cypriniformes: Cyprinidae) in the Ganga River, India and its impacts. *Acta Ichthyologica et Piscatoria* **40**: 11–19.

Singh K P, Sinha S and Malik A. 2005. Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques—a case study, India. *Analytica Chemica Acta* **312**: 14–27.

Sinha M and Khan M A. 2001. Impact of the environmental aberration on the fisheries of the Ganga (Ganges) river. *Aquatic Ecosystem Health and Management* **4**: 493–504.

Soni V, Shekhar S and Singh D. 2014. Environmental flow for the Yamuna River in Delhi as an example of Monsoon Rivers in India. *Current Science* **106** (4, 25): 558–64.

Talwar P K and Jhingran A. 1991. *Inland Fishes of India and Adjacent Countries*. 2 volumes. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.

Vass K K, Tyagi R K, Singh H P and Pathak V. 2010. Ecology, changes in fisheries, and energy estimates in the middle stretch of the River Ganges. *Aquatic Ecosystem Health and Management* **13** (4): 374–84.