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RESEARCH PAPER

Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats and conservation perspectives

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Abstract The river Ganges is the largest river in India and the fifth longest in the world. Although, many studies on fish ecology and systematic have been conducted largely to improve fisheries but fish diversity and their distribution pattern from conservation point of view have never been adequately addressed in the Ganges. In this connection, current distribution and abundance of freshwater fishes of river Ganges was studied and assessed from April 2007 to March 2009. We documented and described 143 freshwater fish species in the all stretches of the river which is higher than what was reported earlier. Some species were observed with shift in their distribution ranges. First time, a total of 10 exotic fishes, including *Pterygoplichthys anisitsi*, which has never been reported from India found in the Ganges. Alterations of the hydrological pattern due to various types of hydro projects was seems to be the largest threat to fishes of Ganges. Indiscriminate and illegal fishing, pollution, water abstraction, siltation and invasion of exotic species are also threatening the fish diversity in the Ganges and as many as 29 species are listed under threatened category. The study advocates a need to identify critical fish habitats in the Ganga basin to declare them as conservation reserves to mitigate the loss of fish diversity from this mighty large river.

Keywords River Ganges · Freshwater fish diversity · Distribution · Abundance · Conservation issues · India

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Introduction

Riverine ecosystem of India have suffered from intense human intervention resulting in habitat loss and degradation and as a consequence many fresh water fish species have become heavily endangered, particular in Ganges basin where heavy demand is placed on fresh water. This was coupled with irreversible changes in natural population by introduction of exotic species and diseases (Dudgeon et al. 2005; Arthington and Welcomme 1995; Arthington et al. 2004; De Silva and Abery 2007). River conservation and management activities in most countries including India suffer from inadequate knowledge of the constituent biota. Therefore, research is being pursued globally to develop conservation planning to protect freshwater biodiversity (Pusey et al. 2010; Margules and Pressey 2000; Lipsey and Child 2007).

The basin of river Ganges, which has very high cultural, heritage and religious values drains about 1,060,000 km^2 area and it is the fifth largest in the world (Welcomme 1985). The River originates from ice-cave '*Gaumukh*' (30°55′N/70°7′E) in the Garhwal Himalaya at an altitude of 4,100 m and discharges into Bay of Bengal. The length of the main channel from the traditional source of the Gangotri Glacier in India is about 2,550 km. The mean annual water discharge is the fifth highest in the world with a mean of 18,700 m^3/s. Extreme variation in flow exists within the catchment area, to the extent that the mean maximum flow of the river Ganges is 468.7×10^9 m^3 which is 25.2% of India's total water resources and a vast amount of sediment ($1{,}625 \times 10^6$ tons) are transported downstream by the river and distributed across the fringing floodplains during the monsoon. The basin sustains more than 300 million people in India, Nepal and Bangladesh (Gopal 2000). In India, all tributaries of the Ganges are controlled by barrages diverting flow for irrigation and as a result fish catch has been declined, and thereafter, loss of species diversity have been reported (Das 2007a; Payne et al. 2004). Moreover, twenty nine freshwater fish species as recorded in this study from river Ganges have been recently listed as threatened under vulnerable and endangered categories (Lakra et al. 2010). Therefore, conservation and restoration of river have become vital for the overall development and nutritional and livelihood security of the Indo-Gangetic region. Although, studies on the fish fauna of the river Ganges and its tributaries have been made by several authors and information was mostly reported on the systematic, biogeographical and ecological aspects (e.g., Hamilton 1822; Hora 1929; Day 1875–1878, 1889; Krishnamurti et al. 1991; Bilgrami and Datta Munshi 1985; Srivastava 1980; Revenga and Mock 2000; Sinha 2006; Payne et al. 2004; Sarkar et al. 2010) but these information are still inadequate to address the critical issues related to the conservation of fishes in the Ganges. In this connection, this study was carried out (1) to determine the current pattern of freshwater fish biodiversity, distribution and abundance; (2) to review the threats to fish diversity; and (3) to make recommendations for fish biodiversity conservation and management.

Materials and methods

In addition to primary data on fish distribution and abundance collected for a period of 3 years, the secondary data from different publications and the data sources (Payne et al. 2004; Sinha 2007a; Vass et al. 2009) have also been used to understand the change in distribution pattern of fishes in the Ganges. The data on annual fish catches in the river were obtained from Vass et al. (2009). The river Ganges was divided into three zones i.e., upper zone (Uttarakhand State) in Northern Himalayan area, where as middle zone (states of Uttar Pradesh and Bihar) and lower zone (States of Bihar and West Bengal) in plain area of river Ganges to sample and monitor fishes. Apart from main stream of the river Ganga, major tributaries of the river also sampled for fishes. In each zone, the sampling sites were further divided into several sub-zones and each sub-zones were sampled in all seasons of the year. Different threats faced by the fish biodiversity of river Ganges in each sampling points were also observed. We also studied status of fishes in four wildlife protected areas falling in the basin, of which, Rajaji National Park, Jhilmil Conservation Reserve falls under upper stretch, Turtle sanctuary in the middle stretch and Vikramshila Gangetic Dolphin Sanctuary in the lower stretch. The detail of the sampling sites of river Ganges is presented in Fig. 1.

In the upper zone (UZ), UZ 1 and UZ 2 cover the Bhagirathi River and its streams. UZ 1 consists of area between Gangotri and Uttarkashi, and sampling points were in Gangotri, Harsil, Ganeshpur and Uttarkashi. UZ 2 consists of area from Tehri to Devprayag and included the sampling points of Bandarkot, Tehri and Devprayag. The zones UZ 3 and UZ 4 were the river Alaknanda and its streams. UZ 3 starts from Phata and up to Karanprayag included the sampling sites of Phata, Nao Gaon, Nandprayag and Karnaprayag. UZ 4 covers from Rudraprayag to Pauri Garhwal included sampling points of Rudra prayag, Chamouli and Sri Nagar. UZ 5 falls outside Himalaya, covering areas from Ajeetpur to Lakshar includes Ajeetpur, Raiwala, Kulhal, Dehradun, Haridwar and Lakshar.

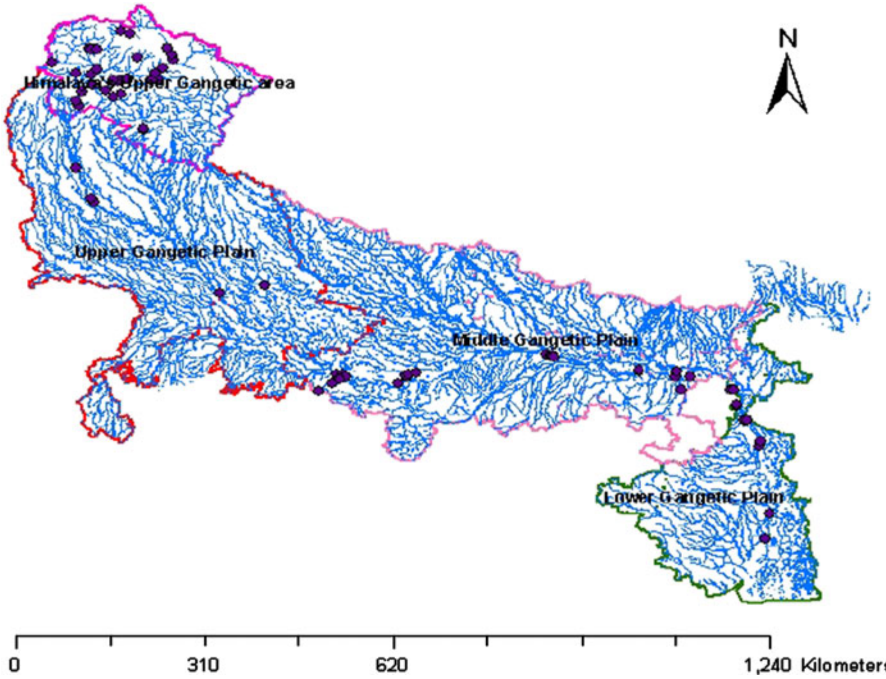


Fig. 1 River Ganga basin map showing study area across the stretch

In the middle zone (MZ), MZ 1 consists of area between below Haridwar to Ramsar site (Brijghat to Narora) which include the sites Brijghat, Narora. MZ 2 covers the area between Narora to Kanpur include Apsara, Ganga barrage, Tutaghat, Kannauj, Kanpur and MZ 3 from Kanpur to Allahabad include Dalerganj, Baruaghat, Sadiyapur and Allahabad. The stretch between Allahabad to Varanasi is termed as MZ 4 contains Varanasi and MZ 5 contains the stretch between Varanasi to Patna include Digha ghat, Adalat ghat, Ghagha ghat, Gai ghat, Lallupokhar ghat.

Similarly, in the lower zone, LZ 1 covers the stretch between Patna to Bhagalpur include Patna, Munger and Bhagalpur and LZ 2 contains the stretch between Bhagalpur to Rajmahal include Bhagalpur, Kahelgaon and Rajmahal., LZ 3 from Rajmahal to Farakka include the sampling sites Taltala ghat, Farakka and LZ 4 from Farakka to Navdeep include Manikchowk, Mushidabad, Raghunathganj, Lalgola, Mathurapur, Ahiron, Radha rghat, Nabwadeep and LZ 5 from Nabwadeep to Hoogly include the sampling sites Triveni ghat, Seraphulighat, Armenianghat and Hoogly.

The sites covered in the upper stretches are Raiwala, Aamsera, Vidoon, Banderkot, Uttarkashi, Harsil, Phata, Karanprayag, Gangotri, Shimili, Naogaon, Duggadda Gad, Khanda gad, Khankara gad. The middle zones consists of Brijghat, Narora, Apsara, Ganga barrage, Tutaghat at Kanpur; Dalerganj, Baruaghat, Sadiyapur at Allahabad and at lower zone the sites, Digha ghat, Adalat ghat, Ghagha ghat, Gai ghat, Lallupokhar ghat, Kastharny ghat, Hanuman ghat, Barari ghat, Kahalgaon, LCT ghat, Mahajan toil, Gudara ghat in Bihar and Manikchowk, Mathurapur, Farakka, Ahiron, Radharghat, Nabadweep, Trivenighat, Seraphulighat, Armenianghat in West Bengal were covered.

Sampling and analysis

Samples were collected at all sites covering pre rain and post rain at daytime (7:00–5:00) during April 2007 to March 2009. Experimental fishing was carried out in all sampling points with help of locally hired professional fishermen. Fishes were collected with gill nets (mesh 2.5 × 2.5 cm; 3 × 3 cm; 7 × 7 cm; length × breadth = 75 × 1.3 m; 50 × 1 m), cast nets (mesh 0.6 × 0.6 cm), drag nets or locally called *mahajal* (mesh 0.7 × 0.7 mm, L × B = 80 × 2.5 m with varying mesh sizes) and fry collecting nets (indigenous nets using nylon mosquito nets tied with the bamboo in both ends. At each site, all gears except cast nets were used at least ten times during each sampling occasion. The cast nets (5.5 m^2) were operated 20 times at each sites/sub sites covering about 100^2 meter of river segment allowing 3–5 min settled times in each cast. The relative abundance (percentage of catch) of fish across different sites was calculated by the following formula.

$$\text{Number of samples of particular species} \times 100/\text{Total number of samples}$$

Captured fish samples were released after recording of data except for a few individuals which needed to confirm species identifications in the laboratory. The fish diversity indices were calculated following formula (Shannon and Wiener 1963).

$$H = \sum_{i=1}^{n} \left(\frac{ni}{N}\right) \log 2 \left(\frac{ni}{N}\right)$$

where $H =$ Shannon-Wiener index of diversity; $n_i =$ total numbers of individuals of species, $N =$ total number of individual of all species. A data matrix was constructed with presence and absence of fish species for each of the sample stations in the protected and unprotected areas. Analysis of variance was conducted to test the presence of fish species in the different sites in river protected and unprotected area. Comparisons of mean data of diversity index were done using Tukey's Multiple Comparison Test. Statistical calculations were performed using Graph pad Prism 5 software package.

Similarity of the species in all sampling station was calculated using Jacquard's index:

$$S_j = j/(x + y - j)$$

where S_j is the similarity between any two zones X and Y, j the number of species common to both the zones X and Y, x the total number of species in zone X and y total number of species in zone Y. Similarity[1] within the sites was generated by using the Estimates *S* (version 8) software. Other analyses were carried out using the Statistica package.[2]

All specimens were identified based on the classification system of Nelson (2006) and scientific names were verified using http://www.fishbase.org. The colour, spots if any, maximum size and other characters of the fishes caught were recorded in a format developed for this purpose. Representative specimen ($n = 10$) of all fishes were preserved in 10% formaldehyde and transferred to the laboratory and stored in glass jars. Fishes were also collected from nearby fish market and landing centre associated with the river system which was not collected during experimental sampling. Taxonomy discrepancies were resolved with the latest database.

Results and discussion

Pattern of fish diversity

In India, 2,246 indigenous finfishes have been described of which 765 belongs to freshwater (Lakra et al. 2009). In the present study a total of 143 species belong to 11 orders, 72 genera and 32 families were recorded across all the stretches of river Ganges, which is about 20% of freshwater fish of the total fishes reported in India. This study added three more species in the checklist of freshwater fishes of Ganges basin in India (Payne et al. 2004; Shrestha 1990; Pathak and Tyagi 2010; Krishnamurti et al. 1991). A list of species with present distribution in all the stretch of river Ganges is provided in "Appendix". Out of 143 species, 133 species were native to river Ganges and its tributaries and remaining 10 species were exotics. The overall species richness of the Ganges basin is high (Hamilton 1822; Hora 1929; Venkateswarlu and Menon 1979; Day 1875–1878, 1889; Bilgrami and Datta Munshi 1985) despite several threats.

There was no endemic species reported during this study although in Asia the most number of endemic freshwater finfish species occur in India (De Silva and Abery 2007). However, there were reports of few endemic species in the upper streams of Ganges (Husain 1995; Uniyal 2010) which we could not find. High species richness found in orders of Cypriniformes, Siluriformes and Perciformes, accounting for 50.34, 23.07 and 13.99% of the population, respectively. The family Cyprinidae (53.47%), Bagridae (8.46%) and Channidae (1.47%) were found to be the most dominant in the Ganges (Fig. 2a). Studies in

[1] Colwell (1996). User's Guide to Estimates- Statistical estimation of Species richness and shared species from samples. Version 8. User's guide and application published at http://www.viceroy.eeb.uconn.edu/estimates.

[2] StatSoft, Inc. (1999). Electronic Statistics Textbook. Tulsa. OK: StatSoft. Web: http://www.statsoft.com/textbook/stathome.html.

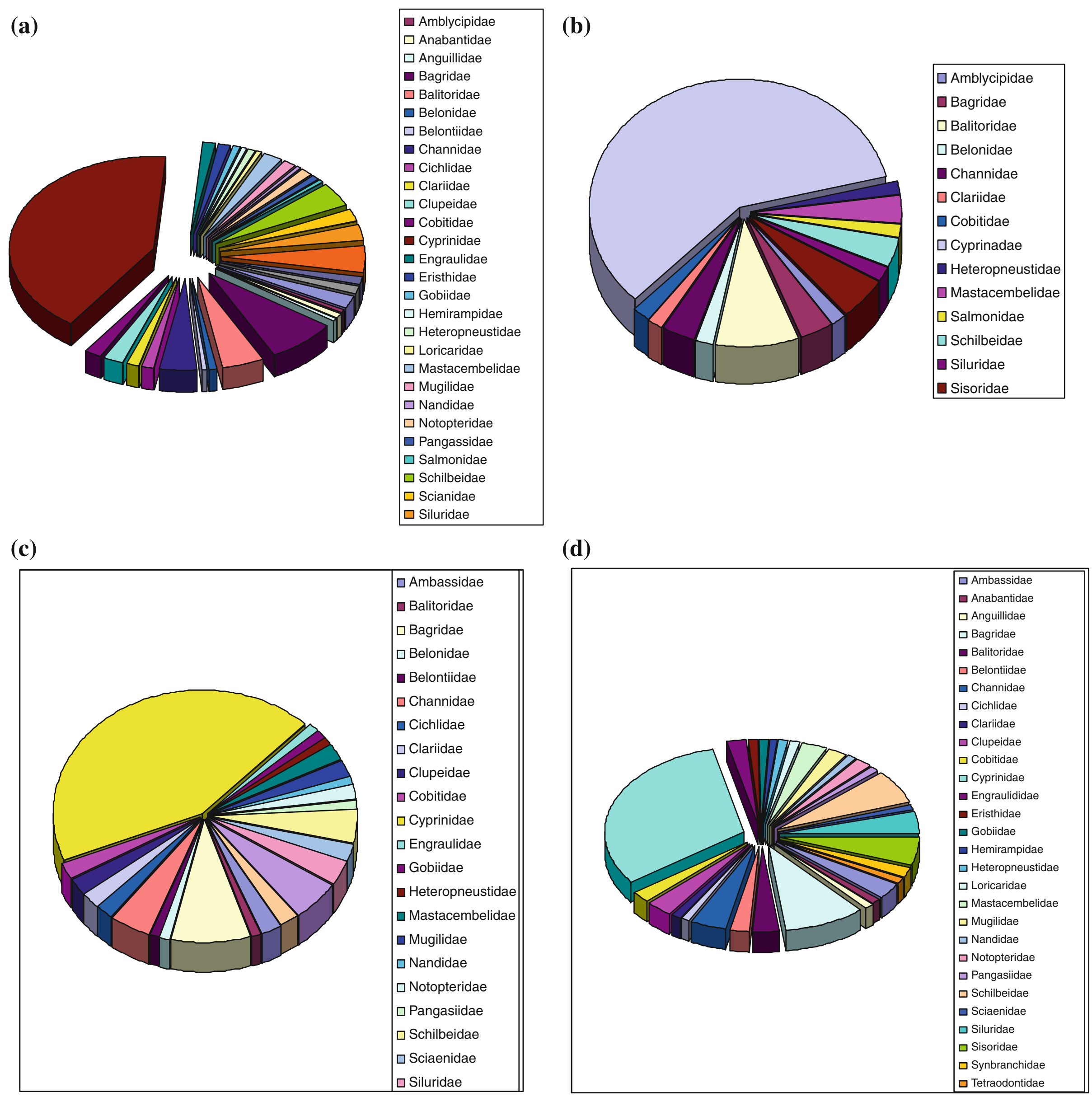


Fig. 2 Representation of families in River Ganga. **a** overall, **b** *upper* stretch, **c** *middle* stretch and **d** *lower* stretch

other Asian rivers have also found the more or less similar patterns (De Silva and Abery 2007; Raghavan et al. 2008; Sarkar et al. 2010). For instance, many of the species found in this river including the Cyprinids (e.g., *Barilius*, *Garra*, *Labeo*), Channids (*Channa*) Mastacembelids (*Mastacembelus*) as well as Notopterids are common to Africa as well. Review of literature shows that fish species richness in the Ganga river basin is low compared to that in other Asian rivers as indicated and the species area relationship could explain this phenomenon, because the area of the basin is second larger than those of other Asian rivers (Table 1).

Relative abundance of fishes of river Ganges showed dominancy of small sized indigenous species such as *S. bacilia* (19.68%), *G. chapra* (6.27%) and *P. ticto* (6.12%). However, this trend was reversed for the conservation important species like *M. vittatus* (2.33%), *R. corsula* (1.12%), *S. aor* (1.11%), *S. richardosonii* (0.74%), *P. sarana* (0.59%), *O. pabda*

Table 1 Drainage area, freshwater fish species number and species density of Asian rivers

River	Drainage area (km^2)	Number of species	Species density (number of species per 10,000 km^2)
Yangtze (China)	1,800,000	361	2.01
Ganges (India)	1,051,540	141,143[a]	1.34
Mekong	802,900	500	6.00
Yellow (China)	750,000	150	2.00
Zhujiang (China)	425,700	296	6.95
Salween (Burma)	279,720	150	5.36
Chao Phraya (Thailand)	177,500	222	12.51
Kapuas (Borneo)	94,480	290	30.69
Mahakam (Borneo)	93,423	147	15.73

Raw data from Kang et al. (2009), Fu et al. (2003)

[a] Present study

(0.51%), *S. silondia* (0.46%), *H. fossilis* (0.45%), *T. ilisha* (0.44%), *B. bagarius* (0.40%), *T. putitora* (0.39%), *T. tor* (0.28%), *C. chitala* (0.15%), *N. notopterus* (0.05%) and *P. pangasius* (0.02%).

The changes in the distribution pattern and range extension of some fishes in the Ganges were observed when compared to earlier reports (Payne et al. 2004; Shrestha 1990; Pathak and Tyagi 2010; Krishnamurti et al. 1991; Hamilton 1822; Hora 1929; Venkateswarlu and Menon 1979; Day 1875–1878, 1889; Bilgrami and Datta Munshi 1985) and there was a reduction in freshwater fish bio-diversity in general (Vass et al. 2009) which was mainly due to compartmentalization of river stretches largely due to hydro projects (Payne et al. 2004). The distribution pattern of the fishes of river Ganga basin has been presented in "Appendix". A total of 28 species including *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*), *B. bagarius*, *C. marulius*, *C. striata*, *C. batrachus*, *C. garua*, *C. latius*, *G. gotyala*, *W. attu* and some minor carps showed long range extension across all the three stretches. However, about 62 species had a narrow range distribution in the three zones. Fish composition of upper and lower zones of Ganges showed a high level of dissimilarity as observed in other rivers (Anderson et al. 2006) this might be due to difference in hydrology and temperature.

However, the Shannon-Weiner diversity index of upper, middle and lower stretches of the river indicated a strong relationship with overall species richness (Table 2). The minimum fish diversity index (3.0) was observed in middle stretch as compared to upper (3.05) and lower stretches (3.59) as shown in Fig. 3. Overall, the fish community indices across the river was low (Table 2) when compared to larger rivers in the world. Based on Namin and Spurny (2004) category, the low Shannon diversity index ($H = 2.85$) indicates that the river Ganges is moderately impacted. The low evenness index (0.27) across all the stretches may be due to phenomenon that river Ganges covers a great variation of latitude

Table 2 Indices of fish community structure of river Ganga

Sampling zones	No. of species	No. of family	Shannon Weiner index (H′)	Evenness (J)
Upper				
UZ 1	8	4	1.72	0.37
UZ 2	19	4	2.45	0.43
UZ 3	10	2	1.86	0.33
UZ 4	13	3	2.16	0.33
UZ 5	37	12	2.96	0.45
Total upper	56	33	3.05	
Middle				
MZ 1	40	16	1.44	0.19
MZ 2	33	12	1.53	0.18
MZ 3	30	14	2.44	0.33
MZ 4	48	13	3.26	0.47
MZ 5	64	23	3.27	0.35
Total middle	92	58	3.0	
Lower				
LZ 1	59	24	2.97	0.35
LZ 2	50	19	3.43	0.41
LZ 3	47	20	2.79	0.33
LZ 4	43	21	2.35	0.28
LZ 5	31	18	2.42	0.29
Total lower	95	65	3.59	
Total				
UZ1–LZ5	143	32	2.85	0.27

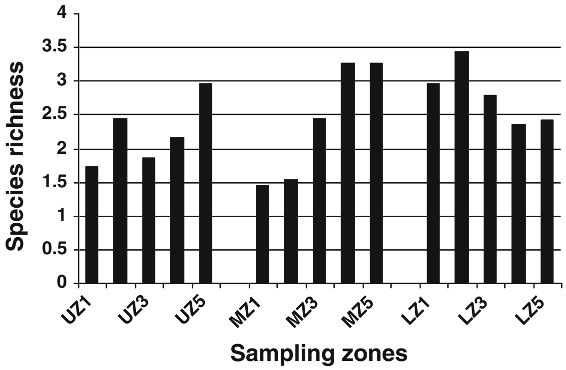


Fig. 3 Shannon Weiner diversity index across all sampling zones of river Ganga

and altitudes (10,000 ft), which mean that the some species are restricted to particular geographical area and do not appear in other areas especially, the cold water species in upper stretch.

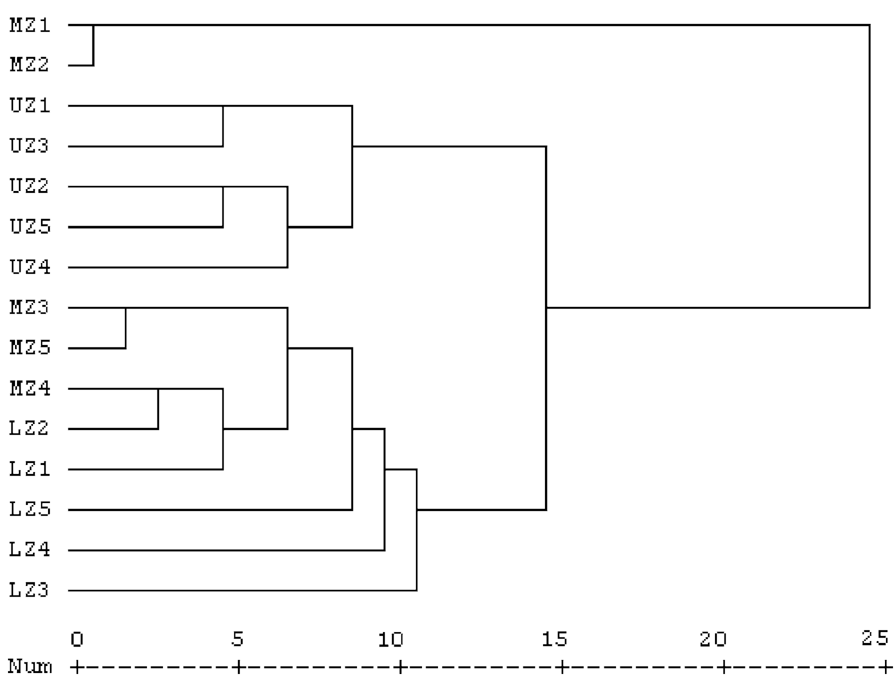
The ANOVA based on tukey's test showed significant difference ($P < 0.05$) between and among the sampling zones of all three stretches except between zone UZ 1 and UZ 3 where the value of "*P*" was observed high at 95% confidence interval. The similarity in species composition across the river is shown in Fig. 4. We have recorded more similarity was between the sampling zones in upper stretch, while sampling zones of middle and lower stretches showed less similarity among themselves. The probable reason can be the more evenness in the fish community in the sampling zones of upper stretch compared to middle and lower stretch.

Stretch-wise fish diversity

Upper stretch

A total of 56 fish species belonging to 32 genera and 13 families were recorded from all the five zones of upper stretch of river Ganges (Table 2). The cyprinidae with 33 species and 14 genera was the major dominant family (78.97%) and much behind were the presence of other families like, Balitoridae (15.58%) and Sisoridae (1.22%) as shown in Fig. 2b. Overall, the community structure in upper stretch of river was characterized by a few specialized cyprinid types, specifically the snow trouts (*Schizothorax* spp.), the mahseers (*Tor* spp.) and the lesser barils (*Barilius* spp.), the hillstream loaches (*Nemacheilus* spp.) and the sisorid torrent cat fishes (*Glyptothorax* spp.). In the upper stretch alone, only 4 species including *S. richardsonii*, *T. putitora*, *B. bendelisis* and *P. chelinoides* were recorded from all the five sampling zones. Restricted distribution was observed for

Fig. 4 Dendrogram showing similarity between all sites in river Ganga



41 species under the genus *Barilius*, *Nemacheilus* and *Schizothorax* species and most of them were restricted to upper three zones. There was no record of fish above 2400–3000 masl elevation. Surveys in Nepal have shown no fish records beyond an altitude of 1,650 masl (Shrestha 1978) and 1,800 masl (Jha 1992). The relative abundance of conservation and management important fish species in this river stretch was dominated by *B. bendelisis* (18.64%) followed by *S. richardsonii* (16.21%), *T. putitora* (8.51%), *S. montana* (5.49%), *T. tor* (4.5%), *G. gotyla* (1.49%) and *G. pectinopeterus* (0.77%).

Although much research was addressed on various ecological aspects (Nautiyal and Lal 1984, 1985; Nautiyal et al. 1998; Singh 1988; Sharma 2003) of the species like golden mahseer (*T. putitora*, *T. tor*) and snow trouts (*Schizothorax* species) from some tributaries in the upper stretches, however, detailed ecological information is still lacking for several cold water species in the region. Estimates of catches at four points along the Alaknanda in the Garhwal Himalaya showed range between 1,035 and 2,475 kg km^{-1} $year^{-1}$ with an average of 1,650 kg km^{-1} $year^{-1}$ while a lower tributary, the Nayar river believed to be an important fish breeding habitat in the region, produced 621 kg km^{-1} $year^{-1}$ (Payne and Temple 1996).

The Shannon-Weiner index within five sub-zones of upper stretch varied from 1.72 to 2.96 (Table 2). More fish diversity in the lower altitude than higher altitudes. However, the evenness index (J′) values ranged between 0.33 and 0.45 in all five sub-zones of upper Ganges reveals that there was a considerable uniformity in the distribution of species in the sampling zones. The evenness index was highest in the sampling zone UZ 5 and lowest at two sampling zones i.e., UZ 3 and UZ 4 (Table 2).

Middle stretch

Among the five zones in the middle stretch of river Ganges, a total of 92 fish species belonging to 58 genera and 24 families were recorded (Table 2). The number was lower than what was recorded earlier i.e., 106 species (Hassan et al. 1998; Srivastava 1968, 1980; Payne et al. 2004). The Cyprinidae with 40 species and 20 genera was the major dominant family (56.10%) followed by, Schilbeidae (10.60% and Clupeidae 8.55%) as shown in Fig. 2c. In the stretch of Allahabad, a constant declining of all economic species observed. For example, major carps catch was 424.91 tons in 1961–1968 which reduced to 38.58 in 2001–2006, similarly cat fishes 201.35 in 1961–1968 to 40.56 2001–2006 (Pathak and Tyagi 2010).

In the middle stretch, the relative abundance of certain threatened species were calculated for *E. vacha* (4.90%) followed *C. garua* (3.41%), *S. aor* (1.75%) *R. corsula* (1.40%), *B. bagarius* (0.78%), *O. pabda* (0.58%), *M. tengara* (0.52%), *C. mrigala* (0.44%), *L. rohita* (0.44%), *N. notopterus* (0.43%) and *C. chitala* (0.08%). This is significantly lower when compared to commonly occurring species like *Salmophasia bacaila* (34.39%), *Puntius ticto* (6.72%) and the clupeids *Gudusia chapra* (8.3%) (Payne and Temple 1996). The present distribution pattern of the fishes in the middle stretch showed that 15 species such as *B. bagarius*, *C. punctatus*, *C. reba*, *R. rita*, *S. aor*, *W. attu* and *C. garua* were common to all the five sampling zones.

The Shannon-Weiner indexes within five sampling zones of middle stretch were varied from 1.44 to 3.27 (Table 2). The highest value was recorded in the sampling zone MZ 5 followed by MZ 4, MZ 3, MZ 2 and lowest in MZ 1. The evenness index (J′) values ranged from 0.18 to 0.35, which indicate that there was high variation in the distribution of species between the sampling zones. The evenness index was recorded highest in the sampling zone MZ 4 and lowest at MZ 2 (Table 2).

Lower stretch

The lower stretch of river that is largely flood plains of the Ganges was recorded with 95 fish species belonging to 65 genera and 29 families (Table 2). Earlier, Bilgrami and Datta Munshi (1985) reported 89 species in this stretch. The Cyprinidae with 30 species and 17 genera was the major dominant family (45.77%, Fig. 2d) followed by Schilbeidae (11.41%) and Bagridae (8.99%). *Labeo rohita* (8.15) and *Johnius coiter* among Sciaenidae (7.59) were dominated in the catch. The relative abundance of economically importance species such as *R. rita* (1.60%), *T. ilisha* (0.82%), *C. panctatus* (0.79%), *O. pabo* (0.18%), *S. silonida* (0.57%), *P. pangasius* (0.51%), *O. pabo* (0.18%) and *C. chitala* (0.15%) were recorded as low except *L. rohita* (8.15%), followed by *A. coila* (5.95%), *M. vittatus* (3.85%), *C. mrigala* (2.29%) and *L. bata* (2.18%).

The rich fish diversity in the lower stretch may be attributed to the significant contributions of larger numbers of tributaries and presence of protected area. A total of 11 species such as *A. coila*, *C. panctatus*, *N. notopterus*, *L. calbasu*, *M. cavasius*, *C. nama*, *P. sophore* and *N. nandus* were recorded from all the five sampling zones, however, about 33 including *A. microlepis*, *A. bengalansis*, *M. albus*, *S. rabdophorus*, *A. gora* and *E. hara* were recorded with fragmented distribution. The recent report (Pathak and Tyagi 2010) on the fish yield at Patna indicates that drastic reduction in the catch of Indian major carps (383.2–118 kg km^2), large cat fishes (373.8–194.48 kg km^2). Migratory hilsa has declined even more dramatically (234.7–1.38 kg km^2).

The Shannon-Weiner index of fishes in the lower stretch ranged from 2.35 to 3.43 (Table 2) with minor variations between zones. The value was highest in the sampling zone LZ 2 followed by LZ 1, LZ 1, LZ 5 and lowest in LZ 4. The considerably low variations within sampling zones indicate that the species composition were almost uniform in this stretch. The evenness index (J') values mainly ranged from 0.28 to 0.4 also revealed considerable uniformity in the distribution of species in the sampling zones (Table 2).

New distribution and biological changes

In our study, we recorded a number of fish species which were never reported in the upper stretch of the river and were predominantly available in the lower and middle stretches in the 1950s (Menon 1954) were recorded from the upper cold-water region. For instance, the range extensions of several fish species including *Mastacembelus armatus* and *Cyprinus carpio*, var. specularis was recorded in the upper stretch (between Tehri and Rishikesh) and *Glossogobius giuris*, *Macrognathus aral*, *Sperata aor*, *Clupisoma garua*, *Puntius sarana* and *Ompok pabda* was recorded in Haridwar stretch indicating a perceptible shift in distribution pattern of fishes ("Appendix"). Correspondingly, species like *Glyptothorax brevipinnis* and *G. telchitta*, common inhabitants of upland waters were also recorded in the middle stretch of river Ganges during premonsoon periods confirming the range extension of these species towards down stream. Additionally, distribution range of *Panna microdon* which inhibits in brackishwater and marine environment was extended to upstream of Ganges up to Patna. This shift might be due to changes in the hydrology as well as increase in water temperature possibly due to global warming. Globally, in the recent years it has been reported that freshwater fish species could greatly change their present-day distribution in response to climate change (Mohseni et al. 2003; Chu et al. 2005; Buisson et al. 2008) and has now become a serious threat to the freshwater diversity (Habit et al. 2006). In India, analysis of 30 years' time series data on river Ganges and water bodies in the plains, Vass et al. (2009) reported an increase in annual mean minimum water temperature in the upper cold-water stretch of the river (Haridwar) by 1.5°C (from 13°C during 1970–1986 to 14.5°C during 1987–2003) and by 0.2–1.6°C in the aquaculture farms in the lower stretches in the Gangetic plains. Possibly, the considerable changes in temperature clime has resulted in a perceptible biogeographically distribution of the fish fauna we reported here. Furthermore, the shrunken distribution range of cold water species *Schizothorax* spp. towards the upstream could be considered as a warranting situation due to temperature increase. Consequently, we also observed that fishes were gravid during winter months (November to December) which is uncommon and never reported earlier indicating a shift in maturity which might also be due to changes in hydrology of river system due to numerous numbers of hydro projects as well as increase in temperature due to climate change (Table 3). It is evident from the literature that temperature is an important factor which strongly influence the reproductive cycle (Planque and Fredou 1999; Svedang et al. 1996), and growth rate in fishes (Brander 1995). In another study, Vass et al. (2009) also reported that failure in breeding and natural spawning of freshwater fishes and stated that the reasons might be due to shift in the rainfall patterns and also alteration of flow and turbidity of the river water.

Fish diversity of the protected areas

India has more than 690 wildlife protected areas, of these, four protected areas which are located in the river Ganges basin contributes a lot for fish conservation. Many fishes might use these protected areas for breeding and spawning grounds. Fishing is totally prohibited in these areas which resulted high fish diversity in these areas with higher size classes. In our study, considerable fish diversity was observed in the Ganges stretch passing through protected area of

Table 3 List of gravid fishes indicating shift in maturity stages collected from Ganga at different sampling sites

Name of fish species	Location	Collection month	Length (cm)	Weight (gm)
Aspidoparia morar	Patna, Munger and Bhagalpur	December	9.5–12.5	15–30
Eutropiichthys vacha	Patna	December	24	105
Mystus tengara	Munger	January	22	50
Gudusia chapra	Allahabad	November	14.2	19.5
Mystus cavasius	Munger	January	18	45
Mystus menoda	Munger	January	25	125
Nangra punctata	Munger	January	7.5	10
Nandus nandus	Allahabad	November	11.9	25.6
Setipinna brevifilis	Kahalgaon	January	19	38
Xenentodon cancilla	Bhagalpur	January	18.5	25
Rhinomugil corsula	Kanpur	November	22.0	126.4

river Ganga basin. A total of 59 species were recorded from the Turtle Sanctuary located in the middle stretch of river Ganges. Similarly, the Rajaji National Park and Jhilmil Conservation Reserve located in the upper stretch recorded with 40 and 41 fish species, respectively. Many cold water fishes especially *Barilius* spp. was observed breeding in large numbers in these protected areas. The percentage contribution of the fishes of the protected areas to the total diversity were 72, 65 and 44% for upper, middle and lower stretches, respectively showing that protected areas are important for fish conservation in the basin. Baird (2006) reported that fish conservation zones can benefit fish stocks, especially relatively sedentary species, but also highly migratory one and concluded that fish sanctuaries can be important tools in the context of participatory community-based fisheries/co-management programmes. Sarkar et al. (2008) reported more species diversity, greater fish abundance and relatively larger individuals in a protected riverine ecosystem in Northern India. Therefore, management strategies of the large rivers should also include protected habitats and hence, more studies should be encouraged.

Exotics

A total of 10 exotic fish species were recorded from the river Ganges and distributed in all stretches of Ganges. The relative abundance was recorded highest for *C. carpio* (50.14%) followed by *O. mosambica* (25.82%) and *C. gariepinus* (12.29%). *C. carpio* was distributed in all the stretches of the river. In the upper stretches alone three species viz., *C. carpio* (3.02%), *C. carpio* var. *specularis* (0.14%) and *O. mykiss* (0.27%) were recorded whereas in the middle stretch 7 species viz., *C. gariepinus* (0.04%), *C. idella* (0.22%), *C. carpio* (1.76%), *H. nobilis* (0.03%), *H. molitrix* (0.01%), *O. mossambicus* (0.98%) and *O. niloticus niloticus* (0.31%) and in the lower stretch 5 species viz., *C. carpio* (0.21%), *H. nobilis* (0.02%), *H. molitrix* (0.04%), *O. mosambica* (0.17%) and *Ptrerigoplichthys anisitsi* (0.01%). All these exotic species were not reported earlier from the main channel of the Ganges although some species like *Ctenopharyngodon idellus*, Silver carp (*Hypophthalmychthys molitrix*), *Oreochromis mossambicus*, Thai magur (*Clarias gareipinus*) and *Cyprinus carpio* have been reported in the tributaries of Ganga basin (Bhakta and Bandyopadhyay 2007; Sarkar et al. 2010). Higher abundance and range extension of *C. carpio* threatening the native species. Changes in hydrology especially more reservoir types of situation due to barriers across river seems to responsible for the flourishing of *C. carpio* in the basin. The stretch wise distribution of exotic fish species is shown in "Appendix".

Structural changes and fishery production

The total annual fishing production in the basin had been declined from 85.21 tons during 1959 to 62.48 tonnes during 2004 (Fig. 5). The dynamics of the 4 different major fish groups showed that the percentage of major carps had decreased from 41.4 to 8.3 tons from 1958–1962 to 1996–1997 (Fig. 6). The proportion of major carps in the fishery declined from 43.5 to

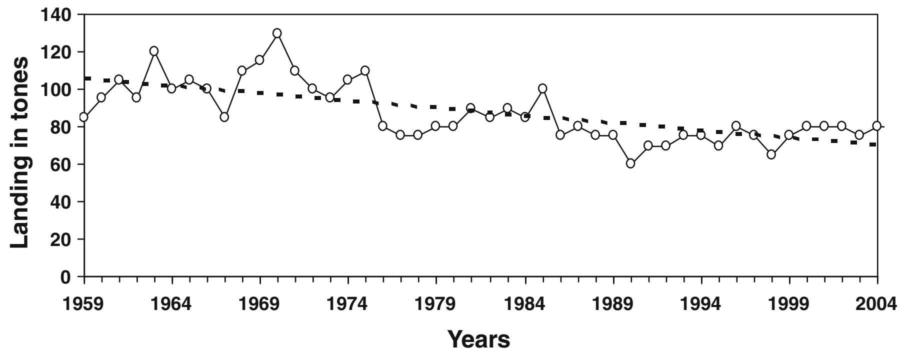


Fig. 5 The dynamics of annual fishery landings in the River Ganga during 1959–2004 (*Source*: Das 2007b)

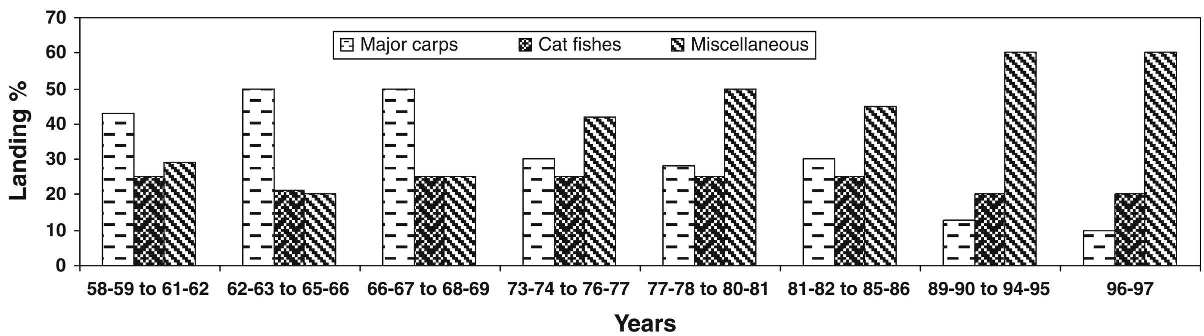


Fig. 6 The dynamics of total annual fishery landings of major fish groups in the River Ganga during 1959–2004. (Source: Das 2007)

29% by 1972–1976 and 13% today (Payne et al. 2004). Significant reductions in catches of around 1,600 tonnes or 13% over 10 years were found at Allahabad. The miscellaneous fish percent increased from 27.1% in 1958–1962 to 63.4% by 1996–1997. During the same time period the catfish percentage increased from 21% to 24.6% (De 1999). The anadromous hilsa (*Tenualosa ilisha*) has also declined due to the Farrakah barrage and the inaccessibility of the connecting canal. The low fish production of the major fish groups in the river Ganges is believed to be the recruitment failure of the young ones due to degradation (decreased runoff, changes in flow, turbidity) of the natural spawning habitat and climate change (Das 2007b). In this light, our findings on the age structure of *Labeo rohita* and *Tor putitora* of river Ganges indicated that the number of older individuals tended to decrease (Khan and Siddiqui 1973; Sarkar et al. 2006) from 1973 to 2006 (Table 4) which is might be due to unsustainable exploitation of the resources. On the other hand, we noticed that the large proportion of younger individuals appears to be expanding as compared to older ones. It is evident that the ratio of various age groups in a population determines the current reproductive status of the population and indicates what may be expected in the future. Usually a rapidly expanding population, will contain a large proportion of young individuals whereas, a declining population will contain a large proportion of old individuals and stationary population will have a more even distribution of age classes (Odum 1971). Therefore, the rapidly expanding population of *Labeo rohita* and *Tor putitora* in river Ganges is nevertheless a stable population. Further, if the effects of unsustainable exploitation can be countered, these populations may rejuvenate itself.

Threats

In the Ganga river basin, alterations in fish diversity and community structure are mainly due to hydrological alterations, dam constructions, over fishing, pollution, water diversions, changing land use pattern, exotic species invasion, rapid sedimentation, deforestation, climatic changes and land erosion etc. Assessing impacts and threats directly informs conservation strategies, management options and priorities for actions (Linke et al. 2007). According to

Table 4 Changes in mean age structure in percentage of *Tor putitora* and *Labeo rohita* in river Ganga and its tributaries

Year	Species	Author	Age																	
			0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
1980–1981	*T. putitora*	Nautiyal et al. (2008)	19.6	21.2	11.3	9.8	7.5	6.06	5.3	3.7	3.03	3.03	3.03	–	3.03	–	–	–	2.27	0.7
1994–1996	*T. putitora*	Do	18.03	46.7	14.2	6.8	5.2	2.8	3.4	–	1.5	0.02	0.01	0.01	–	0.02	–	–	0.01	0.01
1967–1969	*L. rohita*	Khan and Siddiqui (1973)	–	35.7	15.7	8.6	9.1	8.2	7.7	7.4	4.5	1.9	1.2	–	–	–	–	–	–	–
2000–2004	*L. rohita*	Sarkar et al. (2006)	–	62.5	18.9	10.5	6.6	0.14	–	–	–	–	–	–	–	–	–	–	–	–

Karr and Chu (1995) freshwater ecosystem conservation plans rely mainly on assessing ecological integrity of ecosystems, based on the notion that ecosystems of high ecological integrity support and maintain the full natural range of biological features and ecological processes.

The main ecohydrological alterations are construction of dams and barrages on the river, loss of wetlands and floodplain habitat and water diversions. Alterations of water quantity, seasonal flows and patterns of flow variability such as by damming and abstractions, or inter-basin transfers (IBTs) have substantial and negative consequences for the maintenance of biodiversity in many rivers (Arrington and Winemiller 2003; Linfield 1985; Sinha and Khan 2001; Sinha 2007b; Lakra et al. 2011). A series of barrages and dams have been commissioned in the upper segment of river Ganges from Rishikesh to Narora (Rao 2001) and the Tehri dam constructed in the hills of Uttarakhand has considerably reduced the water flow and have shown detrimental effects on physical attributes and destruction of feeding, spawning, and migration routes of mahseer (Sharma 2003). In addition, along with mahseer (*Tor putitora*, *T. tor*) the other migratory species like dwarf goonch (*Bagarius bagarius*), yellowtail catfish (*Pangasius pangasius*), pangas catfish (*Silonia silondia*), hilsa (*Tenualosa ilisha*) and long whiskered catfish (*Sperata aor*) from the middle and upper stretch is under severe threat due to consequences of damming and water diversions projects. Vast amount of sediment (mean annual 1,625 $\times$ 10^6 tons) are transported downstream by the river and distributed across the fringing floodplains during the period of inundation (July to September) which results into sedimentation of fish spawning sites affecting their breeding. Due to siltation, use for dryland farming and construction of embankments wetlands in the Ganges basin are vanishing very fast. In addition, more than 150,000 km^2 of the Ganges basin is irrigated using some 85,000 m^3 of river water which has led to extensive problems of soil salinisation and as a result the salt load of the returning irrigation water over 6.3 million tones of salt are estimated to be added to the water annually (CPCB 1984). Large number of industries located in the basin discharge enormous amounts of toxic wastes to the Ganges. The severe impacts of industrial effluents disposed into the river have resulted in fish kills reported from time to time (Sunderesan et al. 1983; Das et al. 2007). Bioaccumulation of heavy metals was observed in fishes in the lower stretch of the river and at Varanasi (Ghosh et al. 1982; Sinha 2004). The agriculture sector drains about 134.8 million waste into the river basin. Similarly, 2,573 tonnes pesticides, mainly DDT and BHC-Y are applied annually for pest control (Sinha 2007b). The Ganges Basin is reported to carry some 200 tonnes of biological oxygen demand (BOD) per day gross pollution. However, it is still relatively localized and focused on urban centers including Hardwar, Kanpur, Varanasi and Diamond Harbour near Kolkata. This appears to be related to the decline in catch of fisherfolk from 30–40 kg to 15 kg per day downstream of the town (Kumra 1995). Our result suggests that, dominance of exotics, over exploitation and effects of climate change are also posing serious threat to native fishes of Ganges.

Conservation status

The conservation assessment of fishes of river Ganges has been presented in Fig. 6. Of the 143 freshwater fish species, about 20% of fish species in Ganges were assessed as threatened category following IUCN Red List Criteria. More number of threatened fishes found in upper stretch (26%) followed by lower (23%) and middle (20%; Fig. 7). Distinctly threatened species are characteristically those fish belong to very defined taxonomic units of restricted geographic range, and appears to be particularly sensitive to one or more human threats and those populations or range which have undergone a significant decline and seems likely to continue (Lakra et al. 2010).

Conservation and management recommendations

Current efforts

India has legislated the Wildlife (Protection) Act, 1972, Biological Diversity Act (2002) and Biological Diversity Rules (2004), which aimed to conserve and protect the biodiversity in the country and also ensure the sustainable utilizations. Several protected areas declared using the Wildlife (Protection) Act, 1972 which are directly or indirectly conserving fish diversity in the country although none of freshwater fishes listed in the Act. Among current conservation efforts, an innovative approach has been adopted for the first time in the country by NBFGR, Lucknow which involves integration of the key stakeholders in the conservation exercise by the strategies of declaring a State Fish, and 16 states have declared State Fish in order to achieve the real time conservation benefits. Successful artificial propagation of several species like *Chitala chitala*, *Ompok pabo*, *O. pabo*, *Anabas testudineus*, *Nandus nandus* were achieved (Lakra and Sarkar 2009). In

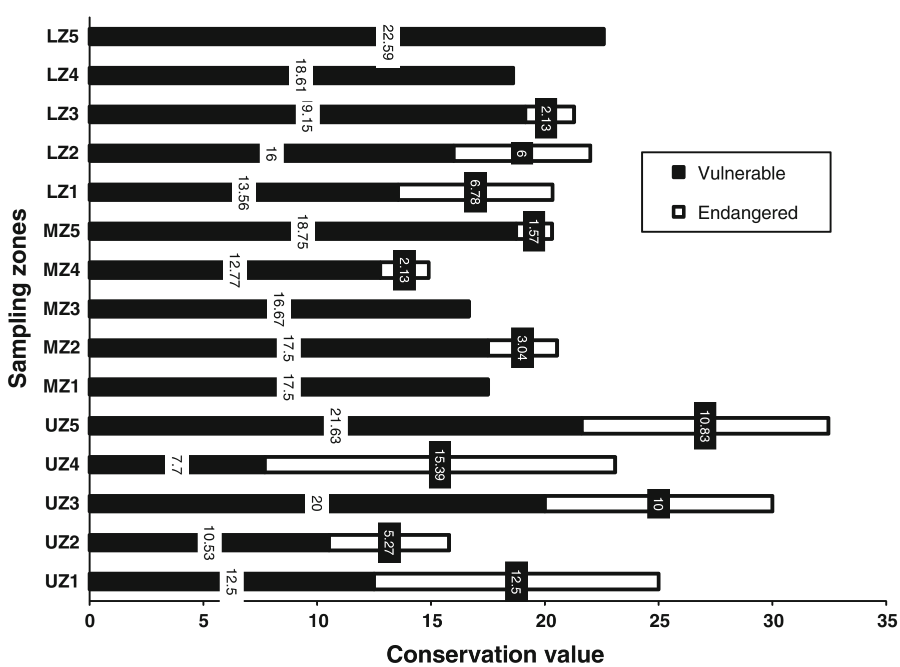


Fig. 7 Conservation status (%) of threatened fish species in different zones in river Ganga

addition, several measures like, in situ conservation, habitat fingerprinting, ex-situ conservation and developing live gene banks have been implemented to conserve the native fish diversity. In this light, in Northern India, observations were made in the water bodies of the selected wildlife sanctuaries in order to conceptualize the need and approach for developing freshwater aquatic sanctuaries (FAS) within the protected area network (Sarkar et al. 2008).

Recommendations

The creation of specially targeted fish protected areas is an important step in the conservation of Ganges and its biodiversity. We identified the Nayar, Mandal, Saung and Kho rivers which are tributaries in the upper stretch of river Ganges, are important habitats of fish to breed and spawn (Atkore et al. 2011; Anupama and Gusain 2007; Nautiyal and Lal 1984) which may be declared as protected areas in consultation with local communities. A proper environment assessment is required before taking up any hydro projects in the Ganges. In the middle and lower stretches of the river Ganges the conservation strategies for fishes must take into account the life history traits and habitat requirements of migratory species. Biological characters of the many species are still unknown and therefore studies are needed. Restoring the natural stocks of the species should be a priority, which includes ensuring minimum flow requirements and revival of lost breeding grounds and thereby restoring the failed recruitment process. This may be achieved by negotiation with the stakeholders so that the required flow and depth of the river is maintained. In addition, restoration of floodplain and associated wetlands should be a priority for conservation because floodplains play an integral part of riverine ecosystem. Many floodplains have already lost their connection with main channel due to heavy siltation. Floodplains serve as breeding and nursery grounds for several species. Towards restoring those critical habitats, research efforts should be translated into social and political actions as early as possible. Efforts should be made to check the sediment flow by extensive plantation of native trees, shrubs, etc. on the riverbank and adjoining catchment area. Effective construction of fish passage structure is necessary. Conventional fish ladders designed may not be successful because most fishes do not jump. In the middle stretch of the river Ganges (Allahabad), Hilsa (*Tenualosa ilisha*), which used to form a good share in catches below Allahabad has almost disappeared after inception of Farakka barrage despite fish ladders were installed. Steps should be taken to improve fish pass way so that the fishes may negotiate upstream areas.

Research efforts on generating the life history of 29 threatened fishes in the river (as listed in "Appendix") is necessary for successful conservation. An ecosystem approach of fish conservation is a new management of fish community in many countries (Frissell 1997; Sarkar and Bain 2007). Therefore, information on the role of species diversity is the functioning of ecosystems should be incorporated into comprehensive environmental management policies of the large Indian rivers.

Conclusions

Range extension of certain species and reduction in ranges of few species is a serious concern in the long term conservation of fishes in the Ganges. Moreover, higher abundance of exotics, fragmentation and changes in the hydrology of river due to hydro projects and barriers are major threat to the fishes in the Ganges apart from indiscriminate fishing, pollution, poor land use pattern. So far, in India fishes are considered as commercial product and failed appreciate their ecological services which pushed large number of species under threatened categories. Fish conservation areas, landscape level conservation plan, proper Environment Impact Assessment for any developmental activities in the basin, habitat restoration plan, species recovery plan for certain threatened species in the Ganges etc. may help the native fish diversity restore in the Ganges. India has recently formed a National River Ganga Basin Authority (NRGBA), Chaired by the Honorable Prime Minister of India, would certainly help to mitigate the threats and conserve the aquatic biodiversity.

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Appendix

See Table 5.

Table 5 List of freshwater fishes of river Ganga

	Fish species	Distribution														
		Upper zone					Middle zone					Lower zone				
		UZ1	UZ2	UZ3	UZ4	UZ5	MZ1	MZ2	MZ3	MZ4	MZ5	LZ1	LZ2	LZ3	LZ4	LZ5
1.	*Alia coila* (Hamilton 1822)						*	*	*		*	*	*	*	*	
2.	*Acanthocobitis botia* (Hamilton 1822)									*		*				
3.	*Amblyceps mangois* (Hamilton 1822)[d]					*										
4.	*Amblypharyngodon gora* (Hamilton 1822)											*	*			
5.	*Amblypharyngodon microlepis* (Bleeker 1854)											*				
6.	*Amblypharyngodon mola* (Hamilton 1822)										*	*	*	*	*	*
7.	*Anabas testudineus* (Bloch 1792)											*	*	*		*
8.	*Anguilla bengalensis* (Gray 1831)											*				
9.	*Aspidoparia jaya* (Hamilton 1822)								*			*	*			
10.	*Aspidoparia morar* (Hamilton 1822)								*			*	*	*		*
11.	*Bagarius bagarius* (Hamilton 1822)[e]					*	*	*	*	*	*	*	*	*	*	
12.	*Bagarius yarrelli* (Sykes 1839)[d]											*	*			
13.	*Barilius barila* (Hamilton 1822)		*						*	*	*					
14.	*Barilius barna* (Hamilton 1822)					*			*							
15.	*Barilius bendelisis* (Hamilton 1807)	*	*	*	*	*						*				
16.	*Barilius tileo* (Hamilton 1822)					*										
17.	*Barilius vagra* (Hamilton 1822)		*		*											
18.	*Batasio batasio* (Hamilton 1822)							*								
19.	*Botia almorhae* (Gray 1831)											*				
20.	*Botia dario* (Hamilton 1822)[e]						*					*	*	*		
21.	*Botia lohachata* (Chaudhuri 1912)		*								*	*				
22.	*Catla catla* (Hamilton 1822)					*	*		*	*		*	*	*	*	
23.	*Chagunius chagunio* (Hamilton 1822)[d]					*					*	*	*			
24.	*Chanda nama* (Hamilton 1822)								*	*	*	*	*	*	*	
25.	*Chanda ranga* (Hamilton 1822)											*	*	*		
26.	*Channa punctatus* (Bloch 1793)						*	*		*	*	*	*	*	*	
27.	*Channa marulius* (Hamilton 1822)					*	*			*	*	*	*	*	*	*
28.	*Channa orientalis* (Bloch & Schneider 1801)									*	*					
29.	*Channa stewartii* (Playfair 1867)									*						
30.	*Channa striatus* (Bloch 1793)					*			*	*	*	*	*	*	*	*

Table 5 continued

	Fish species	Distribution														
		Upper zone					Middle zone					Lower zone				
		UZ1	UZ2	UZ3	UZ4	UZ5	MZ1	MZ2	MZ3	MZ4	MZ5	LZ1	LZ2	LZ3	LZ4	LZ5
31.	*Chela laubuca* (Hamilton 1822)							*			*	*				
32.	*Chela cachius* (Hamilton 1822)									*						
33.	*Chitala chitala* (Hamilton 1822)[d]					*	*	*			*	*	*	*		
34.	*Cirrhinus mrigala* (Hamilton 1822)		*				*	*	*	*	*	*	*	*		*
35.	*Cirrhinus reba* (Hamilton 1822)						*	*	*	*	*	*	*	*	*	*
36.	*Clarias batrachus* (Linnaeus 1758)					*					*	*		*		*
37.	*Clarias gariepinus* (Burchell 1822)[c]								*							
38.	*Clupisoma garua* (Hamilton 1822)[a]						*	*		*	*	*	*	*	*	
39.	*Colisa fasciata* (Bloch & Schneider 1801)										*	*		*	*	
40.	*Crossocheilus latius latius* (Hamilton 1822)[e]					*		*				*	*	*		
41.	*Ctenopharyngodon idella* (Valenciennes 1844)[c]								*							
42.	*Cyprinus carpio* (Linnaeus 1758)[c]		*			*	*	*	*		*	*	*			
43.	*Cyprinus carpio* (Var. *Specularis*) (Lacepède 1803)[c]		*													
44.	*Danio devario* (Hamilton 1822)											*				
45.	*Erethistes hara* (Hamilton 1822)											*				
46.	*Esomus danricus* (Hamilton 1822)											*				
47.	*Eutropiichthys murius* (Hamilton 1822)								*			*	*			
48.	*Eutropiichthys vacha* (Hamilton 1822)[e]						*	*	*	*	*	*	*	*	*	*
49.	*Gagata cenia* (Hamilton 1822)						*	*			*	*	*	*		
50.	*Garra gotyla gotyla* (Gray 1830)[e]											*	*			
51.	*Glossogobius giuris* (Hamilton 1822)[a]							*	*	*	*	*	*		*	*
52.	*Glyptothorax pectinopterus* (McClelland 1842)		*		*											
53.	*Glyptothorax brevipinnis* (Hora 1923)[a]								*							
54.	*Glyptothorax telchitta* (Hamilton 1822)[a,e]				*							*				
55.	*Gonialosa manmina* (Hamilton 1822)[e]										*	*	*	*		
56.	*Gudusia chapra* (Hamilton 1822)						*					*	*	*	*	*
57.	*Hemibagrus menoda* (Hamilton 1822)[d]											*				
58.	*Heteropneustes fossilis* (Bloch 1794)[e]					*	*				*	*		*	*	*
59.	*Hypophthalmichthys molitrix* (Valenciennes 1844)[c]													*		
60.	*Hypophthalmichthys nobilis* (Richardson 1845)[c]									*		*				

Table 5 continued

	Fish species	Distribution														
		Upper zone					Middle zone					Lower zone				
		UZ1	UZ2	UZ3	UZ4	UZ5	MZ1	MZ2	MZ3	MZ4	MZ5	LZ1	LZ2	LZ3	LZ4	LZ5
61.	*Hyporhamphus limbatus* (Valenciennes 1847)[b]											*	*			
62.	*Johnius coiter* (Hamilton 1822)						*				*	*	*	*	*	*
63.	*Johnius gangeticus* (Talwar 1991)										*					
64.	*Labeo angra* (Hamilton 1822)									*						
65.	*Labeo gonius* (Hamilton 1822)						*					*	*			
66.	*Labeo bata* (Hamilton 1822)		*			*	*	*		*	*	*	*	*	*	*
67.	*Labeo boggat* (Sykes 1839)						*				*					
68.	*Labeo calbasu* (Hamilton 1822)			*			*	*	*		*	*	*	*	*	*
69.	*Labeo* (*Bangana*) *dero* (Hamilton 1822)									*				*		
70.	*Labeo dyocheilus* (McClelland 1839)		*			*										
71.	*Labeo fimbriatus* (Bloch 1795)									*	*			*		
72.	*Labeo pangusia* (Hamilton 1822)[e]					*				*	*					
73.	*Labeo rohita* (Hamilton 1822)					*	*	*		*		*	*	*	*	*
74.	*Lepidocephalichthys guntea* (Hamilton 1822)											*	*	*		
75.	*Macrognathus aral* (Bloch and Schneider 1801)[a]		*								*	*	*	*	*	
76.	*Macrognathus pancalus* (Hamilton 1822)						*	*	*		*	*	*	*	*	*
77.	*Mastacembelus armatus* (Lacepède 1800)[a]					*	*	*	*			*	*	*	*	
78.	*Megarasbora elanga* (Hamilton 1822)									*						
79.	*Monopterus albus* (Zuiew 1793)											*				
80.	*Monopterus cuchia* (Hamilton 1822)													*	*	*
81.	*Mystus bleekeri* (Day 1877)										*	*	*			
82.	*Mystus cavasius* (Hamilton 1822)						*	*		*	*	*	*			
83.	*Mystus tengara* (Hamilton 1822)						*	*			*	*	*	*	*	
84.	*Mystus vittatus* (Bloch 1794)										*	*	*			
85.	*Nandus nandus* (Hamilton 1822)						*			*				*	*	*
86.	*Nangra nangra* (Hamilton 1822)[d]													*		
87.	*Nangra punctata* (Hamilton 1822)									*		*	*			
88.	*Nemacheilus beavani* (Günther 1868)		*													
89.	*Nemacheilus botia* (Hamilton 1822)		*			*			*		*			*	*	
90.	*Nemacheilus corica* (Menon 1987)				*											

Table 5 continued

	Fish species	Distribution														
		Upper zone					Middle zone					Lower zone				
		UZ1	UZ2	UZ3	UZ4	UZ5	MZ1	MZ2	MZ3	MZ4	MZ5	LZ1	LZ2	LZ3	LZ4	LZ5
91.	*Nemacheilus montanus* (McClelland 1838)		*													
92.	*Nemacheilus mooreh* (Sykes 1839)															
93.	*Nemacheilus rupecola* (McClelland 1838)				*											
94.	*Notopterus notopterus* (Pallas 1769)						*			*	*	*	*	*	*	*
95.	*Ompok bimaculatus* (Bloch 1794)										*	*		*		*
96.	*Ompok pabda* (Hamilton 1822)[a,e]					*				*	*	*	*	*	*	
97.	*Ompok pabo* (Hamilton, 1822)[d]											*	*	*	*	
98.	*Oncorhynchus mykiss* (Walbaum 1792)[c]	*														
99.	*Oreochromis mossambicus* (Peters 1852)[c]										*	*	*			*
100.	*Oreochromis niloticus niloticus* (Linnaeus 1758)[c]								*	*						
101.	*Osteobrama cotio* (Hamilton 1822)							*		*	*	*	*	*		
102.	*Pangasius pangasius* (Hamilton 1822)[e]											*	*	*	*	
103.	*Panna microdon* (Bleeker 1849)[b]											*	*			
104.	*Pseudambassis baculis* (Hamilton 1822)										*	*				
105.	*Pseuedeutropius atherinoides* (Bloch 1794)											*	*			
106.	*Pterygoplichthys anisitsi* (Eigenmann & Kennedy 1903)[c]											*				
107.	*Puntius chelynoides* (McClelland 1839)		*	*	*	*										
108.	*Puntius chola* (Hamilton 1822)[e]											*	*	*		
109.	*Puntius conchonius* (Hamilton 1822)									*		*				
110.	*Puntius amphibious* (Valenciennes 1842)								*							
111.	*Puntius binotatus* (Valenciennes 1842)								*							
112.	*Puntius puntio* (Hamilton 1822)									*						
113.	*Puntius phutunio* (Hamilton 1822)															
114.	*Puntius sarana* (Hamilton 1822)[a,e]					*				*	*	*	*	*	*	*
115.	*Puntius sophore* (Hamilton 1822)						*	*	*		*	*	*	*	*	
116.	*Puntius terio* (Hamilton 1822)									*						
117.	*Puntius ticto* (Hamilton 1822)					*	*	*	*		*	*	*	*	*	
118.	*Raiamas bola* (Hamilton 1822)						*									
119.	*Rasbora daniconius* (Hamilton 1822)		*			*					*			*		
120.	*Rasbora rasbora* (Hamilton 1822)									*						

Table 5 continued

	Fish species	Distribution														
		Upper zone					Middle zone					Lower zone				
		UZ1	UZ2	UZ3	UZ4	UZ5	MZ1	MZ2	MZ3	MZ4	MZ5	LZ1	LZ2	LZ3	LZ4	LZ5
121.	*Rhinomugil corsula* (Hamilton 1822)[e]							*	*		*	*	*	*	*	*
122.	*Rita rita* (Hamilton 1822)					*	*	*		*	*	*	*	*	*	
123.	*Salmophasia bacaila* (Hamilton 1822)					*	*	*	*		*			*	*	*
124.	*Salmophasia phulo* (Hamilton 1822)											*				
125.	*Schizothorax curvifrons* (Heckel 1838)				*											
126.	*Schizothorax progastus* (McClelland 1839)	*		*	*											
127.	*Schizothorax richardsonii* (Gray 1832)[e]	*	*	*	*											
128.	*Schizothorax sinuatus* (Heckel 1838)				*											
129.	*Securicula gora* (Hamilton 1822)						*				*					
130.	*Setipinna brevifilis* (Valenciennes 1848)											*	*			
131.	*Setipinna phasa* (Hamilton 1822)										*					
132.	*Sicamugil cascasia* (Hamilton 1822)[e]						*		*		*	*	*	*		
133.	*Silonia silondia* (Hamilton 1822)[e]						*		*			*	*	*		
134.	*Sisor rabdophorus* (Hamilton 1822)[d]							*				*				
135.	*Sperata aor* (Hamilton 1822)[a,e]					*	*	*	*			*	*	*	*	*
136.	*Sperata seenghala* (Sykes 1839)						*	*	*	*		*	*	*		
137.	*Tenualosa ilisha* (Hamilton 1822)[e]											*	*	*	*	*
138.	*Tetraodon cutcutia* (Hamilton 1822)										*	*	*	*	*	
139.	*Tetraodon fluviatilis* (Hamilton 1822)									*						
140.	*Tor putitora* (Hamilton 1822)[d]		*	*	*	*										
141.	*Tor tor* (Hamilton 1822)[d]		*	*	*	*				*						
142.	*Wallago attu* (Bloch & Schneider 1801)					*	*	*	*		*	*	*	*	*	*
143.	*Xenentodon cancila* (Hamilton 1822)					*	*	*		*	*	*	*	*	*	

[a] New distribution

[b] Marine species

[c] Exotic species

[d] Endangered species

[e] Vulnerable species

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