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INVASION OF AN EXOTIC FISH—COMMON CARP, *CYPRINUS CARPIO* L. (ACTINOPTERYGII: CYPRINIFORMES: CYPRINIDAE) IN THE GANGA RIVER, INDIA AND ITS IMPACTS

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Singh A.K., Pathak A.K., 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 Ichthyol. Piscat. 40 (1): 11–19.

Background. The Ganga River (Ganges) is known of its rich fish diversity which is adversely affected by degrading environmental and ecological conditions. There are more than 300 exotic fish species in India. Many of them (particularly *Cyprinus carpio*) escaped from confinement and are now present in the Ganga River, challenging its ecological equilibrium. The aim of this project was to study the population characteristics of *Cyprinus carpio* (i.e., the abundance, size range, food and feeding, gonado-somatic index (GSI), gonad maturity stage, maturity and breeding) and the altered fishery dynamics.

Materials and Methods. The commercially caught fishes, including the exotic ones, were identified, examined and measured. Important indices such as: the abundance index of exotic fishes, the gonado-somatic index (I_G), as well as the gonad maturity stage of the escapee *C. carpio* were determined. The gut content was also analyzed to identify food items and thereafter the food richness, diet breadth, and gut repletion index (GRI%) were calculated using the Simpson's diversity index.

Results. *C. carpio* introduced about sixty years ago for aquaculture has now been found to invade into the Ganga, the largest river of the country contributing significantly to the fishery. The abundance index of *C. carpio* ranged from 12.2% to 45.5 % in 250 km long river stretch of the Ganga River flowing along Kanpur to Varanasi in the state of Uttar Pradesh. The gut content analysis revealed the presence of *Eichhornia* (9.8%), *Pistia* (11.6%), *Nymphaea* (8.5%), annelids worms (7.8%), algae (20.2%), mud and detritus (14.8%). The calculated diet breadth ranged from 0.82% to 0.91%; food richness ranged from 12 to 16, and the gut repletion index (GRI%) was 100% at different sampling sites. Mature females represented all the six reproductive stages with varying gonado-somatic index (I_G) (0.5 to 30) in different catches. Presence of spent, ripe, and mature females was recorded.

Conclusion. Abundance of exotic fish primarily *C. carpio* and *Oreochromis niloticus* in the fishery of the Ganga River was observed. The gonado-somatic index (I_G) and the presence of all the six gonadal stages confirmed that *C. carpio* established its breeding population. The dominant catch of exotic fishes negatively impacted on the important indigenous fishes particularly Indian major carps (*Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*). The change in dynamics of the fishery due to the presence of common carp attracted attention to conserve rich indigenous germplasm facing threats of shifting from their natural habitats.

Keywords: Exotic fish, *Cyprinus carpio*, introduction, breeding, biodiversity, conservation

INTRODUCTION

The Ganga River (Ganges) is known to harbour rich fish diversity (Bilgrami 1991, Rao 2001, Kapoor et al. 2002, De Silva et al. 2007); however, environmental integrity of this largest freshwater river systems of the country is being increasingly threatened due to anthropogenic activities such as river course diversions and construction of barrage, dams etc. (Sinha and Khan 2001, Sarkar and Bain 2006) and also through exotic fish introductions (De Silva et al. 2006, García-Berthou 2007, Lakra et al. 2008). Freshwater fish biodiversity of the Ganga River is enormous (Bilgrami 1991, Kapoor et al. 2002, De Silva et al. 2007, Lakra et al. 2009) and the reported impacts of alien fish species emphasized biodiversity threats and conservation (Singh and Lakra 2006, De Silva et al. 2007, Lakra et al. 2008). Ganga is the largest river basin in Asia having highest level of endemism and fish diversity (De Silva et al. 2007). The growing pollution of the river Ganga in recent years makes a noticeable change in its physico-chemical characteristic and the water quality

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to an extent that the fish community is affected (Sarkar and Bain 2006, Khanna et al. 2007) and the fish yield as well as biodiversity has decreased (Sinha and Khan 2001). The growing siltation due to various anthropogenic activities and the unavailability of the fish food has also been reported to disturb the fish breeding grounds particularly the Indian major carps (Rao 2001, Sinha and Khan 2001).

The common carp, *Cyprinus carpio* L., is extensively translocated species around the world (Sivakumaran et al. 2003, De Silva et al. 2006, Lakra et al. 2008) including India where it was introduced in 1959 for aquaculture purpose (Singh and Lakra 2006). In India, it was studied for more than a decade under All India Coordinated Research Project for developing it as a species under composite fish culture. Consequently, three Indian major carps (*Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*), Chinese carps (*Ctenopharyngodon idella* and *Hypophthalmichthys molitrix*), and common carp (*Cyprinus carpio*) were adopted together in composite fish culture (Jena et al. 2002). The Bangkok strain of common carp (*C. carpio communis*) is widely used under aquaculture in plains while mirror carp (*C. carpio specularis*) is used for aquaculture in upland waters of hill states. Common carp has augmented fish production (Jena et al. 2002) in the country and is cultivated in different agroclimatic conditions. While Chinese carps including bighead carp, *Aristichthys nobilis*, and common carp are widely cultivated exotic carps, more than 300 exotic fish species have also been introduced into India from other countries intentionally or illegally for aquaculture, sports, mosquito control, and aquarium purposes (Singh and Lakra 2006, Lakra et al. 2008). Escapement of exotic fishes due to recurring floods or inadvertent releases frequently happened but the occurrence of escapee exotic fishes in the fishery of the Ganga River was never known. The recent appearance of exotic fishes particularly *C. carpio* in the fishery of the Ganga River prompted us to study its population characteristics i.e., the abundance, size range, food and feeding, gonado-somatic index (GSI), maturity, and breeding. Therefore, this study was undertaken under two perspectives; the former was to ascertaining the colonization of the escapee *C. carpio* through natural population in the Ganga River and the latter was to assess its possible impacts on the dynamics of the local fishery.

MATERIALS AND METHODS

The state of Uttar Pradesh is the most densely populated state of the country. Agriculture and allied activities form the backbone of its economy. 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). The faunal resources of the Ganga have distinct characteristic feature and fall into three zones (i) the upper Ganga River in hilly terrain, (ii) the middle Ganga River flowing in the states of Uttar Pradesh, Bihar, and (iii) the deltaic tract of the lower Ganga in the state of West Bengal (Rao 2001).

The study area covered approximately 250 km of the river stretch of the middle Ganga flowing along the districts of Kanpur, Allahabad, Varanasi, and Mirzapur in the state of Uttar Pradesh. Allahabad lies at the junction of the two other major cities Kanpur and Varanasi along the Ganga. Three main fish landing areas at Allahabad: Daraganj, Sadiyapur, and Jhunsi; three in Varanasi the Rajghat, Saraimohana, and Ramnagar, bridge area in Kanpur, Shuklaganj in Unnao and Adalhat in Mirzapur district were the study sites as demarcated in Fig. 1.

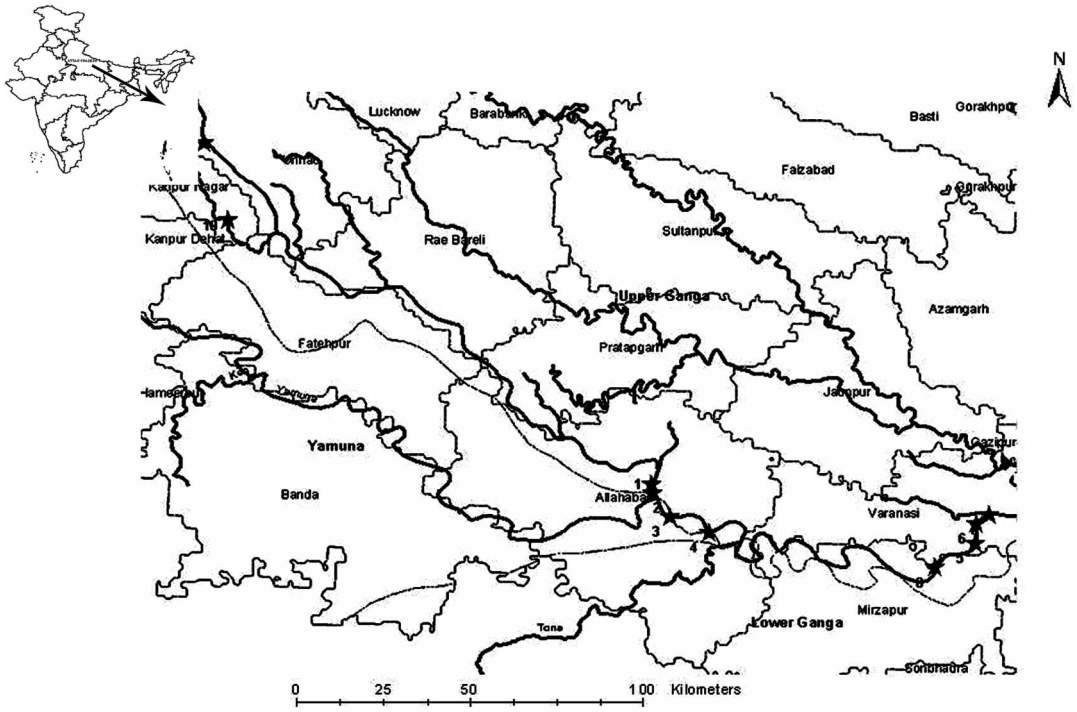

Fig 1. Map of the study area in the Ganga River

Fish samples were collected from the landing centres on quarterly basis during 2004 through 2008. Fishermen generally used multi-meshed gill nets of mesh size 8.5–50 mm as well as dragnets for fishing. From commercial catches, fishes were collected at the landing centres and were identified, measured (fork length, FL nearest mm), and weighed (nearest g) using portable digital balance. Keys for identification of fish species was followed as given by Jhingran (1975) and FAO identification sheet as given by Fisher and Bianchi (1984). From the total catch, the abundance index of exotic fish was calculated using the following formula:

$$\text{AI (\%)} = \frac{n(k) \times 100}{N}$$

Where:

AI = abundance index,

$n(k)$ = number of exotic fish caught at each study site,

N = number of all the fish species caught at that site.

The fish catches were sorted by species by fishermen for marketing and sale. The data from such segregated fish groups were then collected to work out the species contribution. From the catch, *C. carpio* 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 gonado-somatic index (I_G) was calculated from $I_G = M_G (M_T - M_G)^{-1}$ where M_G is gonad mass and somatic mass was total mass $(M_T - M_G)$. The fecundity of individual females was determined gravimetrically, and the gonad maturity stages were determined according to Nagelkerke and Sibbing (1996).

The intestines of 50 collected specimens from different sampling sites were cut and fixed in 5% formalin for gut content analysis. The diet and feeding habits of *C. carpio* were determined based on the contents of the digestive tract and was examined using Leitz dissecting microscope. Different taxa of the food items were identified, counted, and the food richness, diet breadth, and gut repletion index (GRI%) were calculated using the Simpson's diversity index (Begon et al. 1986).

The length–weight regression was calculated by the method of least squares by grouping the sample data into several short length groups and fitting the regression of logarithmic value of the average weight of fishes. The grouping was done according to the size ranges of the collected fish. The degree of adherence was then determined on the basis of length–weight regressions and it was calculated using the following formula:

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{\sqrt{[(\sum x^2 - n\bar{x}^2)(\sum y^2 - n\bar{y}^2)]}}$$

Where:

n = total number of length group,

$\bar{x}$ = mean of x (length),

$\bar{y}$ = mean of y (weight).

RESULTS

The important fish biodiversity of the Ganga River collected between Kanpur and Mirzapur were identified and details of their taxonomy, habitat, size range and conservation status were synthesized and presented in Table 1.

The catch composition of the commercially important fish diversity grouped as Indian major carps (IMCs), minor carp, catfishes, miscellaneous, and exotic fishes was calculated. The Indian major carps comprising of *Catla catla*, *Cirrhinus mrigala*, and *Labeo rohita* constituted 5% to10 % of total catch and their size ranged from 200 to 550 mm in length and 400 to 8000 g in weight. The IMCs included high proportion of large fish weighing 3–7 kg and the small fishes were in low proportion. The proportion of *Labeo rohita* caught was remarkably low. It was also observed that there was a decline in catch of IMCs over the years during the study period. The minor carps in the total catch were mainly represented by *Labeo bata*, *L. calbasu*, *Cirrhinus reba*, *Puntius sophore*, and *P. conchonius* and they constituted 5%–7% with size range of 90 to 250 mm in length and 150–1500 g in weight. Catfishes in general were represented by *Sperata aor*, *S. seenghala*, *Wallago attu*, *Bagarius bagarius*, *Rita rita*, *Clupisoma garua* and constituted 10%–12% of the total catch having common weight range of 600 to 2000 g. Other miscellaneous fishes were *Gonialosa manmina*, *Salmophasia bacaila*, *Glossogobius giuris*, *Ailia coila*, *Johnius coitor*, *Mastacembelus armatus*, and *Anabas testudineus* representing 10%–15% of total catch (Table 2).

Cyprinus carpio was most dominating fish species in all the catches from the Ganga River at all the sampling stations (Fig. 2). It is to mention that there was no existence of *C. carpio* in the fishery of the Ganga River earlier. An assessment of the occurrence of exotic fishes for the years 2004 and 2008 revealed that there was a decline of 24.56% in total catch of local fishes whereas the catch of exotic fishes increased by 115.8 percentage points within four years (Fig. 3).

Gonadal examination of *C. carpio* in different catches revealed that immature, maturing, and mature fishes were available. Mature males were found at smaller size (214 mm FL) while mature females were bigger in size (324 mm FL) and sex ratio revealed slight variation (1 : 1.12) in sex ratio (female : male) = 383 : 429 than the expected Mendelian sex ratio of 1 : 1. Gonads of 132 examined specimens from different locations of the river revealed that mature female represented all reproductive stages (1–6) with varying gonado-somatic index (I_G = 0.5 to 30). The gonado-somatic index and description of different gonad maturity stages are summarized and presented in Table 3. In general, the highest I_G value was recorded during February–March and July–August. A consistent pattern of spawning of *C. carpio* was also found during July–August when spawning of Indian major carps (*Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*) occur. The key indicators of spawning activity were the presence of ripe, mature, and spent female *C. carpio* during rainy as well as spring seasons.

Trophic spectra of 173 examined specimens of *C. carpio* revealed that there was similarity in the ingested food at different locations. Similar types of algae and plant

Table 1

Fish species of the Ganga River

Species	Family	Habitat	Length [cm]	Status
Ailia coila	Schilbeidae	pelagic	18–30	Vu
Bagarius bagarius	Sisoridae	benthopelagic	39–89	Vu
Chitala chitala	Notopteridae	demersal	48–69	En
Gudusia chapra	Clupeidae	pelagic	12–20	LR-Ic
Notopterus notopterus	Notopteridae	demersal	28–74	LRnt
Puntius conchonius	Cyprinidae	benthopelagic	12–14	LRnt
Setipinna phasa	Engraulidae	pelagic	23–40	LRnt
Silonia silondia	Schilbeidae	demersal	58–68	LRnt
Sperata aor	Bagridae	demersal	63–78	NE
Sperata seenghala	Bagridae	demersal	39–65	NE
Tenualosa ilisha	Clupeidae	pelagic	28–74	En
Xenentodon cancila	Belonidae	pelagic	26–40	LRnt
Catla catla	Cyprinidae	benthopelagic	32–56	LRnt
Labeo rohita	Cyprinidae	benthopelagic	21–46	LRnt
Labeo bata	Cyprinidae	benthopelagic	14–28	LRnt
Labeo calbasu	Cyprinidae	demersal	28–38	LRnt
Cirrhinus mrigala	Cyprinidae	benthopelagic	14–42	LRnt
Cirrhinus reba	Cyprinidae	benthopelagic	12–14	Vu
Puntius sarana	Cyprinidae	benthopelagic	18–21	Vu
Pangasius pangasius	Pangasiidae	pelagic	58–92	En
Gonialosa manmina	Clupeidae	pelagic	12–14	LRnt
Clupisoma garua	Schilbeidae	pelagic	16–36	Vu
Mystus cavasius	Bagridae	demersal	26–39	LRnt
Rita rita	Bagridae	demersal	32–56	LRnt
Johnius coitor	Sciaenidae	demersal	12–18	LRnt
Glossogobius giuris	Gobidae	benthopelagic	14–22	LRnt
Mastacembelus armatus	Mastacembelidae	pelagic	21–32	LRnt
Anabas testudineus	Anabantidae	pelagic	14–18	LRnt
Salmophasia bacaila	Cyprinidae	benthopelagic	16–18	LRnt
Wallago attu	Schilbeidae	benthopelagic	56–126	LRnt

En = threatened; LRnt = lower risk near threatened; Vu = vulnerable; LT-lc lower risk least concern (on the basis of the report of the Conservation Assessment Workshop held at NBFGR, Lucknow during 1997 and duly modified where necessary: Ponniah and Sarkar 2000).

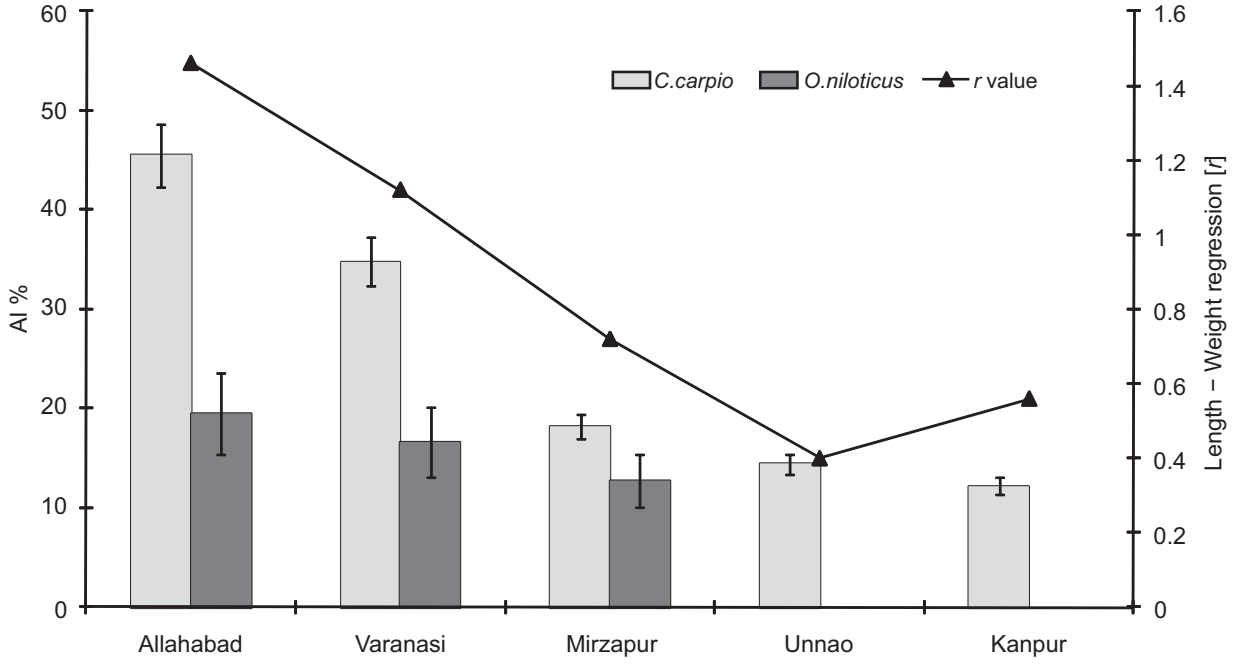

Fig. 2. Abundance index and length–weight regression of *Cyprinus carpio* in the Ganga River

Table 2

Important fish species and their contribution in commercial fishery of the Ganga River

Fish group	Fish species	Length range [mm]	Weight range [kg]	Catch contribution [%] range
Indian major carps	*Catla catla, Cirrhinus mrigala, Labeo rohita,*	200–550	0.4–8	5–10
Minor carps	*Labeo calbasu, L. bata, Cirrhinus reba*, *Puntius sophore, P. conchonius*	90–250	0.15–1.5	5–7
Catfishes	*Sperata aor, S. seenghala, Wallago attu, Channa punctata, C. marulia, Mystus cavasius, Bagarius bagarius, Rita rita, Clupisoma garua, Ailia coila, Notopterus notopterus*	260–780	0.6–2	10–12
Miscellaneous	*Gonialosa manmina, Salmophasia bacaila, Glossogobius giuris, Johnius coitor, Mastacembelus armatus, Anabas testudineus*	36–98	0.023–0.034	10–15
Exotic fishes	*Cyprinus carpio*	70–690	0.025–8.5	12.2–45.5
	Oreochromis niloticus	18–270	0.003–0.97	12.7–19.5
	Aristichthys nobilis		0.39–18	stray catch
	Ctenopharyngodon idella		0.55–7.9	stray catch
	Hypophthalmichthys molitrix		0.45–9.5	stray catch
	Clarias gariepinus		0.28–2.3	stray catch

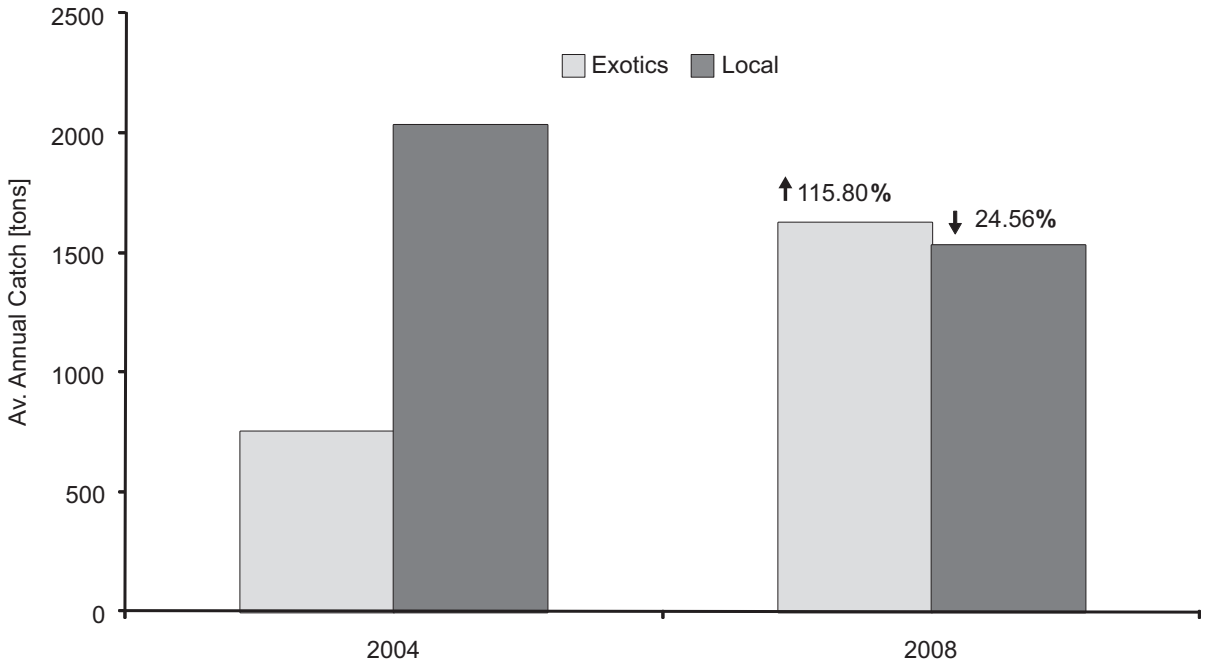

Fig. 3. Increased occurrence of exotic fishes in the Ganga River over the years (2004–2008)

remains were found to be the major food items in common. The analyzed gut contents were *Eichhornia* (9.8%), *Pistia* (11.6%), *Nymphaea* (8.5%), annelids worms (7.8%), algae (20.2%), mud and detritus (14.8%) (Fig. 4). The calculated diet breadth ranged from 0.82% to 0.91%, food richness ranged from12 to 16, and gut repletion index (GRI%) was 100% respectively (Fig. 5).

DISCUSSION

Exotic fish introductions have been reported to impact the fish biodiversity and have provided significant warnings of the various effects on environment posing threats to the community trophic structure disrupting biological integrity (Casal 2006, De Silva et al. 2006, García-Berthou 2007, Rowe 2007, Lakra et al. 2008). It has also been realized that the nature and extent of such changes being complex remains unpredictable. Exotic species may become invasive and are capable of: spreading exotic diseases, decreasing biodiversity through competition, predation and habitat degradation, genetic deterioration of wild populations through hybridization and gene introgression in short or long course of time (Casal 2006, Singh and Lakra 2006, García-Berthou 2007, Lakra et al. 2008).

Table 3

Macroscopic appearance, gonado-somatic index (I_G) and the gonad maturity stage (according to Nagelkerke and Sibbing 1996) of ovary of *Cyprinus carpio* of the Ganga River

Stage No.	Stage	I_G	*n*	Description
1	Immature	< 1	14	Ovaries thin, transparent, circular (0.5–1 cm diameter) in cross section. Oocyte faintly visible upon rupture of tunica albuginea
2.	Immature developing (early)	0.5–5	23	Ovaries opaque, granular and occupied less than a third of body cavity. Oocyte small, green yellow
3.	Immature developing (late)	5–20	45	Ovaries occupied less than two thirds of body cavity with abundant blood capillaries and large opaque oocyte (C.1 mm). Some oocyte appeared translucent
4.	Ripe	15–30	21	Ovaries distinctly bulging and lobular in appearance. They filled the body cavity. Oocyte large (>1 mm)
5.	Spent	1–5	18	Body musculature was stretched and body cavity was flaccid. Ovaries were small, bloodshot and granular with scattered residual vitellogenic oocyte
6.	Regressing	3–10	11	Ovaries difficult to stage but appeared blotchy with atretic oocyte in all developmental stages. Oocytes were variable in colour

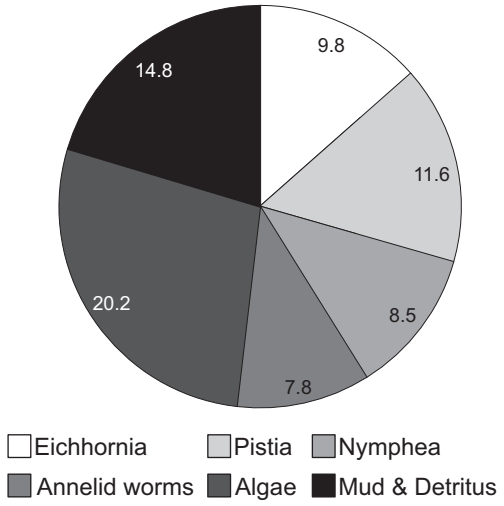

Fig. 4. Major food items [%] in the gut of *Cyprinus carpio* from the Ganga River

Common carp was introduced into India during 1939 and 1957 (Froese and Pauly 2004, Singh and Lakra 2006) for aquaculture purpose and it contributes more than 7.17% in total inland fish production (Dey et al. 2005). The utilization of *C. carpio* gradually expanded for enhancing reservoir fishery production (Suguan 1995, Sugunan 2000) and it was then introduced into reservoirs and lakes. After the expansion of the use of *C. carpio* for enhancement of aquaculture production, its occasional occurrences were later reported from open waters gravitating Jhelum, Mahanadi, and Yamuna rivers (Singh and Lakra 2006, Singh et al. 2008a). However, its occurrence in the fishery of the Ganga River has been observed for the first time and there is no other report. The local fishes of the Ganga River were subjected to the threats of pollution by sewage and industrial wastes, deforestation, excessive use of fertilizers, pesticides, and water development programmes (Rao 2001, Sarkar and Bain 2006, Singh and Singh 2008). Consequently, the catches of local fish species were adversely affected (Lakra et al. 2009) but invasion of exotic *C. carpio* and tilapia in the fishery of the Ganga River has been found to aggravate the threats to the indigenous fish diversity including environmental problem (Gopal and Zutshi 1998, Rao 2001, Das 2007, Khanna et al. 2007, Singh et al. 2008b).

Gonadal development of *C. carpio* has been reported to be continuous in females (Parameswaran et al. 1972) and the results of the present study also provided first evidence of wild spawning of common carp in the Ganga River forming feral population. Since common carp, *C. carpio*, is known to exhibit early sexual maturity, rapid colonization and wide environmental tolerances (Koehn 2004, Singh and Lakra 2006), these attributes have been considered to help this exotic fish to successfully invade into new environment of the Ganga River. Results of this study delineated increased abundance of *C. carpio* in the fishery and the reproductive staging of the fish ascertained the presence of all reproductive stages (1–6) in the river-caught *C. carpio.* This confirmed that common carp has now established itself in the Ganga River and the so colonized fishes constituted the bulk of the catch. Fishermen are desperate of getting mostly low value fish like common carp and tilapia which sell in the market at low price of Rs. 35–40 per kg whereas IMCs, the demand fish cost Rs. 60–70 per kg.

Introduced common carp has been reported to implicate environmental changes principally eutrophication through an increase in turbidity and mobilization of nutrients to the water column from the benthos through its habit of rooting or digging in the bottom (Britton et al. 2007,

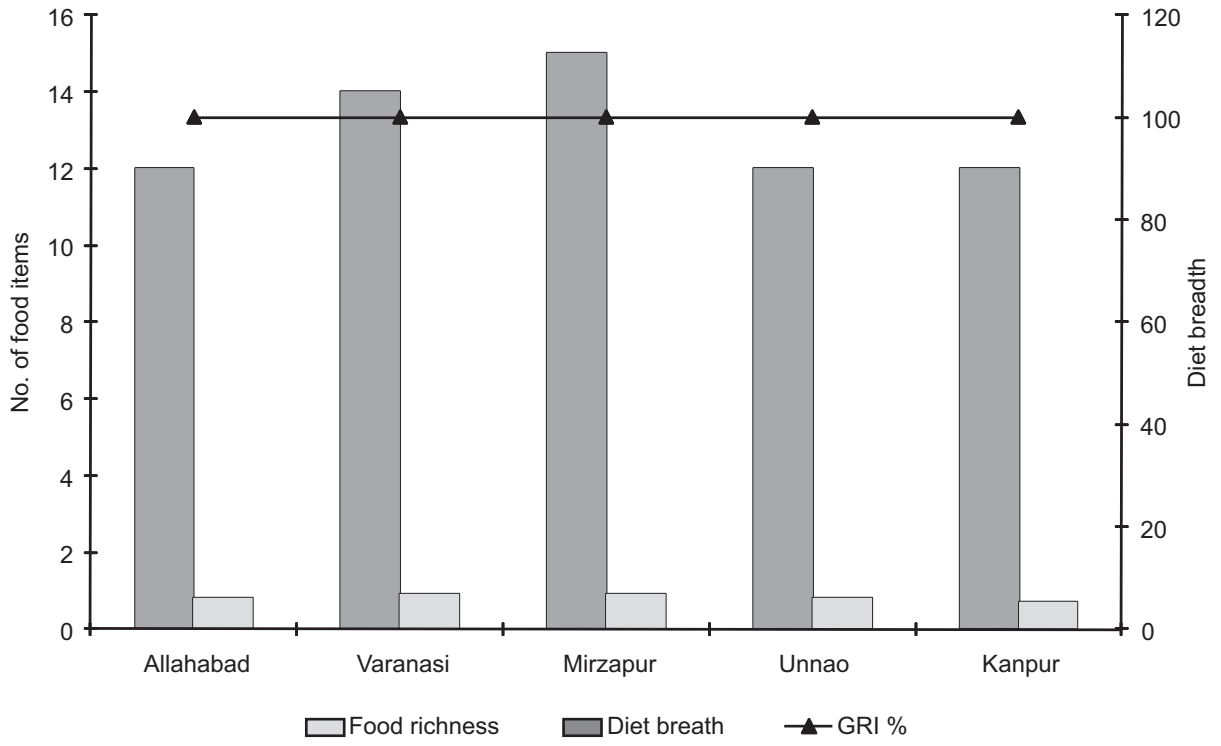

Fig. 5. Trophic spectra of *Cyprinus carpio* in the Ganga River

Khanna et al. 2007, Rowe 2007). The invasion of common carp, *Cyprinus carpio*, in Australia has already been reported to quickly spread and dominate fish communities (Koehn 2004). Significant negative effects of common carp on the piscine diversity have been reported (Lakra et al. 2008, Ross et al. 2008). Common carp in India has already been reported to cause sharp decline in the catches of endemic schizothoracids (Singh and Lakra 2006, Lakra et al. 2008). Due to introduction of common carp in the lakes of Kumaon, the catches of schizothoracids was found to drastically decline (Singh and Lakra 2006) and the production of common carp increased since 1985 (Shyam Sunder 1998). In Manipur, it has escaped in Loktak Lake and now contributing an important fishery replacing the important local and endemic fish species particularly *Osteobrama belangeri* (see Singh and Lakra 2006). The declining trend of Indian major carps in the Ganga River and increasing appearance of common carp in the fishery is a warranting situation of biological invasion threatening ecological integrity. The problem of repopulating *C. carpio* in degrading water of the river (Gopal and Sah 1993, Gopal and Zutshi 1998, Khanna et al. 2007) has come up to conserve rich fish genetic resources of the Ganga River before it faces a major alteration. This would not only influence the human but might induce either more adaptability of the biota living in it or might cause damage to various species which would not be able to adapt to such fast ongoing change. The adverse impacts on the wild population due to common carp have been assessed in the Ganga River and it is a big concern to the conservation biologists. Its rapid spread and colonization in the Ganga is understood to cause dramatic ecological disruptions at the community and ecosystem levels (Titus et al. 2004, Mabuchi et al. 2008). Adverse impacts of *C. carpio* have been recorded across the world, including North America (Britton et al. 2007), Japan (Mabuchi et al. 2008), New Zealand (Rowe 2007), and Australia (Koehn 2004). The results of this study highlights that the common carp has established in the Ganga River as a pest through naturally breeding populations which is now becoming the source for secondary invasions at other places. Impacts of exotic fish in the Ganga have been found to be mild at present but it may cause habitat alteration, trophic structure alteration, and hybridization in due course of time (De Silva et al. 2006, García-Berthou 2007, Lakra et al. 2008). Gut content analysis, the diet breadth, and the gut repetitive index showed similar pattern at all the sampling stations. This result indicated that ecological conditions in the Ganga were homogenizing by the increasing population of common carp which could be a great threat to the ecological integrity for this mighty river sustaining rich fish biodiversity. The gut content analysis delineated presence of mainly plant material and algae of similar kind. Benthic feeding by invasive common carp has been reported to usually result in adverse impacts upon invaded ecosystem with declines in submerged vegetation (Titus et al. 2004). Since degraded ecosystems are often more susceptible to successful invasion of exotic fish species, other introduced exotic fishes may also find access and then negatively impact the biodiversity cumulatively (Singh and Lakra 2006, García-Berthou 2007, Lakra et al. 2008). The present change in dynamics of the fishery due to the burgeoning presence of common carp invites

attention to conserve rich indigenous germplasm facing threats of shifting from their natural habitats.

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