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Fish community structure and ecological degradation in tropical rivers of India

D.Chakrabarty and S. K. Das

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Fish community structure and water chemistry of two tropical rivers of West Bengal, an eastern province of India, were studied for two annual cycles (January 2003–December 2004). Water quality and fish community structure reflected a higher degree of pollution in the Churni river than in the Jalangi river. We observed that 63.6% of fish species had disappeared from the polluted Churni river in 20 yr. For protection of fish biodiversity and enhancement of fish production, a rational management program should be implemented in Churni river.

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In rivers, fish community structure is a good indicator of environmental stress (Barrella and Petrere 2003), because the composition of particular groups in fish communities reflect the level of habitat degradation (Wichert and Rapport 1998). Fish communities in rivers are particularly sensitive to pollution and overexploitation, and in this context rivers Churni and Jalangi, in the Nadia District (West Bengal, Fig. 1) are an interesting case study. The Jalangi river is situated ca 25 km north of the Churni river. Both share the same climatic conditions and had similar fish communities 22 yr ago (Chakrabarty 1983). Over the last years, however, the Churni river has suffered continuous episodes of water pollution and ecological degradation (Ghosh and Konar 1991) which may have led to a loss of species. Both rivers have an almost similar annual discharge (IWMED 2002), and may be seen as twin branches of the Padma river which ultimately discharges into the Ganges (Fig. 1). These two rivers are prominent in West Bengal since they are the major source of surface water, income for thousands of fishermen, and provide food to nearby 0.3 million people of the adjacent towns of Ranaghat and Krishnagar.

In this paper we describe the fish assemblages in these two rivers of contrasted characteristics, their environmental conditions, and the consequences of anthropogenic activities.

Study area

The Churni river is a tributary of the Padma river which originates in Bangladesh and flows for ca 95 km on Indian land. It is subjected to different anthropogenic activities throughout its course. The upper stretches receive discharges of sugar mill effluents from Darshana (Bangladesh), whereas the lower stretch in India is subjected to water obstruction by bamboo-made barrages in several places, industrial effluents and city sewage. The catchment area of this river includes the medium-populated (0.14 million) Ranaghat municipality (23.11°N, 88.37°E). The opposite bank of this river comprises residential areas and

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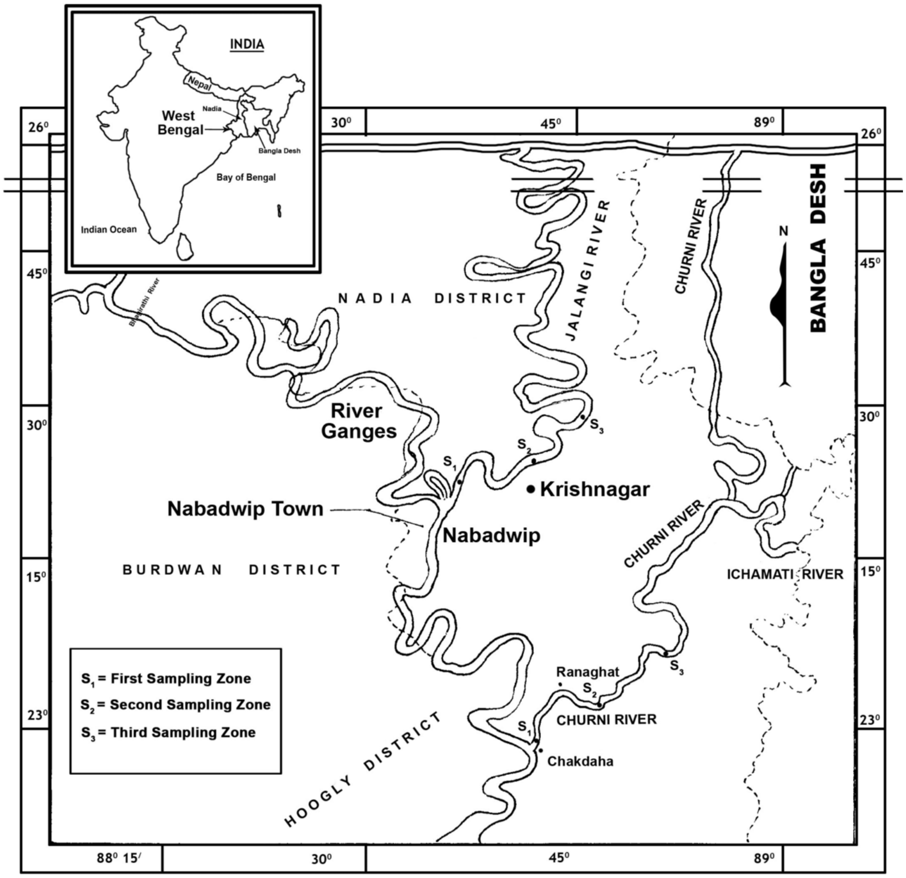

Fig. 1. Geographical location of the two studied rivers.

unorganized small–scale industries, which release their untreated effluents into the river (ca 24 000 l d^{-1}). The river discharges into the Ganges near Chakdaha.

The Jalangi river flows from the western boundary of the Nadia District and crosses the city of Krishnagar (23°24′N, 88°30′E, population of ca 0.15 million). It flows almost straight westwards, and discharges into the Ganges at Nabadwip (IWMED 2002). There are no large industries in the municipality, except Krishnagar State Dairy, which discharges ca 18 000 l d^{-1} of processed water into the river. People residing near the eastern bank of the river use the water for recreational purposes.

Water quality

An approximate 15-km stretch of rivers Churni and Jalangi were selected for sampling in order to address the pollution impact of Ranaghat and Krishnagar cities. All industrial facilities were located within this area. Three sampling zones, ca 5 km apart, were selected upstream, midstream and downstream for each river (Fig. 1). Each zone consisted of three sampling sites; two opposite river banks and midstream, labeled as east (E) besides township, middle (M), and west (W) opposite to township. Results within a zone are expressed as the mean of the three sites.

Water samples were collected monthly between 9 am and 11 am from lotic zones at a depth of 5 cm from the surface. They were saved in 2 litre plastic containers for physico-chemical analysis, and also collected in sterilized glass tubes for bacteriological analysis in the laboratory following Standard methods (2002).

Temperature and pH were measured immediately after collection. Physico-chemical analysis of conductivity, dissolved oxygen (DO), initial biological oxygen demand (BOD), total dissolved solids (TDS), alkalinity, hardness, phosphorus, and total nitrogen, were performed in the laboratory on the same day or within a week. All analyses were done following the methodology outlined in Standard methods (2002) and in Wetzel and Likens (2004).

Fish community data

At each sampling site, fish were collected at weekly intervals and species identified using a pre-tested, structured interview to local fishermen at fish landing stations along 70 km in both rivers. Fish were identified when collected by local fishermen. The nets used for fishing were gill or drag net with floaters and sinkers. The gill nets used were 200 m in length and 12 m in width. The net easily reached the river bottom and covered the length between the two banks. The sampling efforts were similar in all zones. A number of representative trapped fish were fixed in formalin and transported to the laboratory for study. A set of indicators such as weight, habitat orientation, and trophic structure were examined.

Trophic structure

Species in a fish community can be classified into trophic groups based on feeding habits (Karr et al. 1986, OEPA 1987). By analyzing the gut content we distinguished four types of trophic level, namely planktivore (PL), benthic feeder (BE), omnivore (OM), and carnivore (CA) (Table 1). The trophic level score (Gauch 1982, Wichert and Rapport 1998) denotes the relative frequency of the fish using the particular trophic level among all the trophic levels available in the system. E.g. the score in the Churni river for four species of planktivorous fish out of a total of 16 species would be obtained by dividing 4 by 16 and multiplying the result by 100.

Habitat orientation

Fish were classified into three generic groups attending to habitat orientation: pelagic (P), generalist (G) and benthic (B) (Jhingran 1997). Habitat orientation score (Gauch 1982, Wichert and Rapport 1998) denotes the relative frequency of fish using the particular habitat among all available habitat in the system. The mean score of habitat orientation was compared between the two rivers.

Similarity and dissimilarity indices

Sorensen's coefficients (SC) were calculated between for the two rivers to identify the most likely indicator species of pollution (Gauch 1982, Benson and Magnuson 1992, Odum and Barrett 2005). Sorensen's coefficient (SC) measures similarity between two habitats:

$$SC = 2a / (2a + b + c)$$

where a is the number of species common to the two habitats, b is the number of species present in habitat B but absent in habitat A, and c is the number of species present in site A but absent in site B. The index value varies between 0 and 1. Zero indicates no similarity and 1 indicates maximum similarity.

An additional composition attribute was the Bray-Curtis dissimilarity index (BCD), a coefficient which is a robust and ecologically meaning index of changes in species composition (Faith et al. 1987, Legendre and Legendre 1998). BCD was calculated for taxa (n = 44) and abundance (standardized using $\log_{10}$ (X+1) transformation; Legendre and Legendre 1998).

Bray-Curtis (B) is a measure of dissimilarity; hence 1-B is taken as a measure of similarity. This index varies between 0 and 1.

$$B = \frac{\Sigma | X_{ij} - X_{jk} |}{\Sigma | X_{ij} - X_{jk} |}$$

where X_{ij} = number of individuals of ith species in sample or habitat or community j, X_{ik} = number of individuals of ith species in sample or habitat or community k.

Results

Water quality

Mean water temperature and pH were very similar in both rivers (Fig. 2a). The dissolved oxygen content in Churni river water remained at ca 5 mg l^{-1} for most of year (November–May). During the October monsoon season, however, the organic matter contained in runoff water decreased it to 3 mg l^{-1} (Fig. 2b), which is at or near the limit for aquatic life (Jhingran 1997). This DO drop indicated the presence of substantial amounts of dissolved organic matter in the water. By contrast, the Jalangi river water remained saturated with dissolved oxygen most of the year (Fig. 2b). Slight reductions in oxygen concentration were observed during the monsoon (Jun–Aug) months. The average level of BOD was high in the case of river Churni (Fig. 2b), but the seasonal variation in the two rivers was to some extent similar. Both were affected by the occasional addition of degraded or partially degraded organic substances from the banks through erosion.

The mean level of hardness in Churni river was higher than in the Jalangi during for the study period and showed a similar seasonal trend (Fig. 2c). The variation in total alkalinity showed a trend similar to that of hardness (Fig. 2c).

The values of total solids were almost similar in the two rivers (Fig. 2d). The water from Churni river experienced its peak in conductivity values in April while Jalangi had its peak in March. However no definite seasonal trend was found in the two rivers regarding conductivity values (Fig. 2d). The highest differences between the two rivers were observed from July to November during the study period.

Table 1. Taxonomic position, community indices and fish production in two annual cycles (January 2003–December 2004) in the Churni (RC) and Jalangi (RJ) rivers. B: benthic; P: pelagic; G: generalist.

Taxonomic position	Trophic level nature	Trophic level score		Habitat orientation nature	Habitat orientation score		Maximum size captured (kg)		Mean annual fish production in 1000 kg ha^{-1} yr^{-1}	
		RC	RJ		RC	RJ	RC	RJ	RC	RJ
Order Cypriniformes										
Family Cyprinidae										
Sub familj Cyprininae										
*1.*Catla catla* (Hamilton-Buchanan)	PL	25.00	31.81	P	37.50	45.45	0.300	7.000	0.6±0.06	14±1.1
*2.*Labeo rohita* (Hamilton-Buchanan)	PL	25.00	31.81	G	37.50	36.36	0.200	5.800	0.4±0.020	11.6±1.14
3. *Labeo bata* (Hamilton)	PL	eliminated	31.81	G	eliminated	36.36	eliminated	0.200	eliminated	0.4±0.03
*4. *Labeo calbasu* (Hamilton)	BE	12.50	11.36	B	25.00	18.18	0.200	4.600	0.4±0.018	9.2±0.82
*5.*Cirrhinus mrigala* (Hamilton-Buchanan)	BE	12.50	11.36	B	25.00	18.18	0.300	4.000	0.6±0.020	8±0.7
*6.*Puntius sarana sarana* (Hamilton-Buchanan)	PL	25.00	31.81	P	37.50	45.45	0.005	0.020	0.01±0.0014	0.04±0.0038
7. *Puntius sophore* (Hamilton-Buchanan)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.020	eliminated	0.04±0.0035
*8.*Puntius ticto* (Hamilton-Buchanan)	PL	25.00	31.81	P	37.50	45.45	0.025	0.010	0.05±0.012	0.02±0.0028
Sub family Cultrinae										
*9.*Chela laubuca* (Hamilton-Buchanan)	OM	50.00	27.27	P	37.50	45.45	0.025	0.030	0.05±0.013	0.06±0.0054
Sub family Rasborinae										
10.*Amblypharyngodon mola* (Hamilton-Buchanan)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.010	eliminated	0.02±0.0018
11.*Esomus danricus* (Hamilton-Buchanan)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.010	eliminated	0.02±0.0016
12.*Mystus aor* (Hamilton)	OM	eliminated	27.27	G	eliminated	36.36	eliminated	1.500	eliminated	3±0.29
*13.*Mystus seenghala* (Skyes)	OM	50.00	27.27	G	37.50	36.36	0.020	0.030	0.04±0.015	0.06±0.0058
*14.*Mystus vittatus horai* (Jayram)	OM	50.00	27.27	G	37.50	36.36	0.025	0.030	0.05±0.015	0.06±0.0056
15.*Mystus bleekari* (Day)	OM	eliminated	27.27	G	eliminated	36.36	eliminated	0.030	eliminated	0.06±0.0058

Table 1. Continued.

Taxonomic position	Trophic level nature	Trophic level score		Habitat orientation nature	Habitat orientation score		Maximum size captured (kg)		Mean annual fish production in 1000 kg ha^{-1} yr^{-1}	
		RC	RJ		RC	RJ	RC	RJ	RC	RJ
16.*Rita rita* (Hamilton)	OM	eliminated	27.27	B	eliminated	18.18	eliminated	3.000	eliminated	6±0.59
Family Siluridae										
17. *Ompok pabo* (Hamilton-Day)	CA	eliminated	29.54	G	eliminated	36.36	eliminated	0.030	eliminated	0.06±0.0058
18.*Wallago attu* (Schneider)	CA	eliminated	29.54	G	eliminated	36.36	eliminated	18.000	eliminated	36±1.6
Family Schilbeidae										
19.*Ailia coila* (Hamilton)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.200	eliminated	0.4±0.04
20.*Eritropiichlhy gongwaree* (Skyes)	CA	eliminated	29.54	P	eliminated	45.45	eliminated	0.200	eliminated	0.4±0.04
21.*Eutropifchthys vacha* (Hamilton)	CA	eliminated	29.54	P	eliminated	45.45	eliminated	0.200	eliminated	0.4±0.038
Family Clariidae										
*22.*Clarias batrachus* (Linnaeus)	OM	50.00	27.27	P	37.50	45.45	0.050	0.300	0.1±0.018	0.6±0.057
Family Heteropneustidae										
*23.*Heteropneustes fossilis* (Bloch)	OM	50.00	27.27	P	37.50	45.45	0.100	0.300	0.2±0.020	0.6±0.054
Order .Perciformes										
Family Gobiidae										
*24.*Glossogobius guiris* (Hamilton-Buchanan)	OM	50.00	27.27	B	25.00	18.18	0.010	0.450	0.02±0.018	0.9±0.081
*25.*Gobias striatuis* (Day)	OM	50.00	27.27	B	25.00	18.18	0.020	0.050	0.04±0.015	0.1±0.011
Family Anabantidae										
*26.*Anabas testudineus* (Bloch)	OM	50.00	27.27	G	37.50	36.36	0.020	0.075	0.04±0.015	0.15±0.014
Family Belontiidae										
27.*Trichogaster fasciatus* (Bloch)	OM	eliminated	27.27	P	eliminated	45.45	eliminated	0.015	eliminated	0.03±0.0029
28.*Nandus nandus* (Bloch)	CA	eliminated	29.54	G	eliminated	36.36	eliminated	0.030	eliminated	0.06±0.0053
Family Channidae										
*29.*Channa striatus* (Bloch)	CA	12.50	29.54	G	37.50	36.36	0.015	2.500	0.03±0.020	5±0.052

Table 1. Continued.

Taxonomic position	Trophic level nature	Trophic level score		Habitat orientation nature	Habitat orientation score		Maximum size captured (kg)		Mean annual fish production in 1000 kg ha^{-1} yr^{-1}	
		RC	RJ		RC	RJ	RC	RJ	RC	RJ
*30. *Channa punctata* (Bloch)	CA	12.50	29.54	G	37.50	36.36	0.050	0.400	0.1±0.015	0.8±0.078
31. *Channa gachua* (Bloch)	CA	eliminated	29.54	G	eliminated	36.36	eliminated	0.400	eliminated	0.8±0.076
32. *Channa marulius* (Bloch)	CA	eliminated	29.54	G	eliminated	36.36	eliminated	0.500	eliminated	1±0.15
33. *Channa orientalis* (Bloch)	CA	eliminated	29.54	G	eliminated	36.36	eliminated	0.400	eliminated	0.8±0.075
Family Mastacembelidae										
34. *Mastacembelus bengalensis* (Hamilton-Buchanan)	BE	eliminated	11.36	B	eliminated	18.18	eliminated	0.150	eliminated	0.3±0.028
35. *Macrognathus pancalus* (Hamilton-Buchanan)	BE	eliminated	11.36	B	eliminated	18.18	eliminated	0.150	eliminated	0.3 ±0.024
Family Synbranchidae										
36. *Amphipnous cuchia* (Hamilton-Buchanan)	BE	eliminated	11.36	B	eliminated	18.18	eliminated	1.000	eliminated	2±0.21
Order Osteoglossiformes										
Family Notopteridae										
37. *Notopterus notopterus* (Pallas)	CA	eliminated	29.54	P	eliminated	45.45	eliminated	0.400	eliminated	0.8±0.068
38. *Notopterus chitala* (Pallas)	CA	eliminated	29.54	P	eliminated	45.45	eliminated	5.000	eliminated	10±1.1
Family Ambassidae										
39. *Chanda nama* (Hamilton-Buchanan)	CA	eliminated	29.54	P	eliminated	45.45	eliminated	0.010	eliminated	0.02±0.002
Order Clupiformes										
Family Clupeidae										
40. *Hilsa illsha* (Hamilton)	PL	eliminated	31.81	G	eliminated	36.36	eliminated	0.600	eliminated	1.2±0.13
41. *Gadusia chapra* (Hamilton)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.050	eliminated	0.1±0.018
Family Engraulidae										
42. *Setipinna phasa* (Hamilton)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.010	eliminated	0.02±0.0021

Table 1. Continued.

Taxonomic position	Trophic level nature	Trophic level score		Habitat orientation nature	Habitat orientation score		Maximum size captured (kg)		Mean annual fish production in 1000 kg ha^{-1} yr^{-1}	
		RC	RJ		RC	RJ	RC	RJ	RC	RJ
Order Mugiliformes										
Family Mugilidae										
43.*Mugil korsula* (Forsskal)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.020	eliminated	0.04±0.0036
Order Beloniformes										
Family Belonidae										
44.*Xenentodon cancila* (Hamilton)	PL	eliminated	31.81	P	eliminated	45.45	eliminated	0.020	eliminated	0.04±0.0038
Mean score		34.37	27.57		34.37	34.71				
Standard deviation		16.23	6.06		5.41	11.97				
Coefficient of variation		47.22	21.98		15.74	34.48				

RC = River Churni
RJ = River Jalangi
* fish common to both rivers

The level of total nitrogen and total phosphorus in the Jalangi river was considerably lower than in the Churni river (Fig. 1e).

A t-test ($p<0.001$) denoted significant differences between both rivers in the concentration of DO, BOD, total-P, total-N, total alkalinity and conductivity throughout the year. Significant differences ($p<0.001$) were also found in total coliform counts between March and October (Fig. 2f). These data revealed that the Churni river was more contaminated with bacterial (MPN) than the Jalangi river, which was possibly caused by discharges of untreated sewage into the Churni river.

Fish communities

Fish data in 1983 indicate similar communities in both rivers, each represented by 44 different species. While the Jalangi river today still contains the same number of species, only 16 are found in the Churni river.

The mean score for habitat orientation (34.71 for Jalangi and 34.37 for Churni) showed no differences between the two rivers (Table 1). The mean trophic level score for the fish in Churni (34.37) was 124% higher than that for the Jalangi (27.57). A t-test for trophic level score for common fish species showed significant differences between the rivers ($p<0.001$). This indicates that the fish community of the Churni river was likely responding to ecosystems pollution, resulting in the degradation of community structure compared to the Jalangi river. However, the diversity of fish present in the two rivers was markedly different as the Churni has 2.75 times fewer fish species than the Jalangi. Fish production was also reduced, being 18.75 times lower in the Churni river than in the Jalangi (Table 1).

The similarity index (Sorensen's coefficient) showed its lower value (0.266) and the dissimilarity index (Bray-Curtis) its maximum value (0.733) for carnivorous species (Table 2) among the four trophic levels. The dissimilarity index of trophic levels indicated that carnivore species (Table 2) had the highest score (> 0.733) in this study.

Discussion

The dissolved organic load is likely cause for concern in the Churni river, which regularly receives untreated municipal and industrial sewage. The excess in phosphorus may trigger proliferation of nitrogen-fixing algae, thereby enhancing the state of eutrophication and biodiversity loss.

Comparing fish biodiversity in the two rivers, we found 16 species common to both rivers and other 28 species present only in the Jalangi river that had disappeared in the Churni river. Among the taxa living in the Churni river, six are species commercially grown in nearby towns (serial number 1, 2, 3, 4, 15 and 16 in Table 1). The oldest of

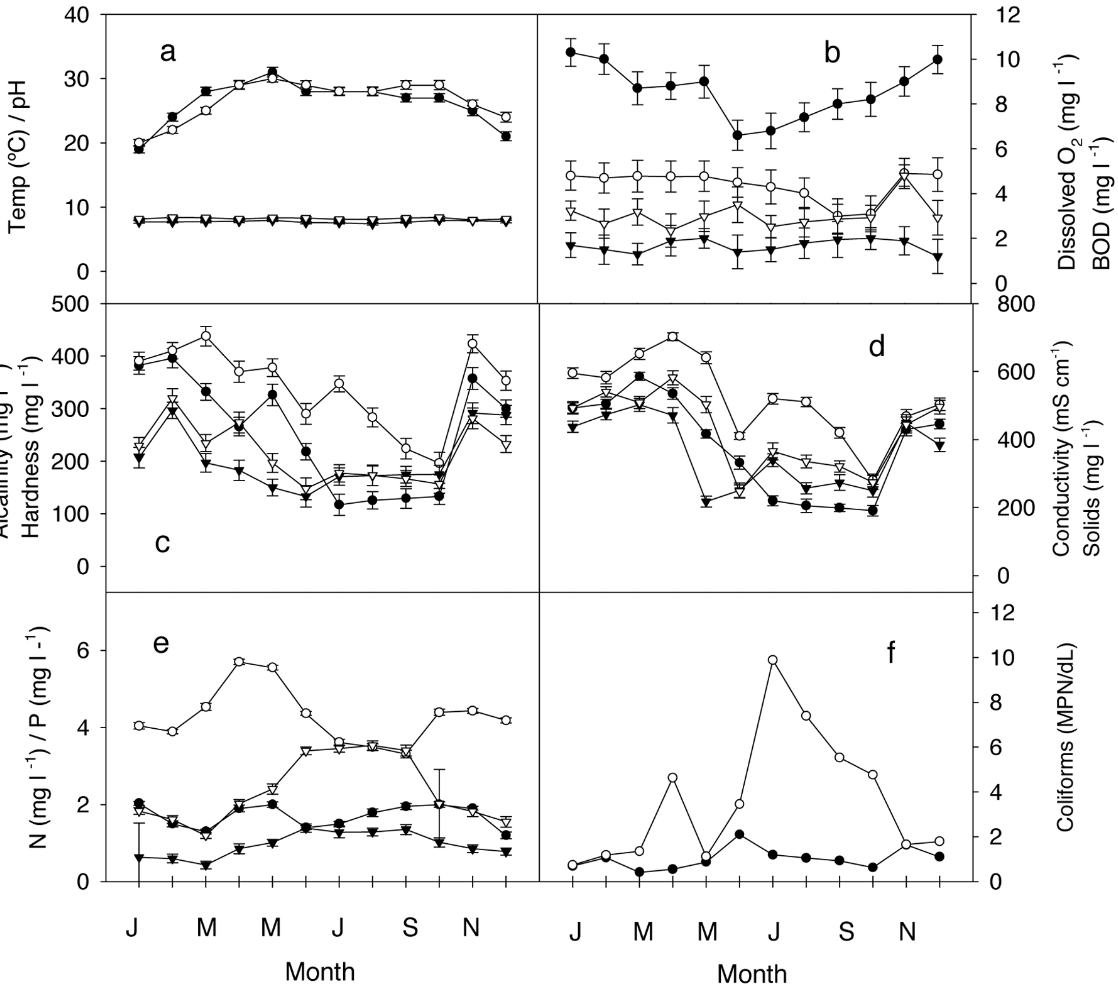

Fig. 2. Monthly means of environmental data in rivers Jalangi (solid symbols) and Churni (open symbols) in NE India. (a) Water temperature (circle) and pH (triangle). (b) Dissolved oxygen (circle) and biological oxygen demand (triangle). (c) Alcalinity (circle) and hardness (triangle). (d) Electrical conductivity (circle) and total solids (triangle). (e) Total nitrogen (circle) and phosphorus (triangle). (f) Coliforms. Standard errors shown when larger than symbol.

these fish captured in the river Churni was less than one year in almost all the cases (Table 1), as calculated from mass and size (Jhingran 1997). This indicates that these fish entered the river system during the rainy season, when nearby ponds are flooded and connected with the river bed through channels. The remaining ten species (Table 1) are not commercially grown and thus are native species resistant to pollution. The analysis of similarity index for trophic level showed that carnivore species (Table 2) were underrepresented with a score close to 0 (>0.266) and thus can be used as an indicator taxon of pollution.

The mean trophic level score in the Churni river was 124% higher than in the river Jalangi, which indicates that fish communities in the latter were altered by ecosystems stress (Rapport 1995), resulting in the degradation of community structure compared to the Churni river. On the contrary, the high diversity of fish species in Jalangi river represents a variety of suitable habitat and food supplies capable of supporting many different species (Washington 1984). The habitat orientation score did not appear to be a useful indicator of ecosystem stress in lotic systems, as shown by Wichert and Rapport (1998).

From the analysis of fish trophic level, it appears that omnivores are the most tolerant to degradation or ecosystem dysfunction because they are able to use food from a wide variety of sources in a changing ecosystem (Wichert and Rapport 1998). Other trophic levels are more sensitive to degradation and include, in reverse order, planktivores, benthic insectivores (i.e. benthic feeders) and insectivores/piscivores, i.e. carnivores at the top of the trophic structure (Karr and Dudley 1981). In the least disturbed systems, present species would belong to the benthic feeders and

Table 2. Data regarding trophic level, habitat orientation, similarity and dissimilarity indices.

Ecological characteristics	River	Trophic level Churni	Trophic level Jalangi	Habitat orientation Churni	Habitat orientation Jalangi
Occurrence of fish species		PL = 4 BE = 2 OM = 8 CA = 2	PL = 14 BE = 5 OM = 12 CA = 13	P = 6 G = 6 B = 4	P = 20 G = 16 B = 8
Total		16	44	16	44
Similarity index		PL = 0.444 BE = 0.571 OM = 0.80 CA = 0.266		P = 0.461 G = 0.545 B = 0.666	
Dissimilarity index		PL = 0.555 BE = 0.428 OM = 0.200 CA = 0.733		P = 0.538 G = 0.454 B = 0.333	

PL = Planktivores, BE = Benthic feeder, OM = Omnivore, CA = Carnivore.
P = Pelagic, G = General, B = Benthic.

carnivores groups in a proportion higher than at degraded sites. As degradation intensifies, species at the top of the trophic structure would disappear first, followed by benthic insectivores, general insectivores, planktivores and omnivores (Wichert and Rapport 1998). In Churni river only two carnivore species were found, against thirteen species in Jalangi river. The dissimilarity index for carnivore species (Table 2) also supports the idea that these species can be used as indicators of pollution.

In conclusion, some structural properties of fish communities in the Churni river changed between 1983 and 2003. These changes appear to be related to anthropogenic activities and industrial practices. Detailed studies are required to quantify these changes and predict future action plans to monitor further loss of aquatic biodiversity.

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