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# Fish diversity with relation to water quality of Bhadra River of Western Ghats (INDIA)

**A. Shahnawaz · M. Venkateshwarlu ·**
**D. S. Somashekar · K. Santosh**

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**Abstract** Water quality assessment and freshwater fish diversity of Bhadra river, Western Ghats, Karnataka was examined. River water was clear except at one station (BV Site) with rocky and sandy substrate. The mean water quality of study sites were as following, pH 6.98, air temperature 22.66°C, water temperature 20.16°C, dissolved oxygen 8.74 mg/l, total hardness 27 mg/l, alkalinity 48 mg/l (as $CaCO_3$), conductivity 135.5 mhos/cm, COD (15.16 mg/l), and BOD (3.78 mg/l), respectively. Altogether, 56 species of fish representing 31 genera and 15 families were recorded. The Cyprinid family was dominant in the present study. Various diversity index packages have been used to assess the fish diversity. Fish diversity is also correlated with physicochemical variables.

**Keywords** Fish fauna · Water quality · Habitat characteristics · Anthropogenic pressure · Bhadra river

A. Shahnawaz (✉) · M. Venkateshwarlu ·
D. S. Somashekar · K. Santosh
Department of Applied Zoology,
Kuvempu University, Shankarghatta-577451,
Shimoga, Karnataka, India
e-mail: shaan_b4u@rediffmail.com

K. Santosh
National Fish Seed Production Department,
B. R. Project, Shimoga, Karnataka, India

## Introduction

India is fortunate to be gifted with a bounty of natural habitats, including snow-covered Himalayas, the Indo-Gangetic plains, the Deccan Plateau, Western Ghats, coastal regions, and seas. Such vast area supports a broad extent of water resources, harboring abundant fish genetic resources. Of the 24,618 (Nelson 1994) species comprising the fish genetic resources of the world, nearly 8.60% that is 2,118 species occur in India, and a database on these fishes has been made at National Bureau of Fish Genetic Resources.

The aquatic resources of Peninsular India including five Southern Indian States like Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Pondicherry, and two Western States that are Goa and some parts of Maharashtra cover about India's 20% river and canal sources, 38.6% of reservoirs, 50% of tanks and ponds, and about 63% of swamp and derelict water bodies. There are three major rivers like Godavari, Krishna, and Cauvery and a number of west flowing rivers, which take their birth from Western Ghats, harbor a unique fish wealth, with high degree of endemicity. The mountains along the West coast of the Peninsula "Western Ghats" constitute one of the 18 biological "hotspots" of the world (Mittermeir et al. 2000). Studies on the endemic fishes from various streams and rivers in the Western Ghats mountain ranges have been compiled recently (Ponnaiah and Gopalakrishnan 2000). Fish diversity in selected streams in northern Karnataka (Arunachalam et al. 1997); Central Western Ghats (Arunachalam 2000); fish fauna of Bhadra and Tunga reservoirs (Venkateshwarlu et al. 2002, 2005) have been reported. Arunachalam et al. (2005) reported a new fish species—*Neolissocheilus wynaadensis*—from the Karnataka part of Western Ghats. Bhat (2001) reported on some new fish species from Karnataka. Bhat and Jayaram (2003) reported on some new fish species from Uttara Kannada district, Karnataka. Recently, Arunachalam and Muralidharan (2007) have reported a new fish species—*Batasio sharavatiensis*—from Tunga river, Karnataka.

However, the study about the fish diversity in Bhadra river of Karnataka in particular is lacking; hence, the present study is aimed at examining the water quality and freshwater fish diversity of Bhadra river system in South Karnataka. The findings from the study will benefit the planning and management of sustainable fisheries and conservation of natural resources at national level.

## Materials and methods

### Study area

Bhadra river originates from “Gangamulla” near Varaha Hills of Western Ghats, Karnataka (India; 13°21′ to 14°0′ N Latitude and 75°26′ to 75°41′ E Longitude), and it is impounded at a distance of 1708 $m^2$ called Bhadra reservoir. Below the dam, the river runs to a distance of 70 km before it confluences with Tunga river at Kudli. Six study sites were selected from Balehonnur (BH) to Kudli Sangam (KS) with a distance of 10 km interval (Fig. 1).

## Sampling design

The selected sites were sampled during Oct–Nov 2006 (dry season). There were four aspects in our study—habitat survey, habitat inventory, fish diversity, and collection of water samples in different study sites. The habitat inventory was done at a fixed point, which is designated as 0 (zero). This could be made as a reference point and can be recognized by means of permanent features like confluence of tributaries, bridge, culvert, or any manmade structure. Substrate types were recorded by visual and snorkeling methods. Maximum depth and mean depth were recorded. Multiple estimations of the extent of riparian cover (the area of the stream channel covered by overhead vegetation) at each site were made by one or two observers. Then mean riparian cover was taken for each habitat. Habitat parameters were taken using the habitat inventory methods (Armantrout 1990; Arunachalam 1999).

Water quality parameters were estimated using standard methods (APHA 1995). Fish sampling was done by using a variety of fishing nets of varying mesh sizes viz. gill nets, cast nets, and dragnets. After collection, fishes were examined and numbers were counted and released to the system. Fishes were identified with the help of keys prescribed by Dutta Munshi and Shrivastava (1988), Talwar and Jhingran (1991), and Jayaram (1999).

Sampling was carried out on 100–150-m stretches of the river at each site. Habitats at each site were quantified or measured on the basis of methods described by Pusey et al. (1993). The depth was taken and categorized into six categories (D1–D6) corresponding to 0–10, 11–30, 31–60, 61–100, 101–150, and >150 cm. Substrate was classified as bedrock (>610 mm diameter), boulder (305–609 mm), cobble (76.1–304 mm), gravel (4.81–76 mm), sand (0.83–4.71), and fine sand (0.83 mm or less), and the leaf litter was also considered, though it covers mostly sand or fine sand substrate. Fish species diversity was subjected to diversity analysis using different indices like species richness (S = number of species); Shannon–Weaver Information Index (1949); Simpson Dominance Index (Simpson 1949); Species Dominance Index (Berger and Parker 1970); Pielous Evenness (Pielou 1966).

### Shannon–Weaver index

$$H{=}S/1 = 1\left[\text{Sum}\,(\text{Pi})\;\;(\text{Log2pi})\right]$$

Where H = Shannon–Weaver index

Sum represents a capital epsilon

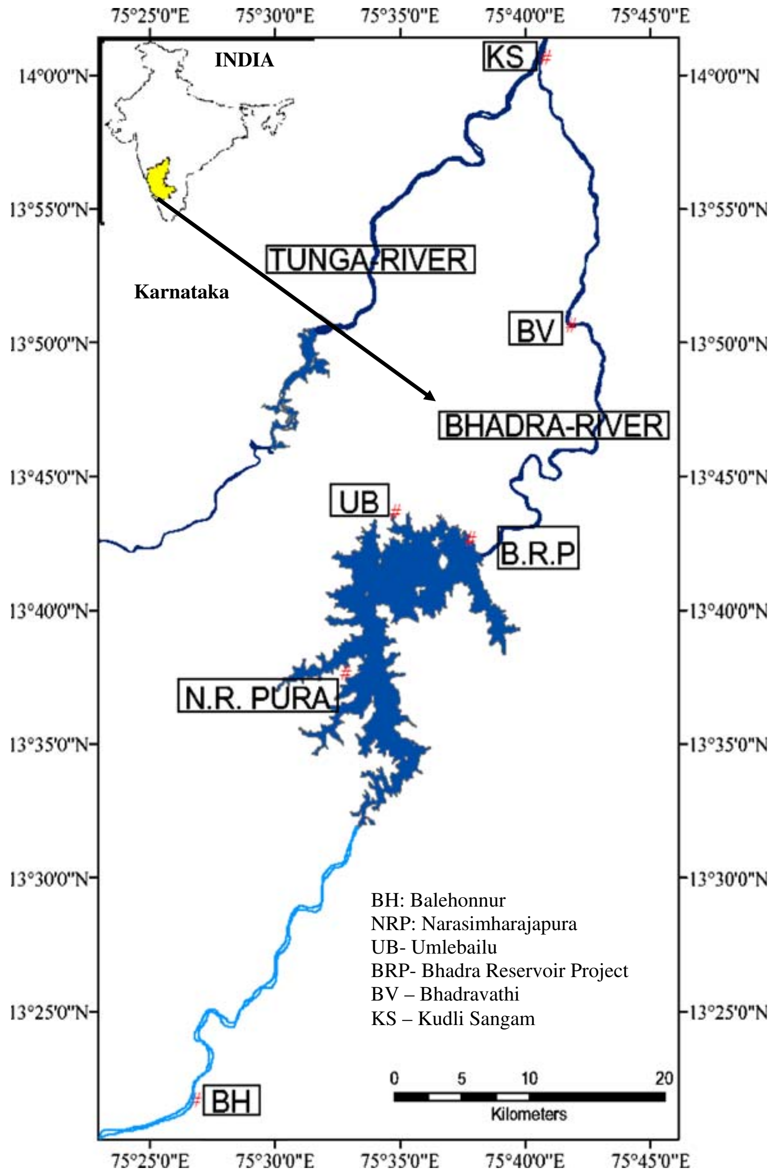


**Fig. 1** Location of sampling sites of Bhadra River

S = number of species, pi = proportion of individuals of the total sample belonging to the *i*th species calculated as ni/N for each *i*th species with ni being the number in species I and N, the number of individuals in the sample.

Simpson diversity

$$D2=\sum_{J=I}^{Sn}\left(nj/n\right)\left(n-nj/n-I\right)$$

Where, nj = number of individuals of the *j*th species in the sample

$$n=\sum_{j} nj = \text{total number of individuals in the sample, and}$$

Sn = number of species in the sample

Evenness formula

$$V' = \Delta/\Delta\max$$

**Table 1** Freshwater fish diversity of Bhadra River

| Sl. no | Species | Study sites | | | | | |
|---|---|---|---|---|---|---|---|
| | | BH | NRP | UB | BRP | BV | KS |
| Family: Cyprinidae | | | | | | | |
| Genus: *Labeo* | | | | | | | |
| 1 | *Labeo calbasu* | – | X | – | X | X | – |
| 2 | *Labeo rohita* | – | X | – | X | – | – |
| 3 | *Labeo porcellus* | – | – | X | X | – | |
| 4 | *Labeo angra* | X | – | – | – | – | – |
| 5 | *Labeo potail* | – | X | X | X | – | X |
| Genus: *Osteobrama* | | | | | | | |
| 6 | *Osteobrama neilli* | – | X | X | X | X | X |
| 7 | *Osteobrama cotio peninsularis* | – | X | – | X | – | X |
| Genus: *Puntius* | | | | | | | |
| 8 | *Puntius sophore* | – | X | X | – | – | – |
| 9 | *Puntius chola* | X | X | X | X | – | – |
| 10 | *Puntius arulius* | – | X | X | – | – | – |
| 11 | *Puntius jerdoni* | – | X | X | X | – | X |
| 12 | *Balitora mysorensis* | X | – | – | X | – | – |
| 13 | *Puntius sahyadrensis* | – | X | – | – | – | X |
| 14 | *Puntius sarana sabnastus* | – | – | – | – | – | X |
| 15 | *Puntius amphibious* | X | – | – | – | – | – |
| Genus: *Salmostoma* | | | | | | | |
| 16 | *Salmostoma boopis* | X | – | – | – | – | – |
| 17 | *Salmostoma sardinella* | – | X | X | X | – | – |
| Genus: *Barilius* | | | | | | | |
| 18 | *Barilius bendelisis* | X | – | – | – | – | – |
| 19 | *Barilius canarensis* | X | – | – | – | – | – |
| Genus: *Devario* (*Danio*) | | | | | | | |
| 20 | *Devario aequipinnatus* | X | X | X | – | – | – |
| 21 | *Danio malabaricus* | X | – | – | – | – | – |
| Genus: *Garra* | | | | | | | |
| 22 | *Garra bicornuta* | – | – | – | – | – | X |
| 23 | *Garra mullya* | – | – | – | – | – | X |
| Genus: *Cirrhinus* | | | | | | | |
| 24 | *Cirrhinus fulungee* | – | X | X | X | – | X |
| 25 | *Cirrhinus reba* | – | X | X | X | – | X |
| 26 | *Cirrhinus mrigala* | – | – | – | X | – | – |
| Genus: *Rohtee* | | | | | | | |
| 27 | *Rohtee ogilbii* | X | – | X | X | – | – |
| Genus: *Catla* | | | | | | | |
| 28 | *Catla catla* | X | – | X | – | – | – |
| Genus: *Cyprinus* | | | | | | | |
| 29 | *Cyprinus carpio** | – | – | X | X | – | – |
| Genus: *Hypselobarbus* | | | | | | | |
| 30 | *Hypselobarbus kolus* | – | X | – | X | – | X |
| Genus: *Osteochilichthys* | | | | | | | |
| 31 | *Osteochilichthys nashii* | – | – | – | – | – | X |
| 32 | *Osteochilichthys thomassii* | – | – | – | – | – | X |
| Family: Cobitidae | | | | | | | |
| Genus: *Botia* | | | | | | | |
| 33 | *Botia straita* | – | – | – | X | – | – |
| Family: Bagridae | | | | | | | |
| Genus: *Sperata* | | | | | | | |
| 34 | *Sperata oar* | – | – | X | X | – | – |

**Table 1** (continued)

| Sl. no | Species | Study sites | | | | | |
|---|---|---|---|---|---|---|---|
| | | BH | NRP | UB | BRP | BV | KS |
| 35 | *Sperata seenghala* | – | – | X | X | – | – |
| Genus: *Mystus* | | | | | | | |
| 36 | *Mystus cavasius* | – | – | – | – | – | – |
| 37 | *Mystus armatus* | – | – | X | X | – | – |
| 38 | *Mystus krishnensis* | – | X | – | – | – | – |
| Genus:*Rita* | | | | | | | |
| 39 | *Rita gogra* | – | – | – | – | – | x |
| Family: Schilbeidae | | | | | | | |
| Genus: *Proeutropichthys* | | | | | | | |
| 40 | *Proeutropichthys taakree* | – | – | – | – | – | X |
| Family: Siluridae | | | | | | | |
| Genus: *Ompok* | | – | – | – | – | – | X |
| 41 | *Ompok bimaculatus* | – | X | X | X | X | – |
| 42 | *Ompok pabo* | – | X | X | X | – | – |
| Genus: *Wallago* | | | | | | | |
| 43 | *Wallago attu* | – | – | – | X | – | – |
| Family: Claridae | | | | | | | |
| Genus: *Clarias* | | | | | | | |
| 44 | *Clarias batrachus* | – | X | – | X | X | – |
| Family: Heteropneustidae | | | | | | | |
| Genus: *Heteropneustes* | | | | | | | |
| 45 | *Heteropneustes fossili*s | – | – | X | X | X | – |
| Family: Sisoridae | | | | | | | |
| Genus: *Gagata* (*Nangra*) | | | | | | | |
| 46 | *Gagata itchkea* | – | X | – | – | – | – |
| Family: Ambassidae | | | | | | | |
| Genus: *Chanda* | | | | | | | |
| 47 | Chanda nama | – | X | – | – | – | X |
| Family: Parambassidae | | | | | | | |
| Genus: *Parambassis* | | | | | | | |
| 48 | *Parambassis thomassi* | – | X | – | – | – | X |
| Family: Cichlidae | | | | | | | |
| Genus: *Etroplus* | | | | | | | |
| 49 | *Etroplus maculates* | – | – | – | – | – | X |
| Genus: *Oreochromis* | | | | | | | |
| 50 | *Oreochromis mossambica** | – | – | – | – | X | X |
| Family: Channidae | | | | | | | |
| Genus: *Channa* | | | | | | | |
| 51 | *Channa marulius* | – | – | – | – | X | – |
| 52 | *Channa punctatus* | – | X | X | X | – | – |
| 53 | *Channa straitus* | – | X | X | – | – | – |
| Family: Notopteridae | | | | | | | |
| Genus: *Notopterus* | | | | | | | |
| 54 | *Notopterus notopterus* | – | X | X | X | X | X |
| Family: Belonidae | | | | | | | |
| Genus:*Xenontodon* | | | | | | | |
| 55 | *Xenontodon cancilla* | – | X | X | X | – | – |
| Family: Mastacembelidae | | | | | | | |
| Genus:*Mastacembelus* | | | | | | | |
| 56 | *Mastacembelus armatus* | – | X | X | X | X | X |

*BH* Balehonnur, *NRP* Narasimharajapura, *UB* Umlebailu, *BRP* Bhadra Reservoir Project, *BV* Bhadravathi, *KS* Kudli Sangam, *X* presence of cultured species, – absence of cultured species

Table 2 Fish species proportion of Bhadra River

| Study sites | Sampling period of Cyprinids (%) | Relative abundance richness | Fish species |
|---|---|---|---|
| BH | November, 2006 | 100.00 | 15.00 |
| NRP | November, 2006 | 70.95 | 25.00 |
| UB | October, 2006 | 58.21 | 24.00 |
| BRP | October, 2006 | 61.08 | 27.00 |
| BV | November, 2006 | 55.44 | 14.00 |
| KS | November, 2006 | 71.35 | 24.00 |

*BH* Balehonnur, *NRP* Narasimharajapura, *UB* Umlebailu, *BRP* Bhadra Reservoir Project, *BV* Bhadravathi, *KS* Kudli Sangam

Where, $V'$ = Pielou evenness

$\Delta$ = observed value of parameter

$\Delta$ max = value parameter would assume if all S species were equally abundant.

## Results and discussion

A total of 56 species representing 31 genera and 15 families (Table 1) were recorded; of which, the cyprinids were found to be the most dominant group (55%). The results are in accordance with those of Wakid and Biswas (2005). Most of these are widely distributed in the Karnataka and other parts of the Western Ghats. *Puntius chola*, *Puntius sophore*, *Hypselobarbus kolus*, *Cirrhinus fulungee*, *Cirrhinus reba*, and *Osteobrama neilli* were the most common and uniformly distributed fishes in the Bhadra river. *Mystus krishnensis*, *Mystus armatus*, *Ompok pabo*, *Wallago attu*, and *Gagata itchkea* were comparatively rare and confined to lower reaches of the river. Our study indicates that Cyprinid fishes show a wide range of distribution and composition. The results are in conformity with those of Naheed et al. (1988) and Jhingran (1991). The present study has also shown that Silurid fishes are mainly confined to lower reaches of the river (B.R. Project, UB and BV). The same observation was noticed by Naheed et al. (1988) in the river Haro, Pakistan.

Comparison of fish species richness between the selected sites is summarized in Table 2. High species richness was observed from sampling sites like BRP, NRP, and KS, and less species richness was recorded at BH and BV sites, respectively. As far as the diversity indices (Table 3) are concerned, the Shannon–Weaver diversity indices of the fishes was found highest at BRP site (3.146) while lowest was at site BH (2.283). The Simpson dominance indices were high at site BRP (0.9511) and low at site BH (0.8871). But the Species Dominance index (D) was high at BH (0.1129) and low at BRP (0.0489). The evenness values were recorded high at UB (0.9183) and low at KS (0.8103). Thus, the results of fish species richness shown by various diversity indices are positively correlated between the selected sites. Only Species Dominance index has shown

Table 3 Fish diversity indices of Bhadra River

| | BH | NRP | UB | BRP | BV | KS |
|---|---|---|---|---|---|---|
| Total number of species | 11.00 | 25.00 | 24.00 | 27.00 | 18.00 | 24.00 |
| Number of Individuals | 198.00 | 220.00 | 146.00 | 203.00 | 98.00 | 185.00 |
| Dominance_D | 0.1129 | 0.05459 | 0.04992 | 0.0489 | 0.06789 | 0.06343 |
| Shannon_H | 2.283 | 3.04 | 3.093 | 3.146 | 2.775 | 2.968 |
| Simpson_1-D | 0.8871 | 0.9454 | 0.9501 | 0.9511 | 0.9321 | 0.9366 |
| Evenness_e^H/S | 0.8916 | 0.8364 | 0.9183 | 0.8612 | 0.8908 | 0.8103 |

*BH* Balehonnur, *NRP* Narasimharajapura, *UB* Umlebailu, *BRP* Bhadra Reservoir Project, *BV* Bhadravathi, *KS* Kudli Sangam

**Table 4** Mean of physicochemical parameters of six study sites of Bhadra River (dry season)

| Sl. No | Parameters | BH | NRP | UB | BRP | BV | KS |
|---|---|---|---|---|---|---|---|
| 1 | Air temperature, ˚C | 24.00 | 20.00 | 22.00 | 23.00 | 22.00 | 25.00 |
| 2 | Water temperature, ˚C | 20.00 | 19.00 | 20.00 | 21.00 | 20.00 | 21.00 |
| 3 | pH | 7.00 | 7.10 | 7.10 | 7.00 | 6.70 | 7.00 |
| 4 | Dissolved oxygen (mg $l^{-1}$) | 10.50 | 10.00 | 8.10 | 9.70 | 5.67 | 8.51 |
| 5 | Total hardness (mg $l^{-1}$) | 12.00 | 8.00 | 26.00 | 14.00 | 110.00 | 26.00 |
| 6 | Alkalinity, (mg $l^{-1}$) | 38.00 | 47.00 | 42.00 | 45.00 | 90.00 | 26.00 |
| 7 | Conductivity (mhos/cm) | 88.00 | 98.00 | 99.00 | 80.00 | 316.00 | 132.00 |
| 8 | COD (mg $l^{-1}$) | 14 | 13 | 12 | 10 | 27 | 15 |
| 9 | BOD (mg $l^{-1}$) | 2.3 | 2.0 | 1.5 | 2.3 | 10.6 | 4.0 |

*BH* Balehonnur, *NRP* Narasimharajapura, *UB* Umlebailu, *BRP* Bhadra Reservoir Project, *BV* Bhadravathi, *KS* Kudli Sangam

negative correlation between BRP and BH sites. Low species richness at BH site may be correlated with the physical barrier for the fish movement and the physical stability is one of the important factors for fish diversity (Arunachalam et al. 1997). At BH site, a lot of physical barriers like big log inside the river site and fallen trees were noticed, and this could be the reason for low species richness. The same observations were made by Karr et al. (1986), Arunachalam (2000), and Bramblett et al. (2005).

The present study has shown positive correlation between fish species and physicochemical parameters. For instance, the BV study site has also witnessed low species richness. Here, only six fish species were recorded which was the least number among all the study sites. The fish species recorded were *Labeo calbasu*,*Osteobrama neilli*, *Ompok bimaculatus*, *Clarias batrachus*, *Heteropneustes fossilis*, and *Oreochromis mossambica.* There are other factors responsible for fish retardation other than physical stability like pollution threats, over fishing, dynamiting, etc. Hence, low fish species richness at BV site might be because of the effluents discharged by the industries like Vishweshwaraya Steel and Iron Limited (VSIL) and Mysore Paper Mills (MPM) which are located at the river bank. As it is supported by the fact

**Table 5** Habitat characteristics of study sites of Bhadra River

| Parameter | BH | NRP | UB | BRP | BV | KS |
|---|---|---|---|---|---|---|
| Substrate types (%) | | | | | | |
| Bedrock | – | – | – | 41.00 | 30.00 | – |
| Boulder | – | 35.00 | 45.00 | 20.00 | 13.00 | 15.00 |
| Cobble | 55.00 | 46.00 | 42.00 | 22.00 | 24.00 | 35.00 |
| Gravel | 40.00 | 13.00 | 5.00 | 10.00 | 27.00 | 30.00 |
| Sand | 03.00 | 04.00 | 05.00 | 06.00 | 01.00 | 15.00 |
| Leaf litter | 02.00 | 02.00 | 03.00 | 01.00 | 05.00 | 05.00 |
| Fine sand | – | – | – | – | – | – |
| Depth (cm) | | | | | | |
| D1 | – | – | – | – | – | – |
| D2 | – | – | – | – | – | – |
| D3 | 51.30 | – | – | – | 41.70 | 58.25 |
| D4 | – | – | 69.75 | – | – | – |
| D5 | – | 110 | – | 146.75 | – | – |
| D6 | – | – | – | – | – | – |
| Riparian cover (%) | 30 | 55 | 50 | 60 | 25 | 35 |

*BH* Balehonnur, *NRP* Narasimharajapura, *UB* Umlebailu, *BRP* Bhadra Reservoir Project, *BV* Bhadravathi, *KS* Kudli Sangam that the lowest DO level (5.67 mg/l) was recorded at this site. The physicochemical water parameters are summarized in Table 4. The mean pH of the sampling stations ranged between 6.70 mg $l^{-1}$ (BV) to 7.10 (NRP and UB). The pH at BV site shows the acidic nature of water. Mean water temperature was observed to be lower than air temperature which is attributed to less heating of the water body. This result is in accordance of Sunkad and Patil (2003). Dissolved oxygen was high at all sites except one site (BV, 5.67 mg/l) with a mean of 8.74 mg/l shows good aeration of the river. Total hardness, conductivity, and alkalinity values were under permissive limits except at BV site, respectively. BV site showed total hardness more than (110 mg/l), which is considered as hard water. The present results are in conformity with those of Kannan (1991). Also, maximum COD (27 mg/l) and BOD (10.6 mg/l) were recorded at BV site. Increasing trend of BOD and decreasing trend of DO at BV site clearly indicates the increasing load of pollution. High value of COD and BOD indicate high degree of organic pollution (Adholia 1992).

High alkalinity (90.00 mg/l) and conductivity (316.00 mg/l) at BV site is probably because of addition of waste from the VSIL and MPM. The water coming from the industries is rich in some heavy metals like Fe, Phenol, etc.; thus, water is polluted at this point of river. Therefore, high values of BOD, COD, total hardness, alkalinity and conductivity, and low values of pH and DO at BV site have adverse effect on abundance of fish diversity. That is why least fish richness (six species) was recorded at this site and such observation was also made by Martin (2004).

In addition to above, habitat characteristics have also shown a considerable variation in microhabitat types such as substrate types, depth, and riparian cover, which are given in Table 5. It is clear from the study that water at all stations was clear (except at BV site) with sandy, rocky bottom, and the banks were lined by boulders and rocks. The shore vegetation consists of primary forest. This appearance was a typical of undisturbed forest stream at high altitudes. However, many of the fish habitats such as pools and deep areas were covered with sediments and rocks. The riparian cover is one of the important attributes for fish population to survive. It is having the direct influence on fish habitat as it works as a barrier from predators and food source as some species feed on insects which fall from trees. Therefore, it might be also one of the reasons for low fish diversity at BV site where the riparian cover was found least among all the study sites (25%).

Variations in species diversity at sampling stations indicate that altered habitats support less biological communities while less disturbed sites are characterized by a diverse fish fauna in a variety of habitats as it is clearly shown by the present study. Physical stability (any barrier like log, rocks, etc. for fish movement) and anthropogenic activities like overexploitation of fishes and discharge of various types of pollutants from various types of industries have a crucial role in the retardation of fish diversity at BH and BV sites, respectively.

Therefore, it is obvious that the river is receiving pollution threats at BV site, which should be checked by taking necessary steps. We need to formulate sustainable strategies to save fish community of this river system as a whole.

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