Journal of Research & Development, Vol. 12 (2012) *ISSN 0972-5407*

Habitat Ecology of Cyprinid Fish Community in Relation to Environmental Factors of Tunga and Bhadra Rivers, Western Ghats, Karnataka (India).

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ABSTRACT

Fish assemblages were sampled by standard methods and assessed in relation to environmental factors from Tunga and Bhadra river systems, Western Ghats, Karnataka. Cyprinids were found to be the most dominant group in the assemblage composition with 62.3%. They dominated the fish populations at all sites in terms of species richness and numerical abundance. Among cyprinids 5 species were most dominant and incidences of occurrence were about ≥55% for these five species, but overall most of the species were found at ≥15% of all the sites. Both the rivers exhibited dissimilarity in cyprinid occurrence and composition. Cyprinids represented all 14 sites, being highest in Balehonnur (99.42 %) and lowest in Hosalli (36.73%).

Key words: Cyprinids, abiotic factors, Tunga and Bhadra rivers, ecological adaptations.

INTRODUCTION

Fishes are large in diversity and constitute approximately half of all the described vertebrates (24,618 species out of the total of 48,170) and comprise of 482 families with living species, (Maitland, 1995). Over 10,000 fish species live in freshwater which are approximately 40% of global fish diversity and one quarter of global vertebrate diversity, (Lundberg *et al.,* 2000). Approximately 100 new fish species are described each year (Maitland, 1995) and about 1% of fishes, which are described from synonymy each year, (Stiassny, 1999). This trend of describing new fish species is going on, (Lundberg *et al.,* 2000). There are scientific reports which states that at least 5,000 fish species await discovery (Jenkins, 2005). Fish communities in particular are at threat from habitat alterations including changing water flow, changes in water quality and riparian cover. Therefore, these impacts have made restrict distribution pattern of several fish species (Ponnaiah and Gopalakrishnan, 2000).

Habitat is one of the most important criteria for fish survival and it provides the medium in which fish may flourish or perish. The importance of habitat has long been recognized through studies on environmental influences on individual species (Brett, 1979; Albaugh, 1972) and assemblages (Lobb and Orth, 1988; Meffe and Sheldon, 1988). These and other studies have identified important environmental variables for riverine and lake-dwelling fishes, particularly in temperate regions of the world (Jackson *et al*., 2001). By comparison, these relationships have been largely neglected in tropical regions, although we can quote some studies like Rodriquez and Lewis (1977) and Tejeriro-Garro *et al*. (1998) in South America and Martin-Smith (1998), Lee (2001) and Beamish *et al*. (2003) in Southeast Asia.

The Cyprinidae is the largest family of all freshwater fishes (Nelson, 1994) with more than 1500 species have evolved partially through highly adapted body forms and mouth structures (Ward-Campbell *et al*., 2005), so that they occupy virtually all habitats throughout their distribution (Howes,1991). In fact, in Southeast Asia, the cyprinids may contribute 40% or more of the species in a watershed, Taki (1978; Watson and Balon, 1984). To study the impact of specific environmental characteristics on cyprinid fishes and this information is important not only to understand their environmental ecology but provides the means and conservation measures where populations or species are at the verge of declining or extinction. The study may be useful in constructing bio-assessment models to monitor water quality. In this paper, we examine the cyprinid distribution and abundance in relation to habitat characteristics in Tunga and Bhadra rivers, Karnataka (India).

MATERIAL AND METHODS

Study Area

Fourteen (14) study sites were selected from Tunga and Bhadra rivers in Karnataka part of Western Ghats. Gangamula, the source of both the Tunga and Bhadra rivers, is situated at 13^0 15' N Latitude and 75^0 14' E Longitude (Fig. 1)The hill from which they originate is called the Varaha Paravatha, that confines to the Koppa and Balehonnur taluks of Karnataka, India. The Tunga and Bhadra rivers are the major sub-basins of the east flowing largest peninsular river, the Krishna and two west flowing rivers that are Seetanadi and Netravati.

The 130 km river Tunga, which flows for about 64.4 km in Shimoga district with catchment area of 22,39.4 km^2. Its course is at first north-east passes Shringere town to Baggunji, where it turns north-west direction and then continues up to Thirthahalli. It is a medium, perennial river and for most of the year, the riverbed flows thinly. The water is abundant during the period of June to October and becomes a good source for drinking and irrigation purposes. Its banks are not steep like that of Bhadra river and its streams are generally considered as more healthy and less disturbed.

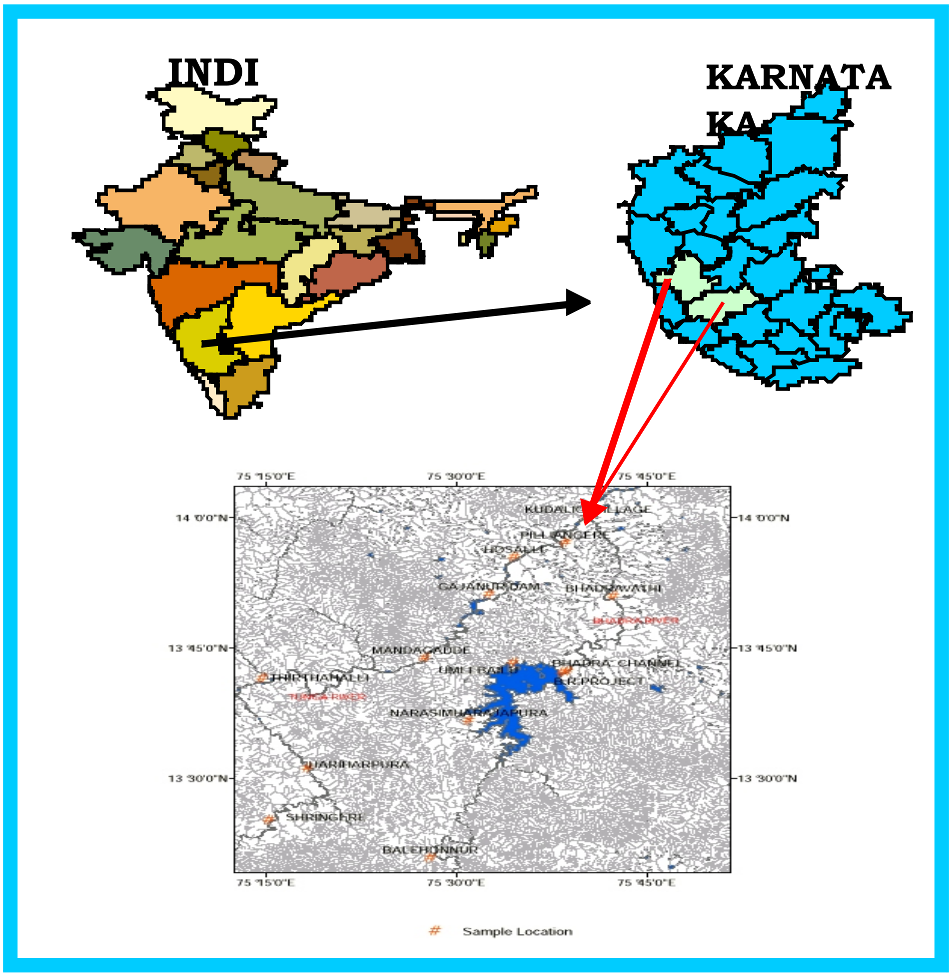

Figure. 1. Location of the study area

The Bhadra river rises close to the Tunga in the Gangamula in the Varaha Hills of Western Ghats, 15 miles west of Kalasa with fast flow of water. It flows in an eastern direction and then joins at Sangameshwara by the Anebidda halla from the south, then turns north-east and runs past Khandeya forest, across the mouth of the Jagar valley. The drainages of which it receives in the Somavahini at Hebbe and then nearby Gakvalli by small unnamed streams from Kalhatti, Giri and Kalgurga join with the main river and the course continues upto Benkipur and Hollehonnur until the point of confluence with Tunga at Kudli in the Shimoga district. The river Bhadra is fairly a big river and flows almost throughout the year. seven study sites each from Tunga and Bhadra rivers, were selected for the present study (Fig. 1).

Sampling Methods

The study was conducted for a period of two years from June 2006 to June 2008. There were four aspects in our study- habitat survey, habitat inventory, fish diversity and collection of water samples in different study sites. Sampling stations were selected from locations depending on forest, riparian cover or residential or polluted areas. All sites were sampled throughout the year during the period of study. A site of 100m length of similar habitat was selected. Habitats at each site were quantified or measured on the basis of methods described by Pusey et al. (1993) and Aruunachalam (1995). The depth was taken and categorized into six categories (D1-D6) corresponding to 0-10,11-30,31-60,61-100,101-150 and >150cm. 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), fine sand (0.83 mm or less) and the leaf litter was also considered though it covers mostly sand or fine sand substrate.

Habitat features measured at each site included temperature (^{0}C), width (m), depth (cm) and velocity (cm/s). Depth was the mean of three to five measurements made at approximately equal intervals across the river. Velocity was measured at the surface and adjusted to represent the mean flow rate, Gillner and Malmqvist (1998). Conductivity (mhos/cm), turbidity (NTU), pH (pH meter) and dissolved oxygen (mg l-1) were measured with regularly calibrated meters. Alkalinity (as $CaCO_3$ mg l) and overall parameters were measure by using standard methods (APHA, 1995). Latitude, longitude and elevation were measured by GPS.

Fishes were sampled by using a variety of fishing nets of varying mesh sizes viz.

gill nets, cast nets and dragnets. After collection, fishes were examined, numbers were counted and released to the system. When unable to assign species status in the field, few individuals from each species were killed by an overdose of anaesthetia and preserved in 10% formalin for subsequent identification and then transferred to 70% ethanol for permanent storage in the laboratory. Fishes were identified with the help of keys prescribed by Talwar and Jhingran (1991) and Jayaram (1999).

Multiple regression curves (SPSS 11.5) were used to show the relationship between cyprinid species richness and abundance and the significant habitat variables. Principal Component Analysis (PCA) was used to know the variance among study sites in relation to habitat variables.

RESULTS

Water quality parameters varied greatly among study sites of both Tunga and Bhadra rivers which are summarized in the Table 1. Air and water temperature ranged between 25 to 33 °C and 21 to 28 °C among the study sites. The pH values were recorded low in Bhadravathi site of Bhadra river where as high 7.6 in Shringere site of Tunga river. Do, total hardness, alkalinity and conductivity values were high in Bhadravathi site of Bhadra river than in the other sites of Tunga river. Physical habitat characteristics such as water depth and velocity, substrate composition and canopy showed variability among study sites of both rivers. Substrate composition varied from sand to bedrock among sites but gravel was the average particle size within sites. Canopy ranged from full cover to moderate exposure in the range of 2060% cover and elevation ranged between 550 and 766 m. (Table 2).

Table 1: Water quality parameters of the sites of Tunga and Bhadra rivers, Karnataka

Sl. No.	Location	Air temp. (C°)	Water temp. (C°)	pH	Dissolved Oxygen (mg/l)	Total Hardness (mg/l)	Alkalinity (mg/l)	Conductivity (mhos/cm)
Tunga river								
1	Shringere	27	24	7.6	6.7	23	28	0.075
2	Hariharpura	28	25	7.2	9.4	32	18	0.078
3	Thirthahalli	32	25	6.9	7.9	31	12	0.132
4	Mandgadde	31	27	6.8	8.2	16	30	0.111
5	Gajanur Dam	33	24	6.8	7.2	35	14	0.076
6	Hosalli	31	26	7.1	6.5	40	13	0.147
7	Pilliangere	32	28	7.3	6.9	17	17	0.104
Bhadra river								
8	Balehonnur	25	21	7.2	8.3	12	38	0.088
9	N.R. Pura	29	24	7.1	7.4	14	47	0.098
10	Umlebailu	32	25	7.3	8.1	26	42	0.101
11	B. R. Project	30	27	7.4	9.7	20	45	0.082
12	Bhadra channel	33	25	7.3	8.5	22	35	0.079
13	Bhadravathi	33	26	6.1	6.1	76	90	0.316
14	Kudaligi village	27	22	7.5	9.1	27	26	0.132

Table 2: Physical characteristics of Tunga and Bhadra rivers, Karnataka

Tunga river									
1	Shringere	680	°, 56’N	75°, 84’E	7.3	43.8	60	4	80
2	Hariharpura	620	13°, 31’N	75°, 18’E	10.8	55.2	60	4	80
3	Thirthahalli	625	13°, 41’N	75°, 14’E	15.4	85.3	30	3	40
4	Mandgadde	615	13°, 44’N	75°, 27’E	18.2	80.5	60	3	80
5	Gajanur Dam	580	13°, 50’N	75°, 31’E	22.2	140.3	40	2	60
6	Hosalli	570	13°, 52’N	75°, 34’E	13.4	50.8	60	3	80
7	Pilliangere	550	13°, 57’N	75°, 38’E	19.5	90.2	40	3	50
Bhadra river									
8	Balehonnur	766	13°, 21’N	75°, 26’E	14.1	51.3	60	4	60
9	N.R. Pura	660	13°, 37’N	75°, 32’E	20.3	102.5	30	2	40
10	Umlebailu	665	13°, 43’N	75°, 34’E	18.2	67.7	25	2	50
11	B. R. Project	700	13°, 42’N	75°, 37’E	22.1	146.7	30	2	80
12	Bhadra channel	630	13°, 43’N	75°, 38’E	8.4	55.5	40	5	40
13	Bhadravathi	580	13°, 50’N	75°, 41’E	16.1	41.7	60	3	20
14	Kudaligi village	600	14°, 0’N	75°, 40’E	14.5	58.2	25	5	80

***Velocity (m/sec):** 2. Slow (0.05 -0.2); 3. Moderate (0.2 -0.5); 4. Fast (0.5 -1.0); 5. Very fast (>1).

Among the 77 species of fishes recorded from Tunga and Bhadra rivers, the order Cypriniformes (Table 3) was found to be the most dominant group in the assemblage composition with 62.3% followed by Siluriformes with 18.18%, Perciformes with 15.58%, Cyprinodontiformes with 2.59% and least was Osteoglossiformes with 1.29% respectively.

Table 3: Cyprinid species of Tunga and Bhadra rivers, Karnataka

Sl. No	Order/Family/Genus/Species/Author
	Order: Cypriniformes
	I Family: Cyprinidae
	I Subfamily: Cyprininae
1	*Osteobrama neilli* (Day)
2	*Osteobrama cotio peninsularis* (Silas)
3	*Puntius chola* (Hamilton-Buchanan)
4	*Puntius arulius* (Jerdoni)
5	*Puntius sophore* (Hamilton-Buchanan)
6	*Puntius jerdoni* (Day)
7	*Puntius sahyadrensis* (Silas)
8	*Puntius filamentosus* (Valenciennes)
9	*Puntius ticto* (Hamilton)
10	*Puntius amphibius* (Valenciennes)
11	*Puntius sarana sabnastus* (Valenciennes)
12	*Puntius conchonius* (Hamilton-Buchanan)
13	*Labeo calbasu* (Hamilton-Buchanan)
14	*Labeo potail* (Sykes)
15	*Labeo rohita* (Hamilton-Buchanan)
16	*Labeo porcellus* (Heckel)
17	*Labeo angra* (Hamilton-Buchanan)
18	*Labeo spp.*
19	*Cirrhinus fulungee* (Sykes)
20	*Cirrhinus mrigala* (Hamilton)
21	*Cirrhinus reba* (Hamilton-Buchanan)
22	*Rohtee ogilbii* (Sykes)
23	*Danio malabaricus* (Jerdon)
24	*Danio aequipinnatus* (MaClelland)
25	*Danio rerio* (Hamilton-Buchanan)
26	*Tor mussullah* (Sykes)
27	*Tor khudree* (*Sykes*)

Tabe 3 contd.....

Tabe 3 contd.....

28	*Barilius gatensis* (Valenciennes)
29	*Barilius canarensis* (Jerdoni)
30	*Barilius bendelisis* (Hamilton-Buchanan)
31	*Garra bicornuta* (Rao)
32	*Garra mullya* (Sykes)
33	*Hypselobarbus kolus* (Sykes)
34	*Hypselobarbus thomassi* (Day)
35	*Hypselobarbus lithopidos* (Day)
36	*Osteochilichthys thomassii* (Day)
37	*Osteochilichthys nashii* (Day)
38	*Salmostoma boopis* (Day)
39	*Salmostoma sardinella* (Valenciennes)
40	*Amplypharyngodon mola* (Hamilton-Buchanan)
41	*Rasbora daniconius* (Hamilton-Buchanan)
42	*Psilorhynchus tenura* (Arunachalam-Muralidharan)
43	*Cyprinus carpio cummunis* (Linnaeus)
44	*Catla catla* (Hamilton-Buchanan)
	II Family: Balitoridae
45	*Balitora mysorensis* (Hora)
46	*Schistura semiarmatus* (Day)
47	*Nemachilichthys rueppelli* (*Sykes*)
	III Family: Cobitidae
48	*Lepidocephalus thermalis* (Valenciennes)

Cyprinid fishes dominated the fish populations at all sites in terms of species richness and numerical abundance. Cyprinids represented all 14 sites, being highest in Balehonnur (99.42 %) and lowest in Hosalli (36.73%) respectively (Table 4).

Table 4: Cyprinid abundance and richness (%) in the sites of Tunga and Bhadra rivers

S. No.	Study sites	Taxa (S)	Cyprinid taxa (S)	Total No. of individuals captured	Cyprinid individuals	Cyprinid (%)
Tunga river						
1	Shringere	33	30	237	230	97.04
2	Hariharpura	23	20	149	140	93.95
3	Thirthahalli	25	21	221	210	95.02
4	Mandgadde	29	15	262	115	43.89
5	Gajanur Dam	35	18	340	160	47.05
6	Hosalli	32	16	196	72	36.73
7	Pilliangere	29	15	161	70	43.47
Bhadra river						
8	Balehonnur	31	30	173	172	99.42
9	N.R. Pura	47	25	349	200	57.30
10	Umlebailu	35	23	200	76	38.0
11	B. R. Project	38	26	359	234	65.18
12	Bhadra channel	22	17	66	55	83.33
13	Bhadravathi	20	12	140	62	44.28
14	Kudaligi village	32	24	160	84	52.5

As far as occurrence and distribution of cyprinid is concerned, *Osteobrama neilli, Puntius chola, Cirrhinus fulungee, Cirrhinus reba* and *Garra mullya* were represented by all sites. Incidences of occurrence were about ≥55% for these five species, but overall most of the species were found at ≥15% of all the sites. Both the rivers showed dissimilarity in species occurrence and composition. The 48 cyprinid species were recorded from Tunga and Bhadra rivers. After cyprinid data collection, it was pooled and subjected to dendrogram analysis. In Tunga river, 7 study sites forms two clusters (Fig. 2). Cluster A comprises Mandgadde, Gajanur Dam, Hosalli and Pilliangere. Cluster B comprises Hariharpura, Thirthahalli and Shringere. Clusters A and B shared the presence of 74.62% species. Sites in Cluster A have a different combination of species with more species richness than the sites in Cluster B. Fish species like *Tor mussullah,*

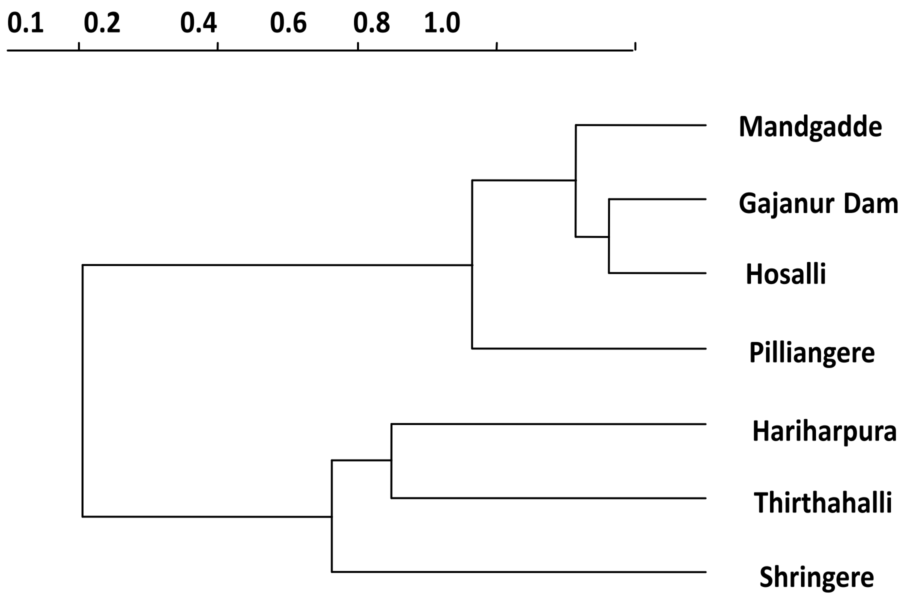

Figure. 2. Cluster of localities resulting from the Jaccard matric of 7 sites of Tunga river

Tor khudree, Hypselobarbus lithopidos, Hypselobarbus thomassi, Psilorhynchus tenura, Danio rerio, Puntius filamentosus, Osteochilichthys nashii and *Osteochilichthys thomassi* were distinct species to cluster A as they were not recorded in the sites of cluster B.

Similarly in Bhadra river also, 7 selected study sites forms two clusters (Fig**.** 3). Cluster A includes Kudaligi village, Bhadra channel, B. R. Project, Bhadravathi and N.R. Pura. While cluster B comprises Umlebailu and Balehonnur. Clusters A and B shared the presence of about 82.75% species. But cluster A has more species richness than the cluster B though they shared most of the species. On the other hand, both the clusters shared some dissimilarity in species combination also. Species like *Balitora mysorensis, Puntius jerdoni* and *Puntius sahyadrensis,* were distinct species to cluster B as they were not recorded in any of the sites of cluster B. Interestingly, only one species that is *Barilius gatensis* was recorded in cluster A which shows its unique distribution.

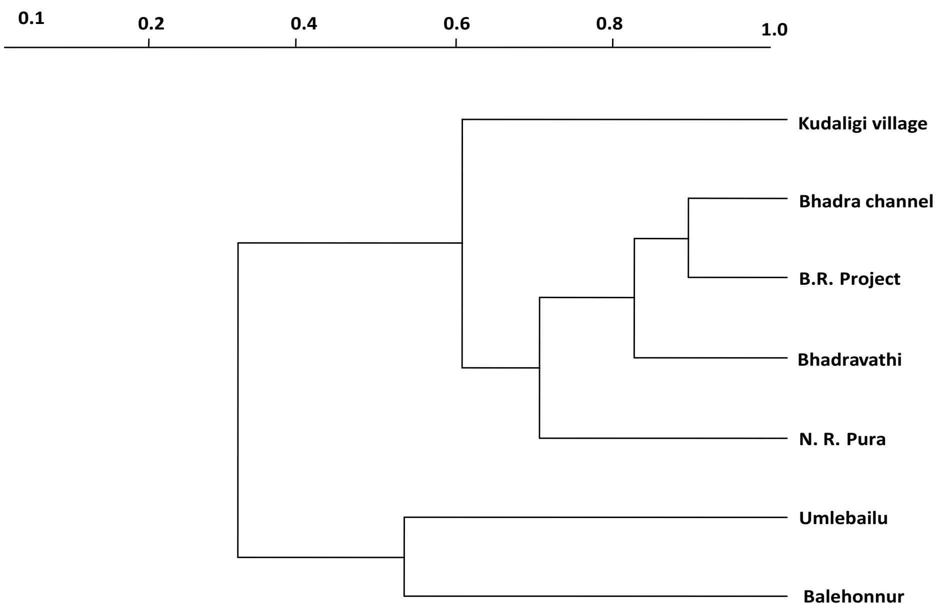

Figure. 3. Cluster of localities resulting from the Jaccard matric of 7 sites of Bhadra river

Cyprinid species showed a wide range of preference to some significant habitat characteristics. There were wide variations in species richness and abundance between the altitudes. Species richness and abundance were high at lower altitudes. Cubic regression analysis showed a highly significant relationship between the altitude and species richness and abundance. This showed that both species richness and abundance were strongly correlated with altitude (Fig. 4 and 5).

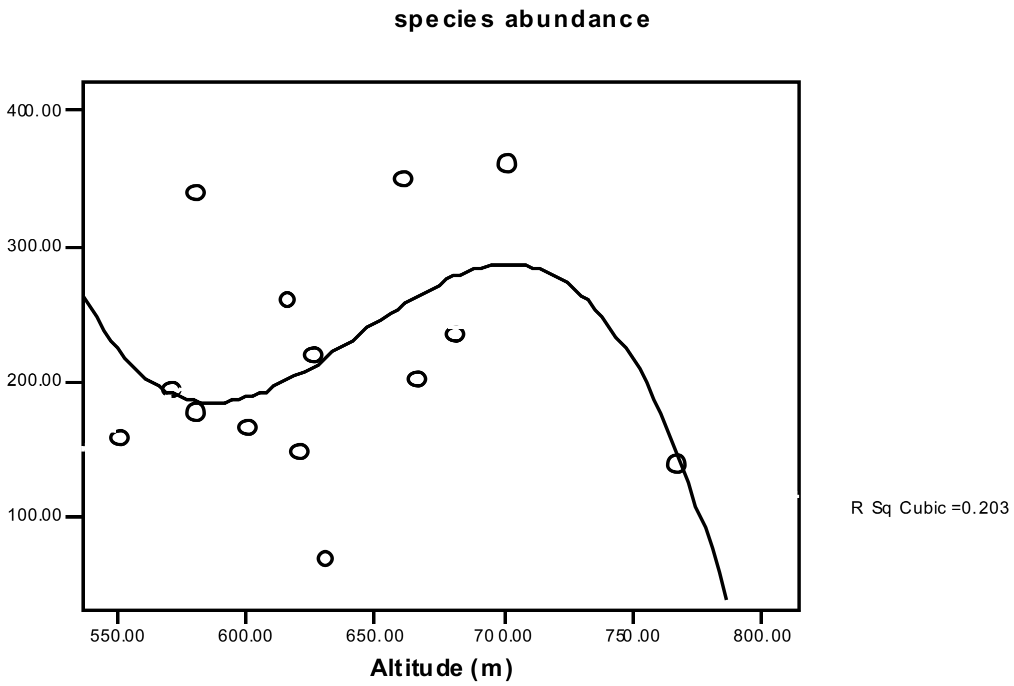

Fig. 4. Cubic regression curve shows the relationship between the cyprinid species richness and altitude of various study sites

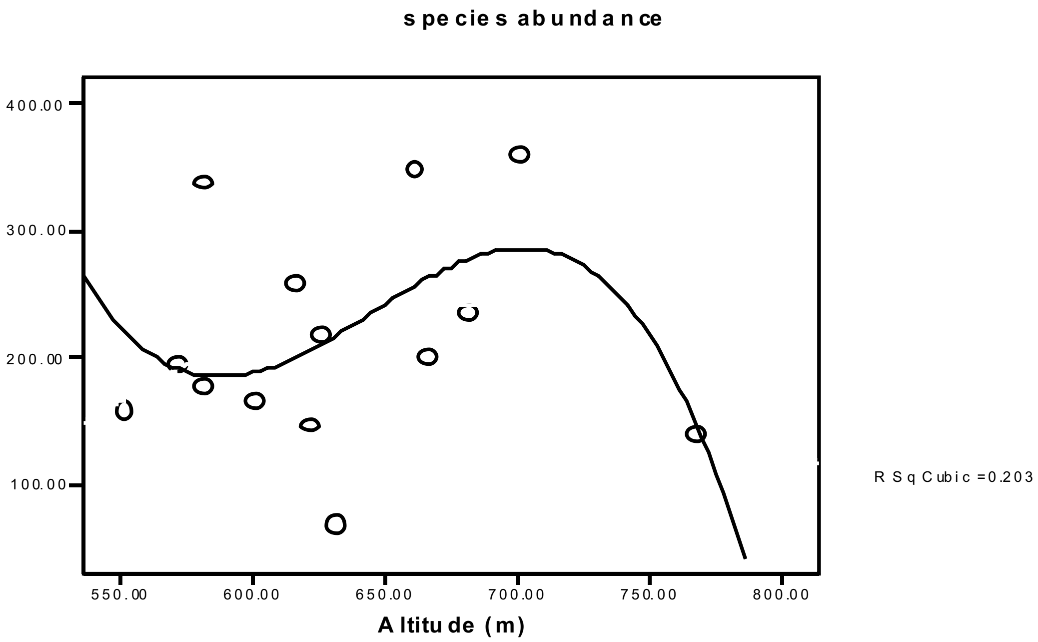

Fig. 5. Cubic regression curve shows the relationship between the species abundance and altitude of various study sites

In case of depth, the species richness and abundance were more at moderate depth and then it has shown the decreasing trend in species richness and abundance with increasing water depth. The depth was related with species richness and abundance through cubic regression analysis which showed significant values (Fig. 6 and 7).

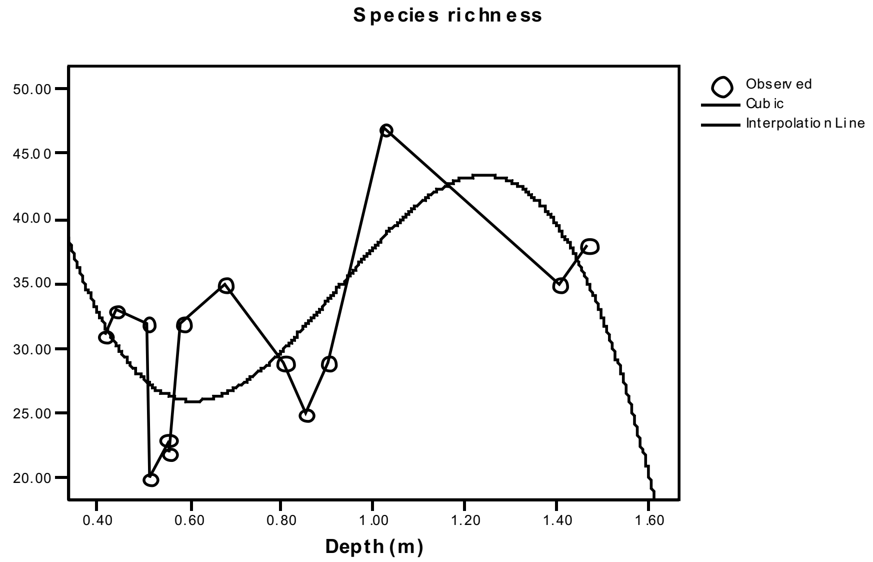

Fig. 6. Cubic regression curve shows the relationship between the species richness and water column depth in the study sites

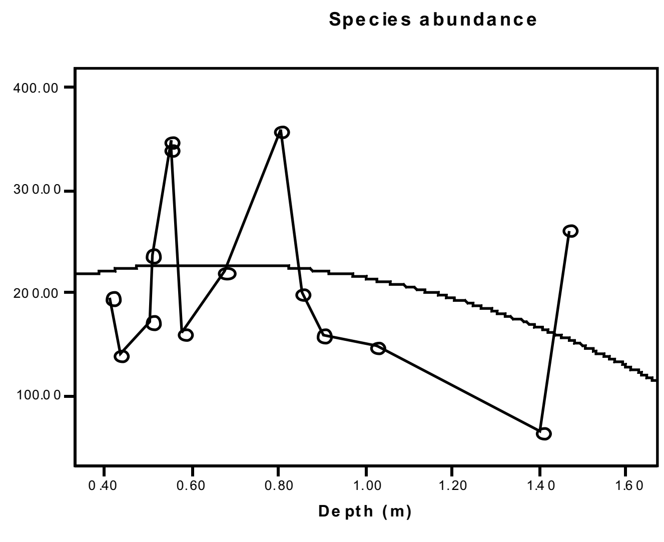

Fig. 7. Cubic regression curve shows the relationship between the species abundance and water column depth in the study sites

A significant relationship was also shown by water velocity and species richness and abundance through Quadratic regression (Fig. 8 and 9).

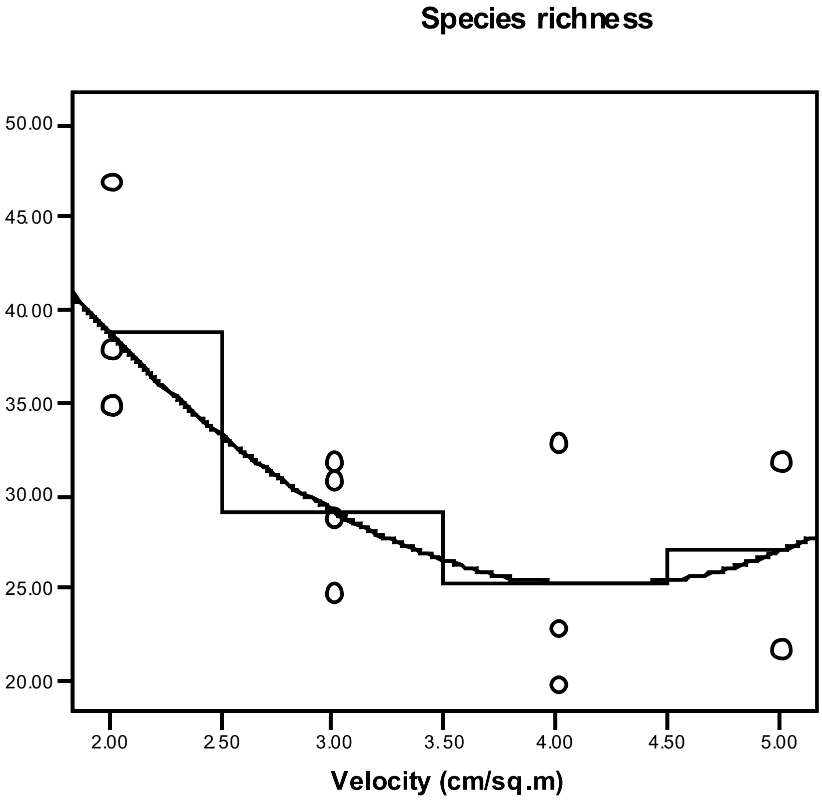

Fig. 8. Quadratic regression curve shows the relationship between the species richness and water velocity in the study sites

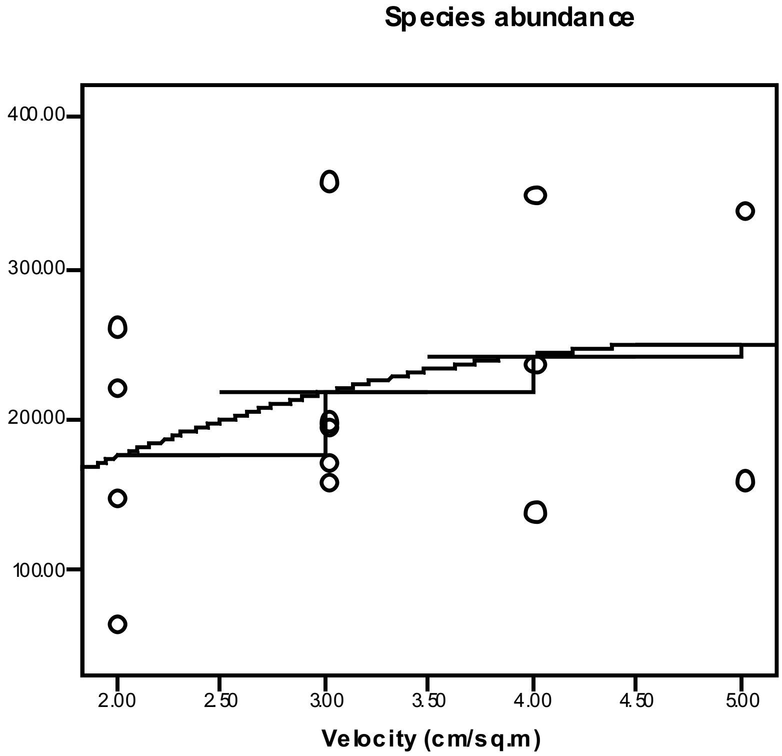

Fig. 9. Quadratic regression curve shows the relationship between the species abundance and water velocity in the study sites

Principal Component Analysis (PCA) also showed significant variance among study sites in relation to environmental variables. Bhadravathi showed its segregation from other sites in terms of habitat variables and showing its trend of pollution (Fig. 10).

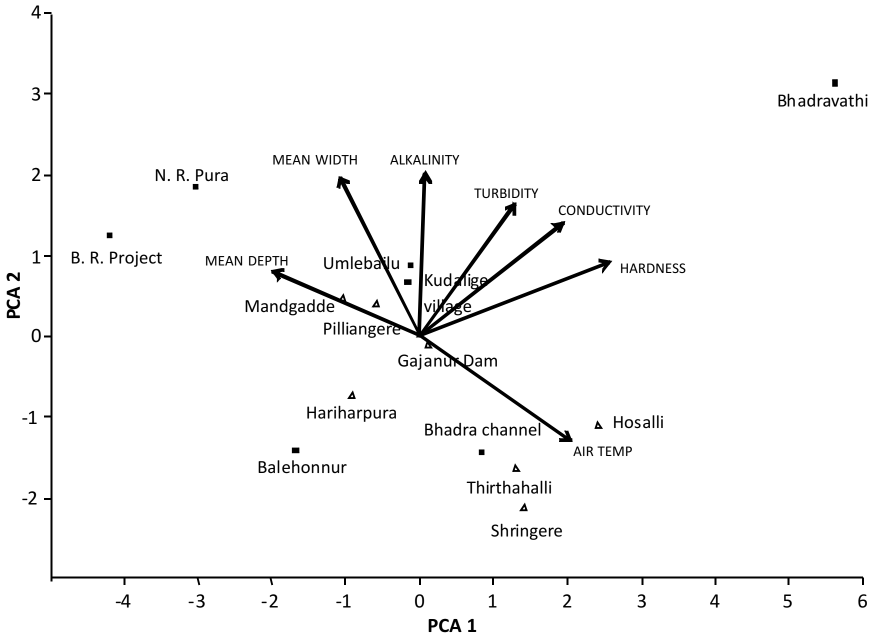

Fig. 10 Principal Component Analysis of habitat parameters from Tunga (Triangles) and Bhadra rivers (Filled squares).

DISCUSSION

The results of present study showed the nature of diverse array and high abundance of cyprinids (62.3%) relative to other species in both Tunga and Bhadra rivers, Karnataka. The dominant nature of cyprinids and their occurrence in pool habitat types are common phenomenon in the Western Ghats streams of Peninsular India (Arunachalam and Sankaranarayanan 1999; Arunachalam *et al*., 2005, 2006). The results are in accordance with that of (Bhat, 2003) who studied the fish diversity of central Western Ghats. Cyprinids have been found at similar proportions elsewhere in Southeast Asia, for example, in Borneo by Inger and Chin (1962) Watson and Balon (1984) Roberts (1989) and in Peninsular Malaysia by Johnson (1967), Bishop (1973), Mohsin and Ambak (1983) and Zakaria-Ismail and Sabariah (1994).

The distribution and composition of species is closely related to various factors such as food availability, breeding sites, water current, depth, topography and water chemistry (Ali *et al*., 1988). Understanding of fish-habitat relationships is essential to management and conservation policies of stream fishes (Wildhaber *et al*., 2000). However, stream fish assemblages are structured by habitat at various spatial scales. At local scales, instream physical habitat can influence community structure and function (Quist and Guy, 2001), while influences at broader scales (e.g., geology and climate) can be important determinants of species distributions (Marsh-Matthews and Matthews 2000). Because fish assemblages are strongly influenced by physical habitat, which have been long used to quantify the effects of disturbance on the environment (Karr, 1981). Disturbance to physical habitat (e.g., riparian vegetation alteration, impoundments (Jones *et al*. 1999; Marchetti and Moyle 2000; Quist *et al*. 2003) and water quality e.g., pollution, sedimentation (Rabeni and Smale 1995; Bonner and Wilde 2002) have resulted in fish assemblage shifts, decreased native species diversity, community homogenization, range reduction and extinction. These environmental factors have great impact on both species richness and the trophic structure of fish assemblages (Pouilly *et al*., 2006). In the present study some environmental factors were found to exercise a significant effect on species richness and total abundance. Altitude plays an important role in species diversity and abundance. It is generalization that diversity changes with respect to altitude on mountainsides and being lowest at high elevation. Our findings also support the above generalization. In both Tunga and Bhadra rivers, species richness and abundance were found high at lower elevation. Relatively high-protected areas are characterized by diverse fish species in a variety of habitats (Arunachalam, 2000). This could be co-related to Shringere site where fishes are protected in the sanctuary since quite a long time. The other reason would be that the exploitation was less in this site and shows that it is still in pristine condition. This supports the observation made by Rahim *et al*. (2002) in Malaysia and in Nepal by Edds (1993) and found that cyprinid and other species vary inversely with altitude.

Habitat variability involves various factors like food type, spawning period, water quality, substrate types and water flow patterns. Flow pattern is very essential factor for the fish species distribution which is shown by various workers like Aadland (1993); Arunachalam (2000); Barko *et al*. (2004) and Pirhalla (2004). Reduced current velocity may benefit fishes by decreasing energy expenditure and increasing growth rates through over feeding (Putman *et al*., 1995; Barko *et al*., 2004). Velocity rate is also one of the important microhabitat variables which influence the habitat selection of fishes, (Arunachalam *et al*., 1997a, 2006). Our findings support the above said concept by studying the cyprinid fish species like *Danio aequipinnatus, Barilius gatensis, Barilius canarensis, Barilius bendelisis, Salmostoma boopis* and *Salmostoma sardinella* which were found to prefer higher velocities. While species like *Puntius amphibius, Puntius filamentosus, Osteochilichthys thomassii* and *Osteochilichthys nashii* prefer low velocities. Other species like *Puntius sahyadrensis* and *Puntius arulius* were found to prefer stagnant water. Angermeier and Karr (1983) found species richness in small central Panama streams to increase with width (16 m) that was partially associated with food availability. The present study also did not witness any significant effect of depth on the cyprinid fishes. In the present study, dissolved oxygen and alkalinity were also important to species richness. The dissolved oxygen reflects the imposition of physiological constraints on metabolism while as alkalinity has got its positive influence on plant productivity (Claiborne, 1998). At most sites alkalinity was not high except Bhadravathi (90.00 mg/l), showing the condition of organic pollution. Probably this might be the reason for low fish species richness at Bhadravathi site. Dissolved oxygen was an important environmental factor to species richness also in studies by Zalewski and Naiman (1984) and Beamish *et al*. (2003).

Now the question arises that there might be some other reasons in addition to above, why cyprinids do show its dominant nature? It might be because of genetic and phenotypic adaptations, which enable them to occupy all diverse habitats. For example some cyprinid species like *Carassius carassius* exhibit a tolerance for low ambient oxygen through efficient extraction mechanisms or relying, at least in part, on anaerobic metabolism (Blazka, 1958). Most of the cyprinids for which information is available are eurythermal with a large capacity for thermal resistance adaptation (Wieser, 1991). Cyprinids get adopted very fast to even extreme environmental conditions than other groups. Studies show that some cyprinid species do exhibit some internal modifications in their digestive tract such as a reduction of stomach size and increased intestine length allowing them to survive on the typically more abundant plant material when animal material is scarce (Persson, 1991). The other reasons could be their wide range of familial life histories and reproductive styles (Balon, 1975 and Mills, 1991). This phenomenon enables them to contribute to high abundance and eventually facilitating colonization of unstable environments (Cambray and Bruton, 1985).

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