Int. J. Aquat. Biol. (2015) 3(1): 42-51
E-ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Effect of water quality on the composition of fish communities in three coastal rivers of Karnataka, India

Arunkumar Shetty[1], Mididodi Venkateshwarlu[1], Murugan Muralidharan*[2]

[1]Department of P.G. Studies and Research in Applied Zoology, Kuvempu University, Shankaraghatta, 577 451, Karnataka, India.
[2]Sri Paramakalyani Centre for Environmental Sciences, Manonmaniam Sundaranar University, Alwarkurichi, 627 412, Tamilnadu, India.

Abstract: The fish assemblage and diversity in relation to water quality of three coastal rivers Sita, Swarna and Varahi of Udupi district, Karnataka, India was studied. 71 species representing 7 orders, 20 families and 41 genera were recorded from 21 sites along the three rivers. Species composition varied longitudinally in relation to the environmental factors of the habitat. The downstream change in the three rivers indicates that fish assemblage changed with increasing loss of riparian canopy cover and increasing agricultural land-use. The richness and abundance of fishes were correlated with land-use type, canopy cover, pH and turbidity. Diversion of water, discharge of domestic sewage and agricultural runoff were prominent among the disturbances that alter the habitat quality.

Article history:
Received 2 March 2014
Accepted 14 April 2014
Available online 25 February 2015

Keywords:
Fish diversity
Karnataka
Sita River
Swarna River
Varahi River

Introduction

Faunal composition is distinct to geographic regions because the diversity and distribution of animals across a landscape can be interpreted in terms of their responses to the habitat characteristics (Belanger and Rodriguez, 2002). Tropical streams with their diverse habitats and the faunal components are commonly used to denote the unique features of pristine landscapes. Under mounting pressure from urbanization, this aquatic systems and their existence is being threatened in a number of ways. Fish communities despite their high degree of natural variability, are indicators of ecosystem health (Moyle, 1994) and hence the occurrence and abundance of fish species can be associated to water chemistry, physical habitat, and land-use activities to provide a more complete picture of quality of water and habitat across a river basin (Deacon and Mize, 1997). Further, freshwater fishes are poorly studied group since information regarding distribution, population dynamics and threats is incomplete, and most of the information is available from a few locations. Modifications in the water and habitat quality are mostly due to the forest removal, urbanization, embankments and diversions for irrigation and hydroelectric power stations (May and Brown, 2002). The deterioration of water quality has been recognized as a potential challenge which directly impacts the aquatic organisms leading to decline in diversity. Given the increasing pressure on aquatic systems, documenting the available richness and establishing accurate estimates of the magnitude of biodiversity loss resulting from common human disturbances, such as land-use change and habitat loss, species invasions, and climate change is of particular importance (Murphy and Romanuk, 2014). Physico-chemical characteristics are important determinants reflecting the condition of freshwater fish assemblages. It has been established that habitat variables such as water temperature, velocity, substrate, conductivity, depth and width, altitude and distance from the source influence river

* Corresponding author: Murugan Muralidharan
E-mail address: muralistream@gmail.com

fish composition (Li et al., 2012).

Extensive work has been done during the last few decades on freshwater fishes of Karnataka (Arunachalam et al., 1997, Arunachalam, 2000; Daniel, 2002; Bhat, 2003, 2004; Ashashree et al., 2008; Vijaykumar et al., 2009; Heda, 2009; Shahnawaz et al., 2010; Shivashankar and Venkataramana, 2012; Ahmad et al., 2013; Anandi et al., 2013). The database on freshwater fishes of Karnataka based on various works lists about 201 freshwater fish species belonging to 9 orders, 27 families and 84 genera. Though details on the distribution, habitat use and preferred substrate, tropic category and niche occupied by species may be available in literature, the ecology of many species vary throughout the range with respect to the changes in that region. In spite of such rich diversity, literature concerning ecology and fish community structure in Karnataka is scarce and little information is available on the coastal rivers. This study summarizes the composition and structure of fish assemblages from three coastal rivers Sita, Swarna and Varahi in southern part of Karnataka and the relation of physico-chemical characteristics on the fish communities of the respective rivers.

Materials and Methods

The Ichthyofaunal survey in three coastal rivers Sita, Swarna and Varahi of Udupi district, Karnataka state in India was carried out in 21 study sites (Fig. 1) during the period from September 2007 to September 2012. Selection of sites was randomly made such that each river comprised 7 stretches with varied environmental settings from upstream to the downstream. These rivers are mostly rain-fed and the magnitude of flow is related to rainfall. The River Sita originates from Narasimha Parvatha (13°29'7"N; 75°0'36"E) and flows for about 56.5 km in Udupi District and drains into Arabian Sea near Mabukala. The River Swarna takes its origin at Kuduremukh, (13°21'48"N; 74°49'54"E) and drains into Arabian Sea near Kalyanapura. The Varahi River has its origin at Hebbagilu (13°41'30"N; 74°59'35"E) near Agumbe in Shimoga district at an altitude of 730 m. There is a dam across Varahi River constructed near Yadur of Hosanagar Taluk. Further a hydro-electric power project is located at Siddapura, Udupi district. Varahi River flows about 65 km from its origin to drain in the Arabian Sea near Kundapura.

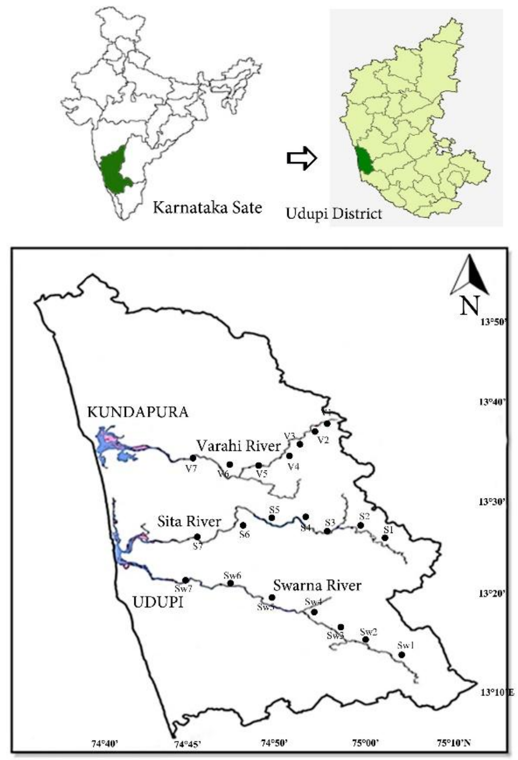

Figure 1. Sampling sites along the stretches of the three coastal rivers.

Sampling of fishes were made in different habitats such as pools, riffles, runs and cascades using gill nets (mesh sizes 10-34 mm), drag nets, scoop nets and cast nets. Most samples were released back immediately after capture, however few specimens (5) of unidentified species were preserved in buffered formalin (10%). Fish identification was done using standard literature by Day (1875), Talwar and Jhingran (1991) and Jayaram (2010). Water samples were collected (in 2 liter PVC container) from each site between 8 AM to 11 AM. Important water parameters such as water temperature, pH, conductivity, dissolved oxygen (DO), biological oxygen demand for a five-day period (BOD) and total dissolved solids of the stream water at each pre-selected sampling sites were determined using standard methods (APHA, 1998).

Table 1. Fish species abundance and distribution in Rivers - Sita, Swarna and Varahi.

Sl. No	Fish Species	River Sita		River Swarna		River Varahi	
		No	Sp Ab	No	Sp Ab	No	Sp Ab
1	*Hyporhamphus xanthopterus*	1	0.05	8	0.73	0	0.00
2	*Xenentodon cancila*	31	1.52	20	1.81	9	1.00
3	*Devario malabaricus*	36	1.77	0	0.00	0	0.00
4	*Devario aequipinnatus*	39	1.91	20	1.81	16	1.79
5	*Hypselobarbus curmuca*	13	0.64	0	0.00	0	0.00
6	*Hypselobarbus jerdoni*	32	1.57	31	2.81	31	3.46
7	*Hypselobarbus kolus*	20	0.98	17	1.54	18	2.00
8	*Hypselobarbus kurali*	18	0.88	18	1.63	28	3.13
9	*Labeo calbasu*	12	0.59	6	0.54	6	0.67
10	*Oreichythys cosuatis*	36	1.77	12	1.09	18	2.00
11	*Cirrhinus reba*	52	2.55	20	1.81	11	1.23
12	*Dawkinsa arulius*	42	2.06	0	0.00	0	0.00
13	*Dawkinsa filamentosa*	83	4.07	63	5.72	11	1.23
14	*Haludaria fasciata*	35	1.71	12	1.09	8	0.89
15	*Haludaria pradhani*	17	0.83	0	0.00	0	0.00
16	*Puntius amphibius*	51	2.50	16	1.45	18	2.00
17	*Puntius chola*	44	2.15	18	1.63	24	2.68
18	*Puntius dorsalis*	58	2.84	44	4.00	9	1.00
19	*Puntius sahyadriensis*	10	0.49	35	3.18	0	0.00
20	*Puntius parrah*	55	2.70	55	5.00	55	6.14
21	*Puntius vittatus*	30	1.47	17	1.54	17	1.90
22	*Pethia ticto*	30	1.47	0	0.00	0	0.00
23	*Systomus subnasutus*	63	3.09	18	1.63	18	2.00
24	*Salmophasia acinaces*	57	2.80	20	1.81	20	2.23
25	*Salmophasia boopis*	30	1.47	0	0.00	9	1.00
26	*Barilius barna*	58	2.85	20	1.81	20	2.23
27	*Barilius bakeri*	39	1.91	20	1.81	0	0.00
28	*Barilius canarensis*	37	1.81	18	1.63	6	0.67
29	*Rasbora daniconius*	18	0.88	31	2.81	23	2.57
30	*Garra gotyla stenorhynchus*	69	3.39	18	1.63	18	2.00
31	*Garra mullya*	28	1.37	0	0.00	0	0.00
32	*Balitora mysorensis*	13	0.64	28	2.54	8	0.89
33	*Bhavania australis*	12	0.59	10	0.91	9	1.00
34	*Schistura denisoni*	16	0.79	6	0.54	5	0.56
35	*Schistura nagodiensis*	4	0.20	0	0.00	0	0.00
36	*Aplocheilus lineatus*	12	0.59	11	1.00	2	0.22
37	*Microphis cuncalus*	11	0.54	0	0.00	0	0.00
38	*Megalops cyprinoides*	16	0.79	9	0.82	0	0.00
39	*Pseudophromenus cupanus*	15	0.74	10	0.91	11	1.23
40	*Glossogobius biocellatus*	4	0.20	0	0.00	0	0.00
41	*Glossogobius giuris giuris*	23	1.13	18	1.63	16	1.79
42	*Sicyopterus grisseus*	18	0.88	16	1.45	9	1.00

Table 1. Fish species abundance and distribution in Rivers - Sita, Swarna and Varahi (Continued).

43	*Chanda nama*	17	0.83	23	2.09	11	1.23
44	*Parambassis thomassi*	39	1.91	13	1.18	9	1.00
45	*Channa marulius*	18	0.88	16	1.45	13	1.45
46	*Channa orientalis*	20	0.98	9	0.82	16	1.79
47	*Channa striatus*	18	0.88	0	0.00	13	1.45
48	*Pristolepis marginata*	0	0.00	9	0.82	0	0.00
49	*Horabagrus brachisoma*	16	0.79	10	0.91	11	1.23
50	*Mystus armatus*	29	1.38	8	0.73	17	1.90
51	*Mystus cavasius*	12	0.59	5	0.45	9	1.00
52	*Mystus gulio*	20	0.98	18	1.63	12	1.34
53	*Mystus malabaricus*	12	0.59	12	1.09	20	2.23
54	*Mystus montanus*	0	0.00	8	0.73	0	0.00
55	*Mystus oculatus*	20	0.98	18	1.63	16	1.79
56	*Clarias batrachus*	6	0.29	17	1.54	12	1.34
57	*Heteropneustes fossilis*	8	0.39	0	0.00	0	0.00
58	*Pseudeutropius mitchelli*	22	1.07	9	0.82	10	1.12
59	*Ompok malabaricus*	24	1.18	12	1.09	16	1.79
60	*Ompok pabda*	0	0.00	12	1.09	0	0.00
61	*Ompok pabo*	20	0.64	10	0.91	10	1.12
62	*Wallago attu*	0	0.00	6	0.54	0	0.00
63	*Mastacembalus armatus*	13	0.98	5	0.45	11	1.23
64	*Etroplus canarensis*	24	1.17	22	2.00	18	2.00
65	*Etroplus maculatus*	48	2.36	0	0.00	12	1.34
66	*Etroplus suratensis*	27	1.32	18	1.63	17	1.90
67	*Oreochromis mossambicus*	38	1.86	12	1.09	12	1.34
68	*Carinotetraodon travancoricus*	22	1.07	0	0.00	0	0.00
69	*Gerres erythrourus*	0	0.00	0	0.00	8	0.89
70	*Gerres limbatus*	0	0.00	0	0.00	9	1.00
71	*Gerres filamentosus*	0	0.00	0	0.00	13	1.45

The length of each study site was about 100 m, a length sufficient to characterize the fish assemblage and to encompass all habitat units (Lyons, 1992). At each site, habitat variables such as stream width, depth, water velocity, canopy cover, and land use were measured or visually estimated along transects. Spherical densiometer was used to measure riparian canopy cover. Stream discharge was measured with an electronic flow meter, water transparency was measured with a secchi disk. Stream width was measured with measuring ropes at transect where flows were recorded and mean depth was calculated from the depths recorded during flow measurements. Land-use category was analyzed for a 50-m-wide region along each side of the stream upstream from the site. The categories were forested area, agricultural sites, grazing area and habitation expressed as % of the total area.

The relationship between the water quality parameters and the fish abundance and species richness were determined by Principal Component-Analysis (PCA) and Canonical Correspondence Analysis (CCA) using PAST (1.89) freeware (Hammer et al., 2001).

Results

Fishes collected during the study comprised of 71 species representing 7 orders, 20 families and 41 genera from the 21 study sites of the three rivers (Table 1). Cypriniformes was the species rich group

Table 2. The mean values (±SD) and ranges of different Physico-chemical parameters of Sita, Swarna and Varahi rivers of Udupi District, Karnataka, India.

	SITA RIVER		SWARNA RIVER		VARAHI RIVER	
Parameter	Mean (±SD)	Range	Mean (±SD)	Range	Mean (±SD)	Range
Air temp (°C)	29.28 ± 1.79	27-32	29.42 ± 1.71	27-32	29.14 ± 1.06	28-31
Water temp (°C)	25.0 ± 1.41	23-27	25.57 ± 1.27	24-27	25 ± 1.15	24-27
pH	6.95 ± 0.35	6.3-7.4	6.97 ± 0.31	6.5-7.4	6.87 ± 0.26	6.5-7.3
DO ($mg.L^{-1}$)	5.24 ± 1.02	3.6-6.1	6.75 ± 0.82	5.1-7.5	5.37 ± 1.33	3.2-6.9
Total Hardness ($mg.L^{-1}$)	14.7 ± 1.11	13-16	13.71 ± 1.49	12-16	14.42 ± 0.97	13-16
Alkalinity ($mg.L^{-1}$)	0.1 ± 0.01	0.03-0.08	0.05 ± 0.01	0.04-0.07	0.05 ± 0.01	0.04-0.06
TDS ($mg.L^{-1}$)	32.27 ± 1.84	29.4-34.5	31.0 ± 1.48	27.2-34.8	33.3 ± 2.02	30.3-35.8
Turbidity (NTU)	3.8 ± 1.8	1-6	3.7 ± 2.13	1-7	4 ± 2.16	1-7
Conductivity ($\mu S.cm^{-1}$)	53 ± 4.24	48-59	71.71 ± 7.12	50-82	48.14 ± 6.38	42-58

Table 3. Principal Component Analysis of water quality parameters as studied from Rivers Sita, Swarna and Varahi.

Variables	Code	Axis 1	Axis 2	Axis 3
Water temperature	WT	-0.0883	-0.2257	**0.848**
pH	pH	**0.9099**	-0.1559	-0.1907
Dissolved Oxygen	DO	0.2181	-0.4889	0.5561
Conductivity	C	**-0.8831**	0.4079	0.05089
Turbidity	T	**-0.8963**	0.2029	0.1376
Total Dissolved Solids	Ds	0.3371	**-0.6974**	0.1849
Mean width	Wid	-0.5599	**-0.6198**	-0.2821
Velocity	V	0.5495	0.5113	0.3674
Stream depth	dep	-0.1409	0.4415	0.4109
Land-use type	LU	**0.6984**	0.312	-0.2036
Canopy cover	Co	**0.7006**	0.3169	0.1047
Eigen value		4.193	2.046	1.55
% variance explained		38.12	18.60	14.15

Values bold are significant.

among the assemblage composition followed by other orders and this was consistent throughout the survey in all the three river samplings. Species representing the family Cyprinidae were dominant with higher abundance, followed by Bagridae (Catfishes) and Balitoridae (Loaches). As for river wise species richness, Sita River recorded 64 species (7 orders, 18 families and 38 genera), Swarna river 54 species (6 orders, 14 families and 36 genera) and Varahi river 52 species (5 orders, 14 families and 33 genera). *Dawkinsa filamentosa* and *Garra mullya* were prevalent in all the study sites of Sita River. Only represented exotic species was *Oreochromis mossambicus* which was predominant in the lower reaches of the river. *Pristolepis marginata*, *Mystus montanus*, *Ompok pabda* and *Wallago attu* were unique to river Swarna. *Gerres erythrourus*, *G. limbatus* and *G. filamentosus* were recorded only from the lower reaches of river Varahi. Species evenness was higher in the upstream sites than the other sampling locations in all the three river systems.

Water quality variables of the sampling stations of the three rivers were provided in Table 2. Environmental variables were subjected to Principal Component Analysis (PCA) and sites were

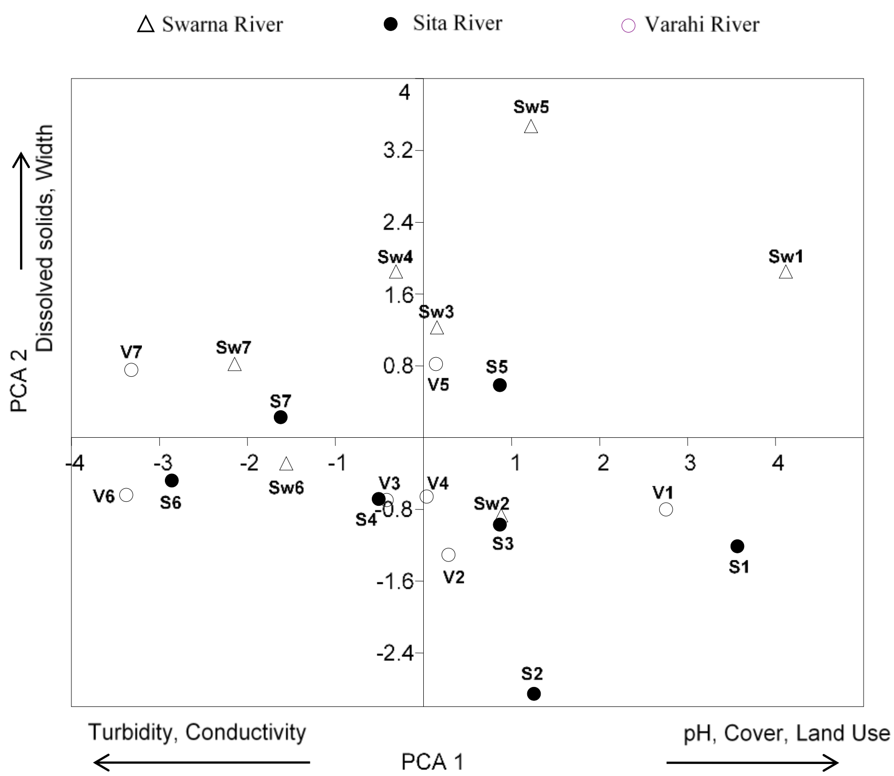

Figure 2. Principal component analysis biplot for environmental variables and sampling sites.

distinguished in relation to their influence on the system (Table 3). The PCA yielded five principal components (Eigen values>1) which altogether explained 80% of the variance in the data. The first two components alone explained 56.7% of the variance (Fig. 2). Conductance, turbidity and pH are significant and showed higher loadings than other variables. Factors land-use and canopy cover contributed to discriminating between sites of the three rivers. Water temperature had highest loadings on the PC3. pH values varied between sites, however the trend decreased from upstream sites towards downstream gradually. Canopy cover (%) was higher and land-use category was unaltered evergreen forests in sites close to the source of the river systems. Turbidity and conductivity values were higher in the downstream in all the three rivers. PCA results also indicate that the patterns of variations in physico-chemical variables among the three rivers and between the sampling sites are represented by patterns of variation in the habitat characteristics governing the respective sites. Species richness was influenced by water quality variables such as turbidity, conductivity and alkalinity. Fish diversity was inversely proportional to the level of turbidity, lower the turbidity higher the diversity. Species also differed with respect to level of turbid conditions of the sites. *Dawkinsa filamentosa*, *Xenentodon cancila*, *Devario aequipinnatus*, *Glossogobius giuris* and *Etroplus suratensis* were abundant and distributed widely. Cyprinids in general occupied clear and shallow habitats. *Oreochromis mossambica* was the non-native species that has naturalized in most of the sites. *Heteropnuestus fossilis* occurred only in limited sites of the three rivers.

The first and second canonical axes of CCA explained roughly 36% and 20% of the general variance, respectively (Fig. 3). The CCA axis 1 was influenced much by the habitat morphological features land-use category and percent canopy cover rather than the water quality parameters. Factors velocity, pH and depth were correlated but were however unrelated to temperature, hardness, conductivity and width. The ordination plane, on the basis of environmental factors, divided the fish

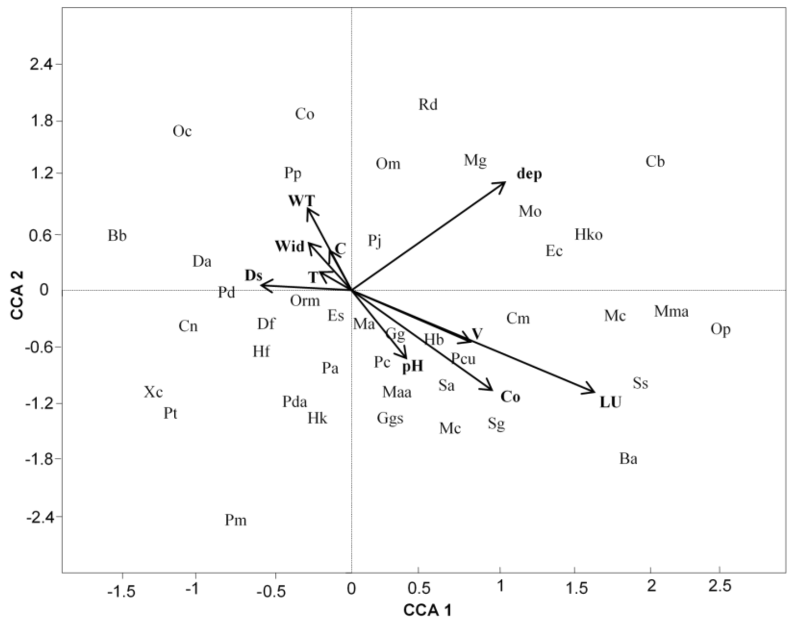

Figure 3. Canonical Correspondence Analysis biplot for environmental variables and fishes.

assemblage into groups irrespective of the family they represent. The group defined by land-use category preferred the sites close to undisturbed evergreen forests the species composed of rare and specialized forms such as *Bhavanaia australis* (Ba), *Sicyopterus griseus* (Sg), *Mastacembeles armatus* (Ma), *Horabagrus brachysoma* (Hb) and *Garra gotyla stenorhyncus* (Ggs). The same group was also positively influenced by the factors percent canopy cover, velocity and pH.

The second group in the ordination segregated based on the habitat depth, species that preferred shallow to moderate depth *Xenentodon cancila* (Xc), *D. filmentosa* (Df), *Puntius amphibius* (Pa), *Pristolepis marginata* (Pm), *Parambassis thomassi* (Pt) and *Hypselobarbus kurali* (Hk) formed a cluster. The other group that occurred in deeper stretches of the river systems was predominately of bagrid cat fishes *Clarias batrachus* (Cb), *Mystus gulio* (Mg), *M. oculates* (Mo) and a few cyprinids *Rasbora daniconius* (Rd) and *Hypselobarbus kolus* (Hko). Other species not found in the above groups, notably *Channa orientalis* (Co) occurred in turbid waters influenced by low flow and high alkaline conditions most of these sites were adjacent to agricultural land. The study reveals that the environment and habitat variables influence fish assemblage structuring in the Rivers Sita, Swarna and Varahi.

Discussion

Differences in fish communities in the three river systems reflect the water quality, habitat structure and the land-use pattern they flow through. Cyprinids dominated the species list comprising most of the endemic species as has been reported previously by other studies (Pethiyagoda, 2006; Senthilmurugan and Prabahar, 2012) in South Asian streams. The dominance of cyprinids in the tropical Indian rivers is due to their high adaptive variability (Johnson and Arunachalam, 2009) and the availability of extensive heterogeneous habitat structure (Bhat, 2004). Our observation that the catfishes and loaches are dominant next to cyprinids and they co-occur with cyprinids in appropriate habitats was similar to the study in river systems of the Central Western Ghats (Bhat, 2003) and the Bhadra River (Shahnawaz et al., 2010) of Karnataka. *Gerres erythrourus*, *G. limbatus* and *G. filamentosus* are estuarine fishes able to withstand the salinity variations and move between the river and the sea through the river mouth. Insectivore species were dominant in streams with good canopy cover and substrates due to the availability of terrestrial and aquatic insects that constitute major part of their diet. As for the distribution of fishes based on trophic category the omnivore species increased in a downward direction towards lowland. This was because the nature of food depends to a great extent upon the nature of environment (Bhuiyan et al., 2006) and species diversity in a given area is the result of stochastic ecological and evolutionary factors that interact on both local and regional scales (Leibold and Mcpeek, 2006).

Physico-chemical variables of lotic systems are considered as important factors in structuring fish assemblage (Marchetti and Moyle, 2001; May and Brown 2002). Turbidity, pH and conductivity influenced the fish diversity and distribution in the present study. Increase in turbidity showed a decline in fish species however the species count was adjusted by few carnivore species known to occur in turbid and deep habitats. The species richness and abundance were higher in clear steams as penetration of sunlight into the water favored the algal growth supporting benthic feeders and algal scrapers like *G. mullya*. The higher turbidity levels could be due to higher suspended solids by human activity. Increasing trend in total dissolved solids may probably be due to stagnation at least at some stretches (Campos et al., 1992). The high conductivity may be due to greater ionic concentration of inlet flow (Oliveira, 2004). It was related to total dissolved solids content and its value becomes higher with proportional increase of the degree of pollution (Prabhakar et al., 2012), which consequently impacts fish diversity, as evident in some sites during this study.

Dissolved Oxygen (DO) fluctuate between sites and is dependent on flow and the organic matter content at the particular site, thus could vary between sites and rivers (Bhalla et al, 2007). Variation in water temperature is regarded as one of the most important factors of environmental variability in rivers as it influences the chemical, biochemical and biological characteristics of the water body and the fish production (Rashleigh, 2004). Width and depth varied between sites irrespective of its position from its origin, flow regulation due to various activities in its course could be the reason. Variations in pH, conductivity and turbidity could be the effect of municipal sewage and the pollution especially due to discharge of effluents from small industries along the stretches of these rivers. Transformation of the surrounding landscape, removal of riparian vegetation agricultural activities adjacent to river lead to increasing nutrient concentrations, mainly of inorganic nitrogen (Pizarro et al., 2010). Moreover, water flow and habitat modifications associated with urbanization and deforestation also influence the habitat quality (Vyas et al., 2012; Ahmad et al., 2013).

A variety of factors like water quality, habitat availability, flow variability and nutrient supplies from riparian habitats control the abundance and distribution of river fishes. Such environmental variables are easier to predict than other biotic variables like predation and competition. The present results corroborate with the established fact that environmental factors have great impact on both species richness and the trophic structure of fish assemblages (Pouilly et al., 2006). The diversity and distribution of fishes of any aquatic system depends on the certain features like type of the ecosystem, water level fluctuations, morphometric features and bottom that have great implications. The unique distribution and variation in fish species observed during our study among the three rivers is likely because of variation in natural environmental features like geographic and geological conditions (Matthews and Robinson, 1998). This suggests that habitat quality and species diversity are related. Among the activities that influence the habitats as observed during the study channelization of water, discharge of industrial effluents and mixing of agricultural runoff are management priorities. Effective measures in controlling these activities rely on the local bodies that govern the stretches of water. Conservation priorities that may yield promising results include strengthening and directing resources to organizations and institutions meant for resource conservation.

Acknowledgements

We gratefully acknowledge Dr. Pramod Mohan, Project Manager, MPEDA, Mangalore and Dr. Uday Kumar Shetty, Programme Officer Zilla Parishad, Udupi, Karnataka for their support during the study.

References

Anandhi U.D., Sharath Y.G., Prashanth R.G. (2013). Study of ornamental fish diversity and water quality of Adda Hole stream, Kabbinale forest range, Western Ghats. Advances in Applied Science Research, 4(5): 158-164.

Ahmad S., Muralidharan M., Venkateshwarlu M., Arunachalam M. (2013). Distribution pattern, endemism, threat status and conservation measures of fishes in the Tunga and Bhadra rivers of Western Ghats, India. Environmental Biology of Fishes, 96(10-11): 1245-1256.

APHA (1998). Standard methods for the examination of water and waste water, American Public Health Association, Inc. New York. 20th Ed., 10-161.

Arunachalam M. (2000). Assemblage structure of stream fishes in the Western Ghats (India). Hydrobiologia, 430: 1-31.

Arunachalam M., Johnson J.A., Sankaranarayanan A. (1997). Fish diversity in Rivers of Northern Karnataka. International Journal of Ecology and Environmental Sciences, 23: 327-333.

Ashashree H., Venkateshwarlu M., Reneuka Swamy H.M. (2008). Diversity of fish fauna in Nagathibelagula pond shimoga, Karnataka. Advances in Aquatic Ecology, 2: 95-97.

Belanger G., Rodriguez M.A. (2002). Local movement as a measure of habitat quality in stream Salmonids. Environmental Biology of Fishes, 64: 155-164.

Bhuiyan A.S., Afroz S., Zaman T. (2006). Food and feeding habit of the juvenile and adult snakehead *Channa punctatus* (Bloch), Journal of Life and Earth Sciences, 1(2): 53-54.

Bhat A. (2003). Diversity and composition of freshwater fishes in river systems of Central Western Ghats, India. Environmental Biology of Fishes, 68: 25-38.

Bhat A. (2004). Patterns in the distribution of freshwater fishes in rivers of Central Western Ghats, India and their associations with environmental gradients. Hydrobiologia, 529: 83-97.

Campos H., Steffen W., Agüero G., Parra O., Zúñiga L. (1992). Limnological studies of Lake Rupanco (Chile). Morphometry, physics, chemistry, plankton and primary productivity. Archive für Hydrobiologie Supplement Band, 90: 85-113.

Daniels R.J.R. (2002). Freshwater fishes of Peninsular India. Madhav Gadgil (ed). India-A life scape 2. Universities Press, Hyderabad.

Day F. (1875-78). The fishes of India; being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon. Text and Atlas in 4 parts. London, 788 p.

Deacon J.R., Mize S.V. (1997). Effects of water quality and habitat on composition of fish communities in the upper Colorado River basin. U.S. Geological Survey Fact Sheet, 122: 6 pp.

Bhalla R., Lomte V.S., Mule M.B. (2007). Investigation of physicochemical parameters of Godavari River in Nashik city, Maharastra. Pollution Research, 26(2): 495-498.

Hammer Ø., Harper D.A.T., Ryan D.D.(2001). PAST: Paleontological statistics software package for education and Data analysis. Paleontologia Electronica, 4: 9 p.

Heda N.K. (2009). Freshwater fishes of central India: A field guide. Vigyan Prasar, Department of Science and Technology, Government of India, Noida, 169 pp.

Jayaram K.C. (2010).The freshwater fishes of the Indian region, Narendra Publishing House, New Delhi. 616p.

Johnson J.A., Arunachalam M. (2009). Diversity, distribution and assemblage structure of fishes in streams of southern Western Ghats, India. Journal of Threatened Taxa, 1(10): 507-513.

Li J., Huang L., Zua L, Kano Y., Sato T., Yhara T. (2012). Spatial and temporal variation of fish assemblages and their associations to habitat variables in a mountain stream of north Tiaoxi River, China. Environmental Biology of Fishes, 93: 403-417.

Leibold M.A., Mcpeek M.A. (2006). Coexistence of the niche and neutral perspectives in community ecology. Ecology, 87: 1399-1410.

Lyons J. (1992). The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management, 12: 198-203.

Marchetti M.P., Moyle P.M. (2001). Effects of flow regime on fish assemblages in a regulated California stream. Ecological Applications, 11(2): 530-539.

Matthews W.J., Robinson. H.W. (1998). Influence of drainage connectivity, drainage area, regional species and richness of fishes of the interior highland in Arkanasa. American Midland Naturalist, 139: 1-19.

May J.T., Brown. L.R. (2002). Fish communities of the Sacramento River basin: implications for conservation of native fishes in the Central Valley, California. Environmental Biology of Fishes 63: 373-388.

Moyle P.B. (1994). Biodiversity, biomonitoring, and the structure of stream fish communities. Pages 171-186 In: S. Loeb, A. Spacie (Eds.). Biological Monitoring of Freshwater Ecosystems. Lewis Publishing, Inc., Boca Raton, Florida.

Murphy G.E.P., Romanuk T. N. (2014) A meta-analysis of declines in local species richness from human disturbances. Ecology and Evolution, 4(1): 91-103.

Oliveira E.F., Goulart E., Minte-Vera C.V. (2004). Fish diversity along spatial gradients in the Itaipu Reservoir, Paraná, Brazil. Brazilian Journal of Biology, 64(3a): 447-458.

Pethiyagoda R. (2006). Conservation of Sri Lankan freshwater fishes in the fauna of Sri Lanka: Status of taxonomy, conservation and research. C.N.B Bambaradeniya (Ed). IUCN, Colombo, Sri Lanka.

Pizarro J., Vergara P.M., Rodríguez J.A., Sanhueza P.A., Castro S.A. (2010). Nutrients dynamics in the main river basins of the centre-southern region of Chile. Journal of Hazardous Materials, 175: 608- 613.

Pouilly M., Barrera S., Rosales C. (2006). Changes of taxonomic and trophic structure of fish assemblages along an environmental gradient in the Upper Beni watershed (Bolivia). Journal of Fish Biology, 68: 37-156.

Rashleigh B. (2004). Relation of environmental characteristics to fish assemblages in the upper French broad river basin, North Carolina. Environmental Monitoring and Assessment, 93: 139-156.

Senthilmurugan A., Prabaharan C.P. (2012). Fish diversity in relation to Physico-Chemical characteristics of Kamala River basin of Darbhanga district, Bihar, India. International Journal of Pharmaceutical and Biological Archives, 3 (1): 211-217.

Shahnawaz A., Venkateshwaralu M., Somashekar D.S., Santhosh K. (2010). Fish diversity with relation to water quality of Bhadra River of Western Ghats (India). Environmental Monitoring and Assessment, 161(1-4): 83-91.

Shivashankar P., Venkataramana G.V. (2012). Ichthyodiversity status with relation to water quality of Bhadra River, Western Ghats, Shimoga District, Karnataka. Annals of Biological Research, 3 (10): 4893-4903.

Talwar P.K. Jhingran A.G. (1991). Inland fishes of india and adjacent countries. Vol. I and II. Oxford - IBH Publishing Co. Pvt. Ltd., New Delhi, India.

Vijaykumar K., Vijayalaxmi C., Parveen Z. (2009). Ichthyofaunal diversity of Kagina River in Gulbarga district of Karnataka. The Ecoscan, (2)2: 161-163.

Vyas V., Damde D., Parashar V. (2012). Fish biodiversity of Betwa River in Madhya Pradesh, India with special reference to a sacred Ghat. International Journal of Biodiversity and Conservation, 4(2): 203-216.