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Fish Biodiversity of Tunga, Bhadra and Tungabhadra Rivers of Karnataka, India

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Abstract

The fish samples were collected from selected stations along the stretch of Tungabhadra river. The multimetric index of biotic integrity (IBI) method was used to integrate the data from individual, population assemblage and ecosystem levels are transformed into a single numerical indicator and quality rating for water. A total of 34, 42 and 48 fish species have been recorded in Tunga, Bhadra and Tungabhadra rivers, respectively. The species belong to the order Cypriniforms was found to be most dominant followed by the order Siluriformes, Perciformes, Osteoglossiformes, Synbranchiformes, Beloniformes and Cyprinodontiformes. The non-native species are generally more successful where native species are depleted in anthropogenically altered water systems. The findings from the study will benefit the planning and management of sustainable fisheries and conservation of natural resources at national level.

Keywords: Freshwater, fish diversity, Cypriniforms, Index of Biotic Integrity.

Introduction

Biodiversity is essential for stabilization of ecosystems, protection of environmental quality and for understanding species diversity. Fish biodiversity essentially represents the fish faunal diversity, occurrence, distribution, abundance and conservation of rich variety of fish species and it also supports the commercial fisheries in river ecosystems. In India there are 2,500 species of fishes of which 930 live in freshwater and 1,570 are marine[1]. About 21,730 species of fishes have been recorded in the world of which, about 11.7% are found in Indian waters[2].

Biological communities reflect water quality conditions since they are sensitive to changes in the wide array of environmental factors. Fish species are an important indicator of health of an aquatic ecosystem[3,4] because of sensitivity to subtle environmental changes[5] and represents a wide range of tolerance at community level[6], the impact of agricultural, municipal and industrial effluents in aquatic environments[7] and cumulative effects of anthropogenic disturbances on habitat conditions[8]. The abundance and health of fish will show the health of water bodies[9]. The distribution and composition of the fish species in each habitat were closely associated with various factors such as the availability of food, breeding sites, water current, depth, topography and physico-chemical properties of water[10]. The adverse effects of human activities have resulted in degradation of stream and riverine ecosystem which ultimately alter the structure and function of stream biota[11].

The river system has been influenced by human activities such as agriculture, mining, discharge of liquid and solid wastes from towns and cities along the stretch of the river. The major industrial activities on the Tunga, Bhadra and Tungabhadra river systems are Mysore paper mills, Iron and Steel Ltd. at Bhadravathi, Harihara Polyfibre industries and sugar industries at Davanagere and mining activities at Hospet. In addition to these, solid and liquid wastes are also discharged into the river along the stretches due to population habitation and their activities from major town and cities such as Kudremukh, Sringeri, Thirthahalli, Shimoga, Bhadravathi, Kudli, Honnalli, Davanagere, Ronebannur, Mylara-Guthal, Hospet, Hampi, Kampli, Gangavathi, Sindanoor, Manvi, Gillesgur and Raichur. Fish assemblages have been widely used as ecological indicators to assess and evaluate the level of degradation and health of rivers and streams at various spatial scales[12]. It has been believed that fishes and their rich diversity and dominance in the river indicate the cleanliness of water. Several studies have been carried out on freshwater fish diversity in different river system of India[13-22]. However, the study about the fish diversity in Tunga, Bhadra and Tungabhadra rivers of Karnataka is lacking. Hence, the present study was aimed to investigate the fish diversity of Tung, Bhadra and Tungabhadra river systems of Karnataka and to suggest water quality states using IBI index.

Material and Methods

Study area: The river Tungabhadra is formed by the union of two small seasonal rivers-Tunga and Bhadra. Both the rivers take birth in the vicinity of Varaha Parvatha at Gangamoola in Chikkamagalore district, Karnataka. A total of 16 stations were fixed along the stretches of the rivers (figure-1), 4 stations in river Tunga - Gangamoola (GML), Sringeri (SGR), Theerthalli

(TRH), Shimoga (SMG); 4 stations in Bhandra - Balehonnur (BHR), Bhadravati Highway (BVH), Bhadravati city (BVC) and Holehoonnur (HHR) and in river Tungabhadra - Koodli sangama (KSM), Honnali (HNH), Harihara city (HHC), Holematta (HLM), Mylar-Guthal (MLG), Annegundhi (ANG), Kampali (KMP) and Gillesugur (GGR). The stations were selected based on the human activities on the river banks, urbanization and industrial activities.

Fish collection and identification: The fish samples were collected from each selected stations along the stretches of rivers Tunga, Bhadra and Tungabhadra using selective and non selective fishing gears *viz*, drag net, seine net, gill net etc, and samples were preserved in 5-7% formalin and transported to laboratory. Fishes were identified to their species level by following standard literature[23-28].

Index of Biotic Integrity (IBI): The multimetric index of biotic integrity (IBI) method was used to integrate the data from individual, population assemblage and ecosystem levels are transformed into a single numerical indicator and quality rating for water. The IBI was calculated for each station following the methods of Fausch et al.[29], Hughes et al.[30] and CIFRI Report[31]. The scoring criteria were modified and developed as per Hughes et al.[30]. The qualitative evaluation of IBI scores were prepared by following Karr et al.[7], Ganasan and Hughes[32], Hughes et al.[30] and Das[33]. The impaired IBI score was used when the values were less than 50% of the maximum observed since the highest metric values observed do not represent numerically disturbed condition as marginally impaired score.

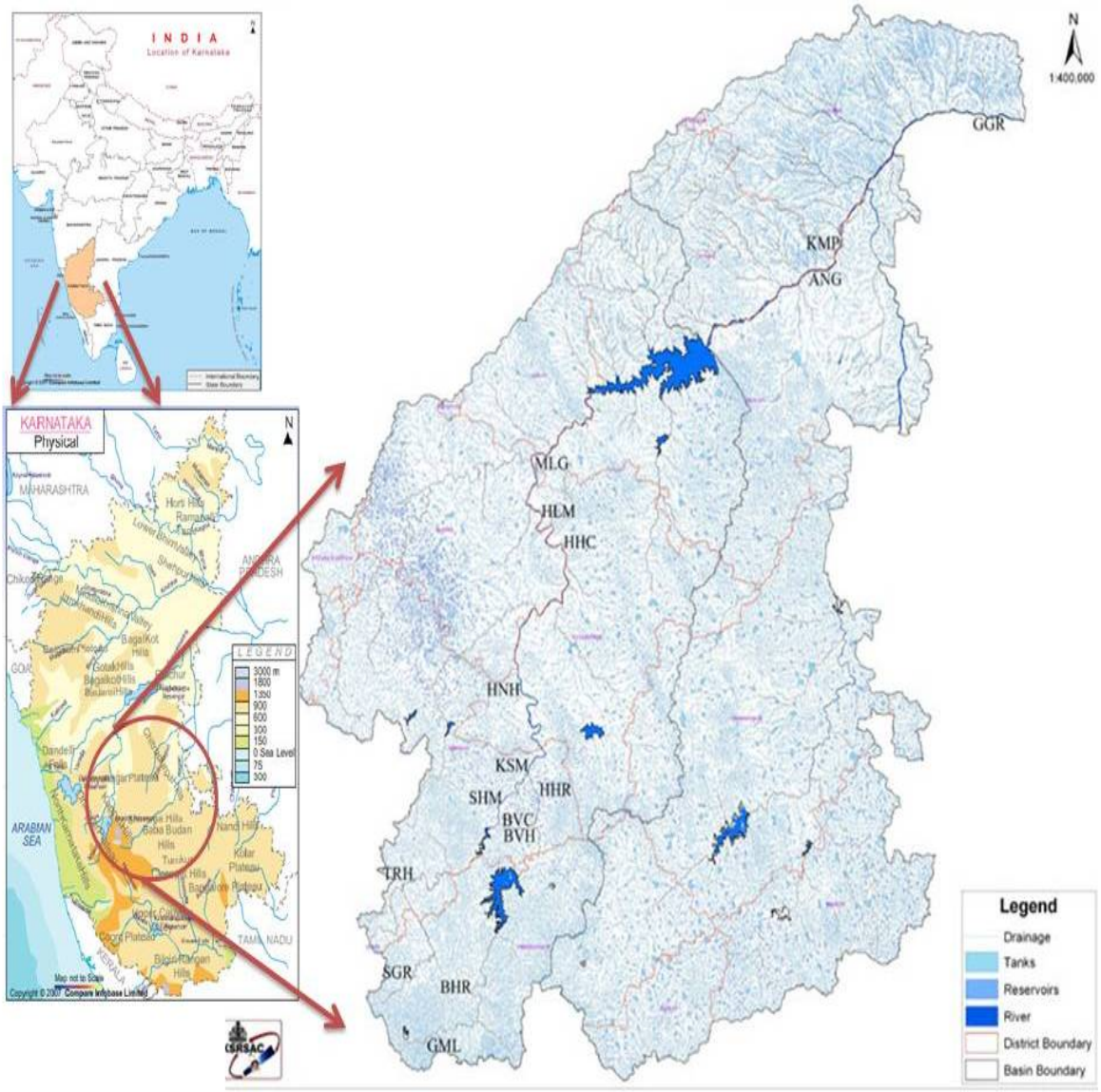

Figure-1
Map showing locations of sampling stations along the river Tunga, Bhadra and Tungabhadra

Species richness is a common measure of biological diversity generally decreased with environmental degradation[5]. The total number of species was modified from Karr[5] to the number of native species and number of native families by Ganasan and Hughes[32] and Das[33]. The number of species is used as a measure of biological diversity that decreases with increased degradation. The families are used as measuring biodiversity[34] that decrease as anthropogenic disturbance increases. Among three matrixes, percentage of omnivores, carnivores were retained and percentage of insectivores was replaced with % of herbivores as insectivore's species. Herbivores fishes are sensitive to physical and chemical alteration in habitat are indication of good quality of waters.

Results and Discussion

River Tunga: Distribution and composition of fish: A total of 34 fish species belonging to 7 orders, 14 families and 29 genera have been recorded during the present study in the river Tunga (table-1). Kumar Naik et al.[35] reported 37 fish species belonging 11 families and 4 orders in Tunga river stretch from Gajanoor fishing village to Kudali of Shivamogga district. The species belong to the order Cypriniforms was found to be most dominant constituting 27.95 - 98.97% followed by the order Silueriformes 0.39 - 31.32%; Perciformes 0.15 - 25.29%; Osteoglossiformes 1.08 - 8.14 %; Synbranchiformes 0.14 - 3.21%; Beloniformes 0.001 - 4.04% and Cyprinodontiformes 0.001 - 2.70% (figure-2). Kumar Naik et al.[35] also observed the dominance of order Cypriniformes with 23 species followed by Siluriformes (11 species) and Perciformes (2 species). The predominant fish fauna in south Asia belongs to the carp family Cyprinidae[36,37]. The members of carps were dominated by 13 - 24 species and cat fishes were represented by 4 - 10 species.

The total number of species varied between 39 species (GML) and 52 species (SMG) (figure-3a). The species of carps were more dominant in the upper stretches (GML) and decreased towards lower stretches (SMG). The cat fishes and other miscellaneous species were appeared to be dominant in the lower stretches compared to upper stretches.

The fish species belong to cypriniformes were dominant and have showed continuous distribution representing the species such as *Barilius bendelisis, B. canarensis, Danio aequipinnatus, D. malabaricus, D. devario, Puntius jerdoni, P. faciatus, P. chola, P. sarana, P. ticto, P. sophore, P. pulchelis, P. sahyadrensis, Rasbora damicus* and *Cirrhinus mrigala.* Among cat fishes the species such as *Aorichthys seenghala, Wallago attu* and *Ompok bimaculatus* were dominant. The miscellaneous species represented by *Oreochromis mossambicus, Notopterus notopterus, Parambassis ranga* and *Aplocheilus lineatus* were also present.

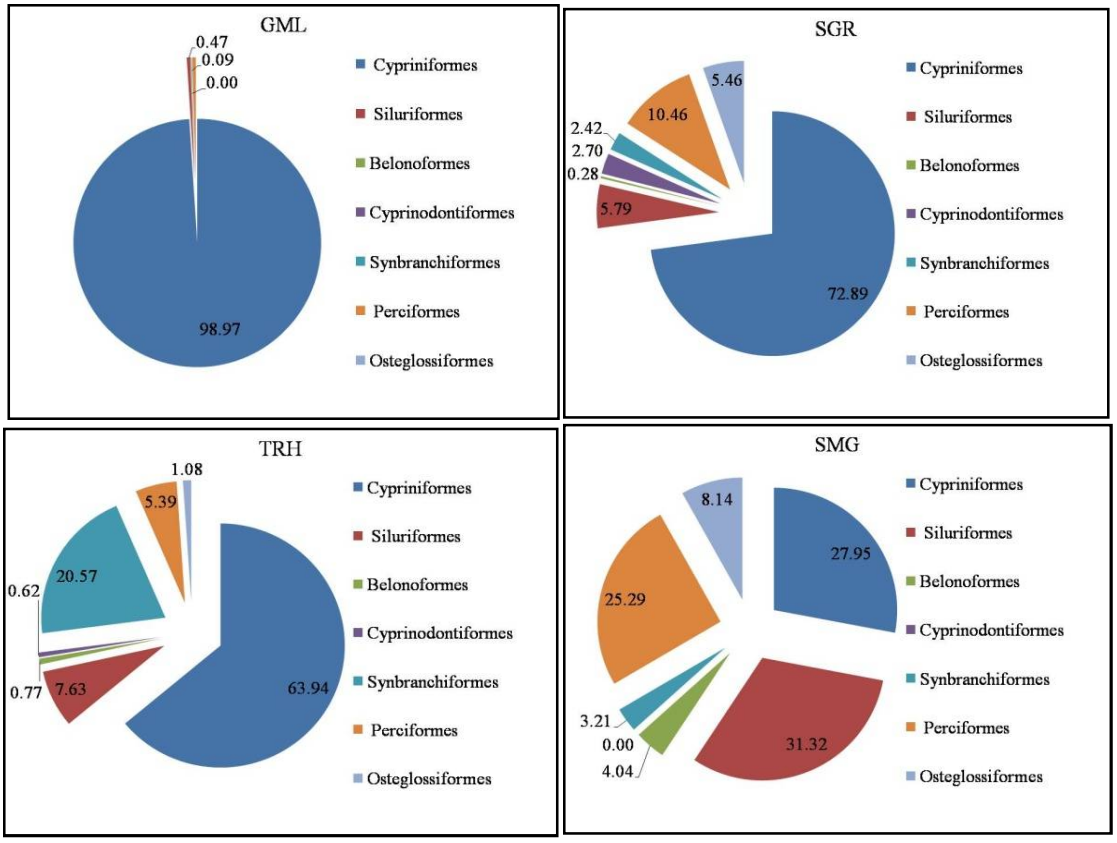

Figure-2
Percent occurrence of major groups of fishes at different stations in river Tunga

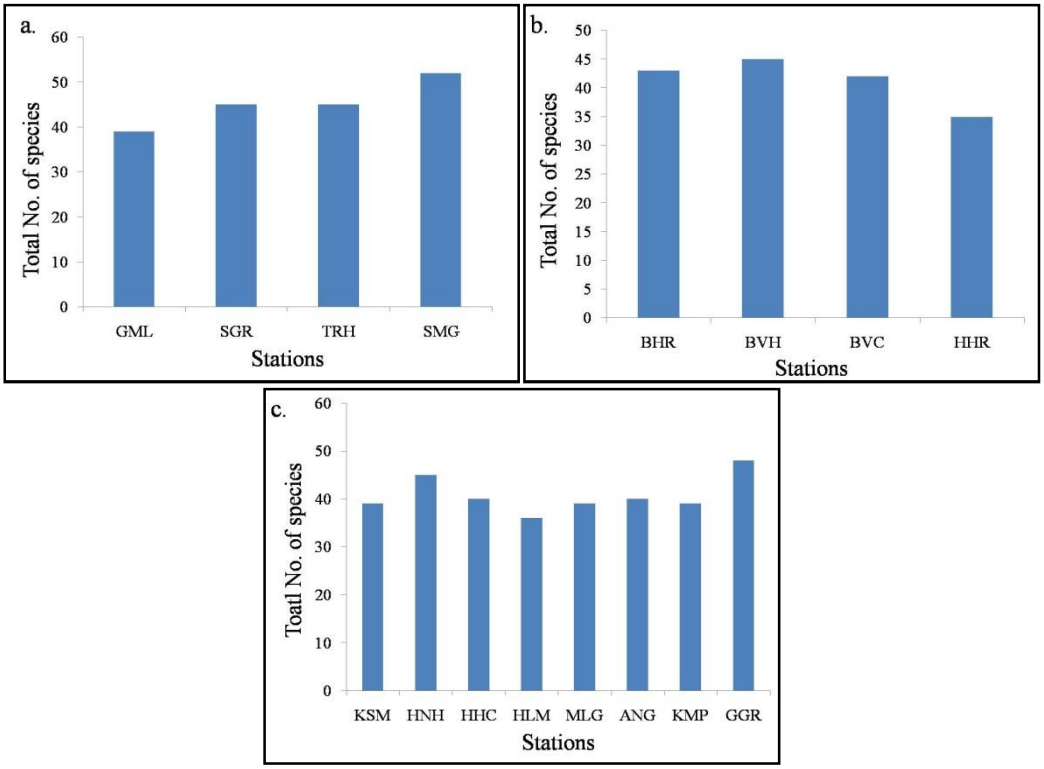

Figure-3 (a-c)
Total number of species of fishes at different stations in rivers a. Tunga, b. Bhadra and c. Tungabhadra

Fish population density was relatively high at upper stretches of river - SGR and SMG (161 No/m² and 164 No/m², respectively) and lower in GML (96 No/m²) which mainly contributed by carps belong to cypriniforms (figure-4a). Carps such as *Labeo bata, L. calbasu, L. rohita* and *Salmostma boopis* were dominant at station Shimoga (SMG) characterized by high BOD, high load of microbial organisms represented by fecal coliformes (FC) and total coliformes (TC). The catfishes such as *Aorichthys seenghala, Clarias batrachus* and *Wallago attu were* dominant and other miscellaneous species of fishes reported include *Pangasius bimaculatus, Oreochromis mossambicus, Notopterus notopterus, Mastacembelus armatus* and *Mystus cavasius.* The site at GML appeared to be clean water with low BOD, TSS, low FE and TC and represented by species of carps belong to cypriniforms - *Barilius barna, B. canarensis, Danio aequipnnatus, D. malabaricus, Puntius chola, P. jardoni, P. sahydrensis, P. serana, P. sophora, P . ticto* and *Rasbora daniconius* have showed their dominance. Whereas species such as *Chela untrachi, Cirrhinus fulunge, Labeo bata, L. potail, Puntius amphibious, P. faciatus, P. filamentasus, P. pulshelus, P. melanostigma* and *P. vittatus have* showed discontinuous distribution with infrequent occurrence.

Species diversity index is varied from 1.65 at SMG to 2.3 at GML (figure-5a). Study of Kumar Naik et al.[35] reported highest Simpson's index of diversity in Gondichatnalli (0.8802) followed by Shivamogga (0.8580) and Honnapura (0.8523) of Tunga river.

IBI assessment: The Index of Biotic Integrity (IBI) indicated the assemblage, occurrence and distribution of fishes in relation to water quality.

It is clear that comparatively lower values of IBI were recorded (figure-6a) at SMG indicating the poor water quality due to discharge of untreated sewage and city waste into the river contributed for the lower values of IBI. Also, it was observed that the number of native species belong to cypriniforms were appeared to be high in the upper reaches (GML) compared to the lower stretches (SMG). Further, the composition of fish species revealed that the number of herbivorous species and the number of intolerant species were observed to be reduced in moderately impaired waters at SMG. In contrast to this the percentage of exotic species and percentage of tolerant species have increased in their number in the same site during the study period indicating the adaptability of fishes to stressed impaired site at SMG.

The species such as *Labeo bata, L. calbasu, Cyprinus carpio, Oreochromis mossambicus, Cirrhinus mrigala, Channa marulius, Clarias batrachus, Notopterus notopterus, Pangasius pangasius, Mystus cavasius* and *Xenontodon cancilla* were more dominant and found to be mainly benthic and tolerant species found in this region of the river. Based on their trophic habitats, composition of fishes revealed that the changes were significantly prevalent in moderately impaired site at SMG. Thus, the percentage of omnivorous and carnivorous fishes has

increased while the percentage of herbivorous was decreased in the stressed and moderately impaired site. The fishes with diseases and anomalies were not observed during the study period.

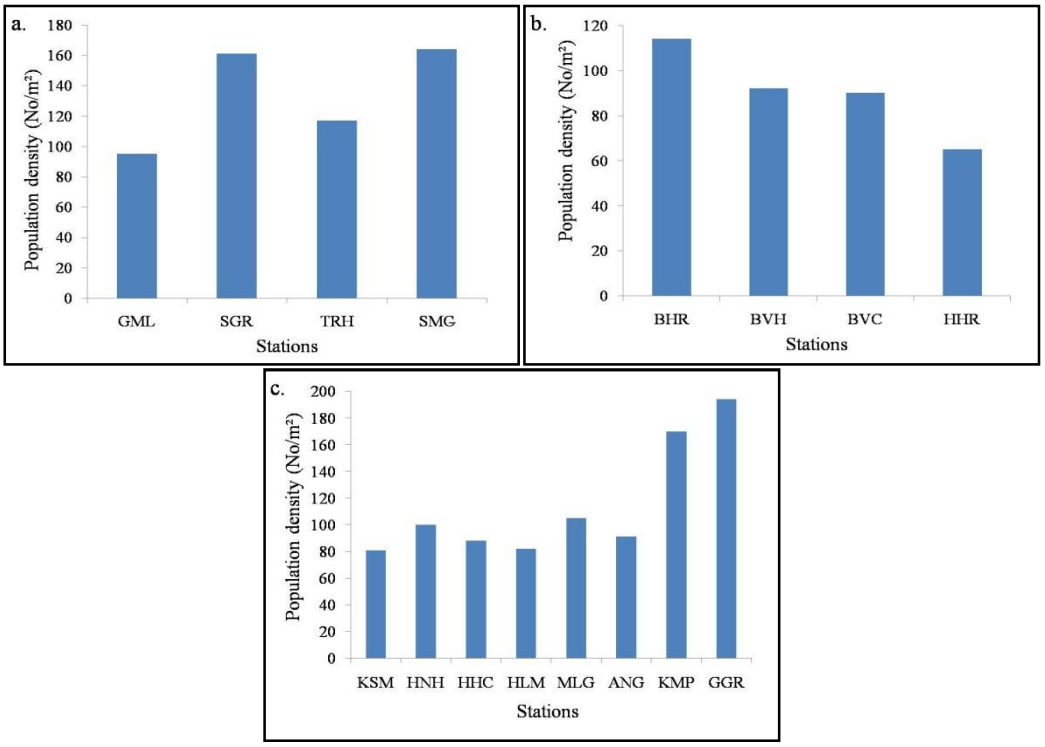

Figure-4 (a-c)
Population density of fishes at different stations in rivers a. Tunga, b. Bhadra and c. Tungabhadra

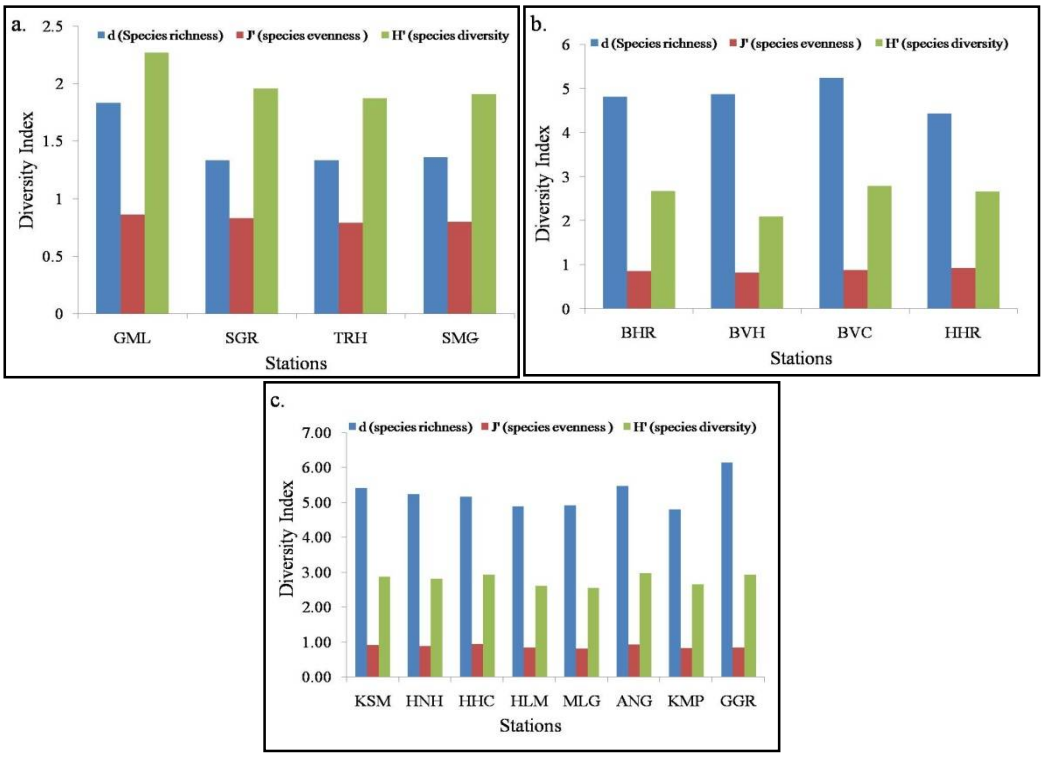

Figure-5 (a-c)
Fish diversity indices at different stations of rivers a. Tunga, b. Bhadra and c. Tungabhadra

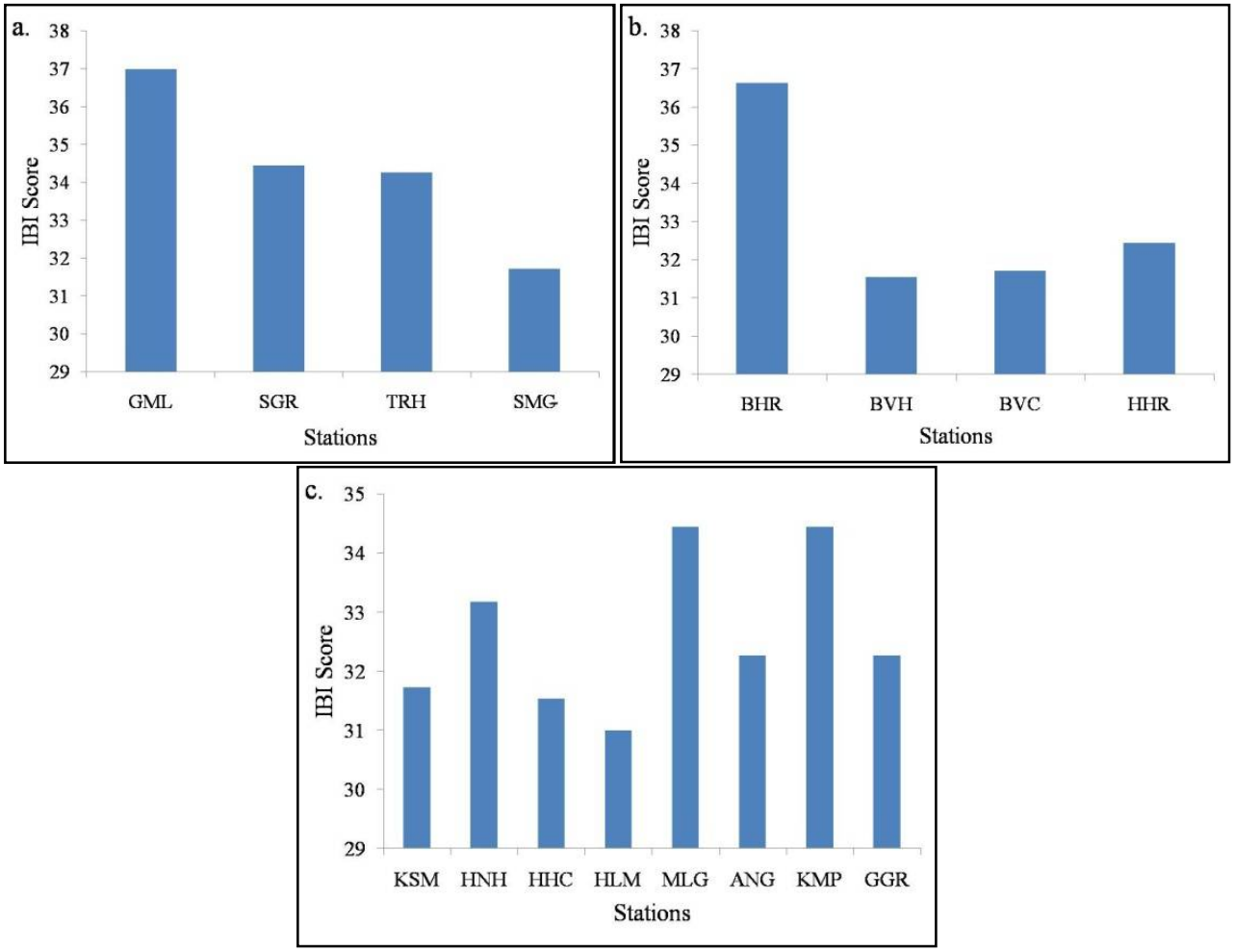

Figure-6 (a-c)
IBI scores at different stations of rivers a. Tunga, b. Bhadra and c. Tungabhadra

The present study showed that the sites at Gangamoola, Sringeri and Theerthalli were found to be acceptable in terms of fish assemblages indicating less environmental stress. Thus, it can be inferred that the upper stretches of river Tunga supported good fishery production, whereas the lower stretches of river at Shimoga did not support good fishery due to impaired water quality as indicated by the presence of low oxygen content, higher concentrations of BOD, ammonia, nitrate and phosphate. The lower starches of river have supported more exotic, tolerant, omnivorous and carnivorous fishes with an uneven distribution in space and time.

River Bhadra: Distribution and composition of fish: A total of 42 fish species belonging to 7 orders, 14 families and 29 genera have been recorded during the present study (table-1). The species belong to the order Cypriniformes were found to be most dominant constituting 30.60 - 69.40% followed by the order Siluriformes 9.80 - 13.15%, Perciformes 2.71 - 16.33%, Osteoglossiformes 0.48 - 3.82%, Synbranchiformes 0.56 - 2.39%, Belonoformes 0.88 - 1.91% and Cyprinodontiformes 1.20 - 1.75% (figure-7). The members of carps were dominated by 15 - 25 species and cat fishes were represented by 6 - 7 species. Earlier study reported 25% of cat fish groups followed by major carps and other fishes with 20.83%[38].

Several studies have been carried out on fish diversity in relation to water quality of Bhadra river of Karnataka[38-40]. The total number of fish species reported by Thirumala et al.[38] was comparatively low (33 species), whereas number of fish species reported by Shahnawaz et al.[39] and Shivashankar and Venkataramana[40] were comparatively high (56 and 48 species, respectively) than the total number of fish species reported in the present study (42 species). Their study revealed the dominance of cyprinids in Bhadra river. This indicated that cyprinidae fishes have wide range of distribution and composition.

The total number of species varied between 35 species (HHR) and 42 species (BVH) (figure-3b). The species of carps were more dominant in the upper stretches (HHR and BVC) and decreased towards lower stretches (HHR). The cat fishes and other miscellaneous species were appeared to be dominant in

the lower stretches (HHR) compared to upper stretches (BHR).

The fish species belong to cypriniforms were dominant and have showed continuous distribution, representing the species such as *Barilius bendelisis, Danio aequipinnatus, D. malabaricus, D. denario, Puntius jerdoni, P. sarana, P. ticto, P. sophore, P. pulchelis, P. sahyadrensis, Rasbora damicus, Labeo potail, L. angra* and *Salmostoma boopis.* Among cat fishes, the species such as *Aorichthys seenghala, Wallago attu* and *Ompok bimaculatus* were dominant. The miscellaneous species represented by *Oreochromis mossambicus, Notopterus notopterus* and *Parambassis ranga* were also present.

Fish population density was relatively high at upper stretches of river - BHR (118 No/m²) and lower in HHR (70 No/m²) which mainly contributed by carps belong to cypriniforms (figure-4b). Carps such as *Barilius bendelisis, Labeo potail, L. bata, L. calbasu, L. rohita, P. sahyadrensis, P. ticto, P. sophore* and *Salmostma boopis* were dominant at BVC and BVH characterized by high BOD, high load of microbial organisms represented by faecal coliformes (FC) and total coliformes (TC). The catfishes such as *Mystus cavacious, Clarias batrachus, Channa marulis* and *Wallago attu were* dominant and other miscellaneous species reported were *Pangasius bimaculates, Oreochromis mossabica, Notopterus notopterus* and *Mastacembelus armatus.* The station at HHR appeared to be clean water with low BOD, TSS, low FE and TC and represented by species of carps belong to the cypriniforms - *Danio aequipinnatus, D. malabaricus, D. denario, Puntius jerdoni, P. sarana, P. ticto, P. sophore, P. pulchelis, P. sahyadrensis, Rasbora rasbora, Labeo potail, L. angra* and *Salmostoma boopis* have showed their dominance. The species such as *Cirrhinus cirrhosa, Labeo bata, L. calbasu, L. potail, Puntius amphibious, P. faciatus, P. filamentasus, P. pulshelus, P. melanostigma* and *Xenontodon cancilla* have shown discontinuous distribution with infrequent occurrence.

Species diversity index is varied from 2.81 at BVH to 3.18 at BVC (figure-5b). Shannon-Weaver diversity indices of fish species found in Bhadra river reported by Thirumala et al.[38], Shahnawaz et al.[39] and Shivashankar and Venkataramana[40] was ranged from 2.20 to 4.10, 2.28 to 3.15 and 3.64 to 3.85, respectively.

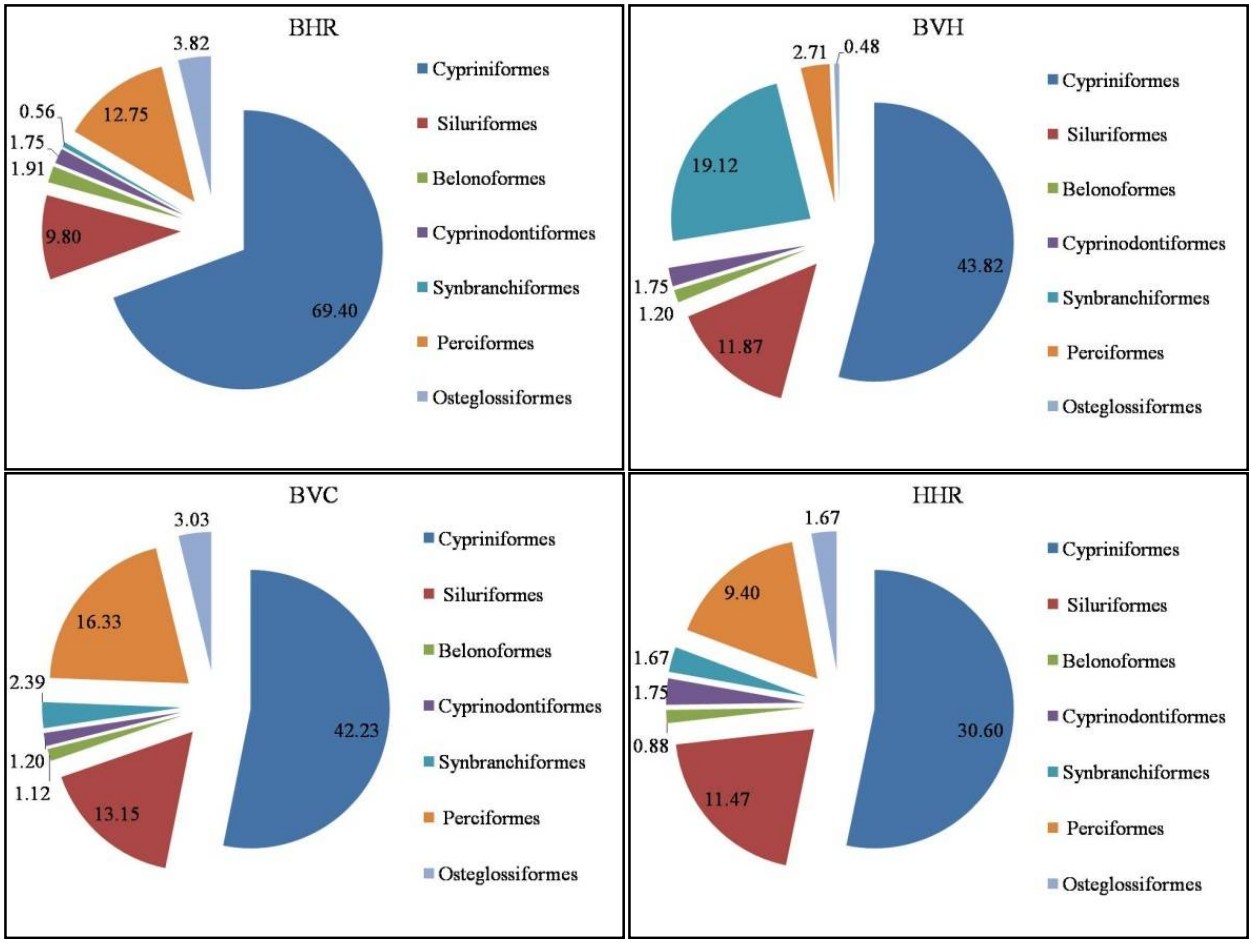

Figure-7
Percent occurrence of major groups of fishes at different stations in river Bhadra

IBI assessment: It is evident that comparatively lower values of IBI were recorded at BVC and BVH (figure-6b) indicating the poor water quality due to discharge of untreated sewage and city waste into the river contributed for the lower values of IBI. It was observed that the number of native species belong to cypriniformes were appeared to be high in the upper reaches (BHR) compared to the lower stretches (BVC and BVH). Further, the composition of fish species revealed that the number of benthic species and the number of intolerant species were observed to be reduced in moderately impaired waters at BVC and BVH. In contrast to this the percentage of exotic species and percentage of tolerant species have increased in their number in the same site during the study period indicating the adaptability of fishes to stressed and impaired site at BVC and BVH. The species such as *Labeo bata, L. calbasu, Oreochromis mossambicus, Cirrhinus mrigala, Channa marulius, Clarias batrachus, Notopterus notopterus, Pangasius pangasius, Mystus cavasius* and *Xenontodon cancilla* were dominant.

Based on their trophic habitats, composition of fishes revealed that the changes were significantly prevalent in moderately impaired site BVC and BVH. Thus, the percentage of omnivorous and carnivorous fishes has increased while the percentage of herbivorous was decreased in the stressed and moderately impaired site.

Further, the present study revealed that stations at Balehonnur and Holehonnur were found to be acceptable in terms of fish assemblages indicating less environmental stress. Thus, it can be inferred that the upper and lower stretches of river Bhadra supported good fishery production, whereas the middle stretches of river Bhadra at Bhadravathi did not support good fishery due to impaired water quality as indicated by the presence of low oxygen content, higher concentrations of BOD, ammonia, nitrate and phosphate. The middle starches of river have supported more exotic, tolerant, omnivorous and carnivorous fishes with an uneven distribution in the river.

River Tungabhadra: Distribution and composition of fish: A total of 48 fish species belonging to 7 orders, 14 families and 29 genera have been recorded (table-1). The species belong to the order Cypriniformes was most dominant constituting 27.16 - 53.30% followed by the order Siluriformes 11.87 - 21.34%, Perciformes 18.01 - 45.76%, Osteoglossiformes 2.29 - 6.83%, Synbranchiformes 0.82 - 5.23%, Beloniformes 0.53 - 1.46 % and Cyprinodontiformes 0.91 - 2.07% (figure-8). The members of carps were dominated by 16 - 25 species and cat fishes were represented by 7 - 13 species. The fish survey made by Shahnawaz and Venkateshwarlu[41] indicated that both Tunga and Bhadra rivers are rich in fish diversity and they reported a total of 77 species represented by 5 orders, 18 families and 44 genera. They also observed that among 77 species, the order Cypriniformes was the most dominant group in the assemblage composition with 62.3% followed by Siluriformes with 18.18%, Perciformes with 16.88%, Osteoglossiformes with 1.29% and Cyprinodontiformes with 1.29%, respectively.

The total number of species varied between 28 species (HLM) and 48 species (GGR) (figure-3c). The species of carps were more dominant in the upper and lower stretches (HNH, MLG, ANG, KMP and GGR) and decreased in the middle stretches (HHC and HLM) near Harihara city. The cat fishes and other miscellaneous species have greater distribution at all stations along the stretches of this river unlike in Tunga and Bhadra.

The fish species belong to cypriniforms were dominant and have showed continuous distribution, representing the species such as *Barilius barna, B. bendelisis, Cirrhinus mrigala, Danio aequipinnatus, D. malabaricus, D. devario, Gerra gotyla, Labeo angra, L. fimbriatus, Puntius jerdoni, P. sarana, P. sophore, Rasbora rasbora* and *Salmostoma boopis.* Among cat fishes, *Aorichthys aor, A. seenghala, Mystus cavasius, Rita pavimentata, Clarius batrachus* and *Wallago attu* were dominant. The miscellaneous species represented by *Pangasius pangasius, Mastacembelus armatus, Channa marulis, C. striatus, Etroplus maculates, Oreochromis mossambicus, Glossogobius giuris* and *Notopterus notopterus* were dominant at the lower stretches of the river. Recently, Chaudhary[42] studied on the effect of effluent and sewage discharge on the aquatic life and the spatial distribution of fish species in 200 km stretch of Tungabhadra river on the basis of oxygen variability throughout the river using QUAL2K model. This simulated model was used to locate the indicator species on the river on the basis of dissolved oxygen level. Also this model revealed that the spatial distribution and species diversity of some fish species is varying with the variation in the effluent load and flow of water in the river.

Fish population density was relatively high at lower stretches of river- GGR (183 No/m²) however in the middle stretches in KSM and HLM (81 No/m²) which mainly contributed by catfishes, carps and miscellaneous species belong to cypriniforms, siluriformes, perciformes and osteglossiformes (Fig. 4c). The carps such as *Barilius barna, Gerra gotylastehynchus, Labeo angra* and *L. potail. Labeo bata, Puntius sarana, P. sophore* and *Salmostma boopis* were dominant at KSM, HHC and HLM characterized by high BOD and high load of microbial organisms represented by fecal coliformes (FC) and total coliformes (TC). The catfishes such as *Clarias batrachus, Rita gogra, Wallago attu, Pangasius bimaculates, Pangasius bimaculates* and *P. saran* were dominant and other miscellaneous species reported were *Oreochromis mossabica, Notopterus notopteru, Channa marulis, C. srriatu, Etroplus maculates* and *Mastacembelus armatus.* The station at HHR appeared to be clean water with low BOD, TSS, low FE and TC and represented mainly by species of carps belong to the cypriniforms - *Danio aequipinnatus, D. devario, Puntius jerdoni, P. sarana, P.*

sophore, Rasbora rasbora, Labeo angra and *Salmostoma boopis*. The species such as *Cirrhinus cirrhosa, Labeo bata, L. calbasu, L. Potail, Puntius amphibious, P. faciatus, P. filamentasus, P.jerdoni, P. melanostigma* and *Xenontodon cancilla* have shown discontinuous distribution with infrequent occurrence.

Diversity index of fish species of Tungabhadra shown in Figure 5c. Species diversity index is varied from 2.79 at MLG to 3.42 at GGR. The evenness of fish fluctuated between 0.61 at HLM and 0.98 at HHC.

IBI assessment: It is clear that comparatively lower values of IBI were recorded at Koodli (KSM) and Harihara city (HHC and HLM) (Fig. 6c) indicating the poor water quality due to discharge of untreated sewage and city waste and also discharge of waste from the Harihara polyfibre factory into the river contributed for the lower values of IBI. During the present investigation, it was observed that the number of native species belong to Cypriniforms, Siluriformes and Perciformes were appeared to be high in the upper and lower stretches of the river compared to the disturbed site at lower stretches (HNH, MLG, ANG, KMP and GGR). Further, the composition of fish species revealed that the number of benthic species and the number of intolerant species were observed to be increased in moderately impaired waters at KSM, HHC and HLM. In contrast to this the percentage of exotic species and percentage of tolerant species have increased in their number in the same site during the study period indicating the adaptability of fishes to stressed impaired sites at BVC and BVH. The species such as *Labeo bata, L. calbasu, Oreochromis mossambicus, Cirrhinus mrigala, Channa marulius, Clarias batrachus, Notopterus notopterus, Pangasius pangasius, Mystus cavasius, Channa marulis, C. srriatus, Etroplus maculates* and *Xenontodon cancilla* were dominant and mainly benthic and tolerant species were found in this region of the river.

Diversity and composition of freshwater fishes in other river systems of Karnataka were reported by many researchers. Bhat and Hegde[43] studied on fish diversity in major tributaries of river Bedti, Uttara Kannada district and reported 19 species belonging to 4 families (Cyprinidae, Balitridae, Aplochaeilidiae and Ambassidae). The occurrence of 14 freshwater fish species belonging to five orders (Cypriniformes, Siluriformes, Channiformes, Mastacembeliformes and Osteoglossiformes) in the Mullameri river, a minor tributary of Bheema River of Gulbarga district was reported by Vijaylaxmi et al.[14]. The fish diversity in the four rivers namely, Sharavati, Aghanashini, Bedti and Kali of Central Western Ghats was studied by Bhat[44] and they reported high number of fish species (63 species) in Bedti, followed by Kali (53 species), Aghanashini (52 species) and Sharavathi (51 species), respectively. Devi Prasad et al.[13] reported 45 species of fish belonging to 15 families and 31 genera in major wetlands of Mysore. Kumar Naik et al.[45] investigated on the fish resources quantitatively by studying the ichthyofaunal diversity of Varada river stretch from Karehonda fishing village to Bankasana of Soraba and reported a total of 78 species belonging to 18 families and 6 orders.

Based on their trophic habitats, composition of fishes revealed that the changes were significantly prevalent in moderately impaired sites at KSM, HHC and HLM. Thus, the percentage of omnivorous and carnivorous fishes has increased while the percentage of herbivorous was decreased in the stressed and moderately impaired sites. The fishes with diseases and anomalies were not observed during the study period.

The stations at Honnalli, MLG, Anegundhi, Kampli and Gillesgur were found to be acceptable in terms of fish assemblages indicating less environmental stress. Thus, it can be inferred that the upper and lower stretches of river Tungabhadra supported good fishery production whereas the middle stretches of river at Harihara city did not support good fishery due to impaired water quality as indicated by the presence of low oxygen content, higher concentrations of BOD, ammonia, nitrate and phosphate. The middle stretches of river have supported more exotic, tolerant, omnivorous and carnivorous fishes with an uneven distribution in the river.

Conclusion

The upper stretches of river Tunga supported good fishery production, whereas the lower stretches of river at Shimoga did not support good fishery due to impaired water quality as indicated by the presence of low oxygen content, higher concentrations of BOD, ammonia, nitrate and phosphate. The lower starches of river have supported more exotic, tolerant, omnivorous and carnivorous fishes with an uneven distribution in space and time. The upper and lower stretches of river Bhadra supported good fishery production, whereas the middle stretches of river Bhadra at Bhadravathi did not support good fishery due to impaired water quality as indicated by the presence of low oxygen content, higher concentrations of BOD, ammonia, nitrate and phosphate. The middle starches of river have supported more exotic, tolerant, omnivorous and carnivorous fishes with an uneven distribution in space and time. The upper and lower stretches of river Tungabhadra supported good fishery production whereas the middle stretches of river at Harihara city did not support good fishery due to impaired water quality as indicated by the presence of low oxygen content, higher concentrations of BOD, ammonia, nitrate and phosphate. The middle stretches of river have supported more exotic, tolerant, omnivorous and carnivorous fishes with an uneven distribution in space and time. The findings from the study will benefit the planning and management of sustainable fisheries and conservation of natural resources at national level.

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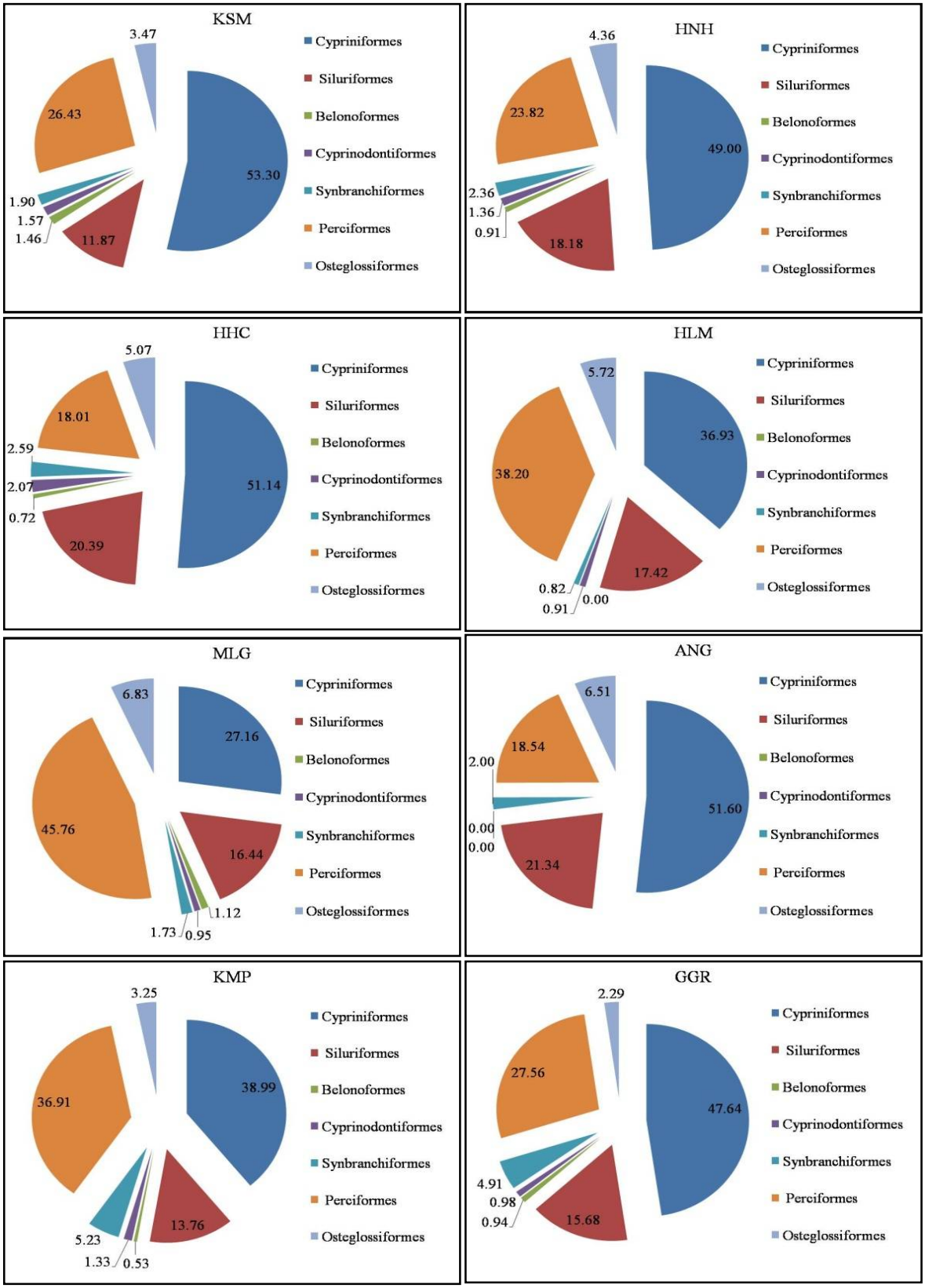

Figure-8
Percent occurrence of major groups of fishes at different stations in river Tungabhadra

Table-1
Fish species recorded in the sampling stations of Tunga, Bhadra and Tungabhadra rivers

Classification/Species	Tunga				Bhadra				Tungabhadra							
	GML	SGR	TRH	SMG	BHR	BVH	BVC	HHR	KSM	HNH	HHC	HLM	MLG	ANG	KMP	GGR
Order-Cypriniformes																
Family-Cyprinidae																
Barilius barna	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
Barilius backeri	+	-	-	-	+	+	+	-	-	+	-	+	-	+	-	-
B. bendelisis	+	+	+	-	+	+	-	-	+	+	+	+	+	+	+	+
B. canarensis	+	+	+	+	+	+	-	-	-	+	-	-	-	-	-	-
Catla catla	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Chela untrachi	+	+	-	-	+	+	+	-	+	+	-	+	-	+	-	+
Cirrhinus cirrhosa	+	+	+	+	-	-	+	+	+	+	+	-	+	+	-	+
C. fulungee	+	-	-	-	+	-	-	+	+	+	+	-	-	-	-	-
C. mrigala	+	+	-	+	+	+	-	+	+	+	+	-	+	+	+	+
C. reba	-	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+
Ctenopharygdon idella	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Cyprinus carpio	-	+	-	+	-	+	+	+	+	+	+	+	+	-	+	+
Danio aquipinnatus	+	+	+	+	+	+	+	+	+	+	-	-	+	-	+	-
D. devario	+	+	-	-	+	+	-	-	+	+	-	-	-	-	-	-
D. malabaricus	+	+	+	+	+	-	+	+	-	+	-	-	-	-	-	-
Garra gotyla stenorhynchus	-	-	+	+	-	+	+	-	+	+	-	+	+	+	+	+
Hypophthalmichthys molitrix	-	-	+	-	-	-	-	+	-	+	-	+	+	+	+	+
Labeo angra	-	+	-	+	+	-	+	-	+	+	+	+	+	-	-	-
L. bata	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+

Classification/Species	**Tunga**				**Bhadra**				**Tungabhadra**							
	GML	**SGR**	**TRH**	**SMG**	**BHR**	**BVH**	**BVC**	**HHR**	**KSM**	**HNH**	**HHC**	**HLM**	**MLG**	**ANG**	**KMP**	**GGR**
L. calbasu	-	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+
L. fimbriatus	+	+	+	+	-	+	-	-	+	+	+	+	-	+	+	+
L. porcellus	+	+	-	+	-	-	-	+	-	+	+	-	+	+	-	+
L.potail	+	+	+	-	+	+	+	+	-	-	-	+	-	-	+	+
L. rohita	-	-	+	+	-	+	+	-	+	-	+	+	-	+	+	+
P.amphibious	+	-	+	+	+	+	-	+	+	-	-	-	-	-	-	+
P. chola	+	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-
P. fasciatus	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
P.filamentosus	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Puntius jerdoni	+	+	+	+	+	-	+	-	+	+	-	+	-	-	-	+
Puntius melanostigma	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-
P. pulchellus	+	+	+	+	+	+	+	+	-	-	+	+	-	-	-	+
P.sahyadrensis	+	+	+	-	+	+	-	+	+	+	-	-	-	+	-	
P. sarana	+	+	+	-	+	+	+	+	+	-	+	+	+	-	-	+
P. sophore	+	+	+	+	+	+	+	-	+	-	-	-	-	-	-	-
P. ticto	+	+	-	+	+	+	+	-	-	-	-	+	-	-	+	+
P. vittatus	+	-	+	+	+	-	-	-	-	-	-	-	-	-	+	-
Rasbora rasbora	+	-	-	+	-	+	+	-	+	+	+	-	+	+	+	+
R. daniconius	+	+	+	+	+	-	-	+	-	+	-	+	-	+	+	+
Salmostoma boopis	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
Tor putitora	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-

Classification/Species	**Tunga**				**Bhadra**				**Tungabhadra**							
	GML	**SGR**	**TRH**	**SMG**	**BHR**	**BVH**	**BVC**	**HHR**	**KSM**	**HNH**	**HHC**	**HLM**	**MLG**	**ANG**	**KMP**	**GGR**
Order - Siluriformes																
Family - Bagridae																
Aorichthys aor	-	+	+	+	-	+	+	-	+	+	+	+	+	+	-	+
A. seenghala	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Mystus armatus	-	+	-	+	+	-	-	-	-	+	+	-	+	+	-	+
Mystus cavasius	-	+	+	+	+	+	+	+	-	-	+	+	+	+	-	+
M. gulio	-	-	-	+	-	-	-	-	-	-	+	-	-	+	+	+
M. krishnesis	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+	+
Rita gogra	-	-	+	+	-	-	+	+	+	+	+	+	+	+	-	+
R. pavimentata	+	-	-	+	-	+	+	-	+	+	+	+	-	+	+	+
Family - Clariidae																
Clarius batrachus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. garipinus	-	+	+	+	-	-	-	-	-	-	-	-	+	+	+	+
Family - Siluridae																
Ompak bimaculatus	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
O. pabo	-	+	-	+	-	+	-	-	-	-	+	-	-	-	+	-
Wallago attu	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Family - Pangasidae																
Pangasius pangasius	-	-	-	+	+	+	+	+	-	+	+	-	+	+	+	+
Order - Belonoformes																
Family - Belonidae																
Xenentodon cancila	-	+	+	+	+	-	+	+	+	+	+	-	+	-	+	+
Family - Hemiramphidae																
Hyporhampus xanthopterus	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-

Classification/Species	**Tunga**				**Bhadra**				**Tungabhadra**							
	GML	**SGR**	**TRH**	**SMG**	**BHR**	**BVH**	**BVC**	**HHR**	**KSM**	**HNH**	**HHC**	**HLM**	**MLG**	**ANG**	**KMP**	**GGR**
Order - Cyprinodontiformes																
Family - Cyprinodontidae																
Aplocheilus lineatus	-	+	-	+	+	+	+	+	+	-	+	+	+	-	+	+
Order - Synbranchiformes																
Family - Mastacembelidae																
Mastacembelus armatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Order - Perciformes																
Family - Ambassidae																
Paraambassis ranga	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
Family - Channidae																
Channa punctatus	+	+	+	+	+	+	+	+	+	-	+	-	+	-	+	+
C. marulius	-	-	+	+	-	+	+	-	+	+	-	+	+	+	-	+
C. striatus	-	+	+	+	+	-	-	+	-	+	+	+	+	+	+	+
Family - Cichlidae																
Etroplus maculatus	+	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+
Oreochromis mossambica	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Family - Gobiidae																
Glossogobius giuris giuris	-	-	+	+	-	+	+	+	+	-	+	-	+	+	+	+
Order - Osteglossiformes																
Family- Notopteridae																
Notoptorus notopturus	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

*+ = Present, - = Absent

References

1. Kar D., Fishes of Barak drainage, Mizoram and Tripura. In: Environment, Pollution and Management (Eds. A. Kumar, C. Bohra and L. K. Singh), APH publishing corporation, New Delhi **(2003)**

2. Kumar B., Murugan A. S. and Chaudhary B. N., Seasonal variation of physico-chemical properties of Kamala basin of Darbhanga district, Bihar, *Int. J. Adv. Biol. Res.*, **1(1)**, 123-125 **(2011)**

3. Fausch K. D., Lyons J., Karr J. R. and Angermeier P. L., Fish communities as indicators of environmental degradation, *Am. Fish. Soc. Symp.*, **8**, 123-144 **(1990)**

4. Simon T. P. and Lyons J., Application of the index of biotic integrity to evaluate water resource integrity in freshwater ecosystems. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making (Eds. W. S. Davis and T. P. Simon), Lewis Publishers, Boca Raton, Florida **(1995)**

5. Karr J. R., Assessment of biotic integrity using fish communities, *Fisheries*, **6**, 21-27 **(1981)**

6. Pielou E. C., The measurement of diversity in different types of biological collections, *J. Theor. Biol.*, **13**, 131-144 **(1966)**

7. Karr J. R., Fausch K. D., Angermeier P. L., Yant P. R. and Schlosser I. J., Assessing biological integrity in running waters: A method and its rationale, Illinois Natural History Survey, Champaign, Special Publication **5**, 28 **(1986)**

8. Moyle P. B. and Leidy R. A., Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. In: Conservation Biology: The Theory and Practice of Nature Conservation, Preservation and Management (Eds. P. L. Fiedler and S. K. Jain), New York, Chapman and Hall **(1992)**

9. Hashemi S. A., Ghorbani R., Kymaram F., Hossini S. A., Eskandari G. and Hedayati A., Fish species composition, distribution and abundance in Shadegan Wetland, *Fish. Aqua. J.*, **6(2)**, 1-8 **(2015)**

10. Harris J. H., The use of fish in ecological assessments, *Aust. J. Ecol.*, **20**, 65-80 **(1995)**

11. Stoddard J. L., Larsen D. P., Hawkins C. P., Johnson R. K. and Norris R. H., Setting expectations for the ecological condition of streams: the concept of reference condition, *Ecol. Appl.*, **16(4)**, 1267-1276 **(2006)**

12. Zampella R. A., Bunnell J. F., Laidig K. J. and Procopio N. A., Using multiple indicators to evaluate the ecological integrity of a coastal plain stream system, *Ecol. Indic.*, **6(4)**, 644-663 **(2006)**

13. Devi Prasad A. G., Venkataramana G. V. and Thomas M., Fish diversity and its conservation in major wetlands of Mysore, *J. Environ. Biol.*, **30(5)**, 713-718 **(2009)**

14. Vijaylaxmi C., Rajshekhar M. and Vijaykumar K., Freshwater fishes distribution and diversity status of Mullameri river, a minor tributary of Bheema river of Gulbarga district, Karnataka, *Int. J. Syst. Biol.*, **2(2)**, 1-9 **(2010)**

15. Mishra S. K., Sarkar U. K., Gupta B. K., Trivedi S. P., Dubey V. K. and Pal A., Pattern of freshwater fish diversity, threats and issues of fisheries management in an unexplored tributary of the Ganges basin, Northern India, *J. Ecophysiol. Occup. Hlth.*, **11**, 149-159 **(2011)**

16. Acharjee B. K., Das M., Borah P. and Purkayastha J., Ichthyofaunal diversity of Dhasiri river, Dimapur, Nagaland, India, *Check List*, **8(6)**, 1163-1165 **(2012)**

17. Sarkar U. K., Pathak A. K., Sinha R. K., Sivakumar K., Pandian A. K., Pandey A., Dubey V. K. and Lakra W. S., Freshwater fish biodiversity in the river Ganga (India): changing pattern, threats and conservation perspectives, *Rev. Fish Biol. Fish.*, **22**, 251-272 **(2012)**

18. Bakawale S. and Kanhere R. R., Study on the fish species diversity of the river Narmada in Western zone, *Res. J. Anim. Vet. Fish. Sci.*, **1(6)**, 18-20 **(2013)**

19. Shukla P. and Singh A., Distribution and diversity of freshwater fishes in Aami river, Gorakhpur, India, *Adv. Biol. Res.*, **7(2)**, 26-31 **(2013)**

20. Sheikh S. R., Studies on ichthyofaunal diversity of Pranhita river, Sironcha, Dist: Gadchiroli, Maharashtra, India, *Int. J. Fish. Aquat. Stud.* **1(5)**, 144-147 **(2014)**

21. Vijayasree T. S. and Radhakrishnan M. V., Fish diversity of Kuttanad river, Kerala state, India, *Int. J. Fish. Aquat. Stud.*, **1(6)**, 55-58 **(2014)**

22. Laxmappa B., Bakshi R. R. and Narayana D. V. S., Studies on ichthyofaunal diversity of Krishna river in Mahabubnagar district, Telangana, India, *Int. J. Fish. Aquat. Stud.*, **2(5)**, 99-104 **(2015)**

23. Mishra K. S., An aid to the identification of the common commercial fishes of India and Pakistan, *Rec. Indian Mus.*, **57(1-4)**, 119 **(1962)**

24. Jayaram K. C., The Freshwater fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka: Handbook, Zoological Survey of India, Calcutta, 475 **(1981)**

25. Fischer W. and Bianchi G., FAO species identification sheets for fishery purposes, Western Indian Ocean (Fishing Area 51), The Danish International Development Agency (DANIDA), FAO, Rome, Vol. 1-6 **(1984)**

26. Day F., The fauna of British India including Ceylon and Burma, Fishes 1: 548 : 2: 509, London, Taylor and Francis **(1889)**

27. Talwar P. K. and Jhingran A. G., Inland fishes of India

and adjacent countries, Vol. No. I & II Inl. Oxford and IBB Publishing Co. Ltd., 1158 **(1991)**

28. Jayaram K. C., The Catfishes of India, Narendra Publishing House, New Delhi, 383 **(2006)**

29. Fausch K. D., Karr J. R. and Yant P. R., Regional application of an index of biotic integrity based on stream fish communities, *Trans. Am. Fish. Soc.*, **113**, 39-55 **(1984)**

30. Hughes R. M., Kaufmann P. R., Herlihy A. T., Kincaid T. M., Reynolds L. and Larsen D. P., A process for developing and evaluating indices of fish assemblages integrity, *Can. J. Fish. Aquat. Sci.*, **55(7)**, 1618-1631 **(1998)**

31. Central Inland Fisheries Research Institute(CIFRI) report, Indian Council of Agricultural Research (ICAR), Barrackpore, Kolkata, West Bengal **(2014-2015)**

32. Ganasan V. and Hughes R. M., Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), India, *Freshwater Biol.*, **40(2)**, 367-383 **(1998)**

33. Das M. K., Application of an index of biotic integrity (IBI) to fish assemblage of the tropical Hooghly estuary, *Indian J. Fish.*, **53(1)**, 47-57 **(2006)**

34. Noss R. F., Indicators for monitoring biodiversity: a hierarchical approach, *Conserv. Biol.*, **4**, 355-364 **(1990)**

35. Kumar Naik A. S., Kumar J., Mahesh V. and Benakappa S., Assessment of fish diversity of Tunga river, Karnataka, India, *Nat. Sci.*, **11(2)**, 82-87 **(2013)**

36. Jayaram K. C., Zoogeography of Indian freshwater fishes, *Proc. Indian Acad. Sci.*, **86B(4)**, 265-274 **(1977)**

37. Ajit Kumar C. R. and Mittal D. D., Habitat preference of fishes in wetland in relation to aquatic vegetation and water Chemistry, *J. Bombay Nat. Hist. Soc.*, **90**, 181-191 **(1993)**

38. Thirumala S., Kiran B. R. and Kantaraj G. S., Fish diversity in relation to physico-chemical characteristics of Bhadra reservoir of Karnataka, India, *Adv. Appl. Sci. Res.*, **2(5)**, 34-47 **(2011)**

39. Shahnawaz A., Venkateshwarlu M., Somashekar D. S. and Santosh K., Fish diversity with relation to water quality of Bhadra river of Western ghats (India), *Environ. Monit. Assess.*, **161**, 83-91 **(2010)**

40. Shivashankar P. and Venkataramana G. V., Ichthyodiversity status with relation to water quality of Bhadra river, Western Ghats, Shimoga district, Karnataka, *Ann. Biol. Res.*, **3(10)**, 4893-4903 **(2012)**

41. Shahnawaz A. and Venkateshwarlu M., A check list of fishes from Tunga and Bhadra rivers, Karnataka, India with special note on their biodiversity status, *Curr. Biot.*, **3(2)**, 232-243 **(2009)**

42. Chaudhary C., Simulation of spatial distribution of fish species in 200 km stretch of Tungabhadra river on the basis of oxygen variability, *J. Ecosys. Ecograph.*, **4(2)**, 1-8 **(2014)**

43. Bhat S. S. and Hegde A. K. K., A note on fresh water fish diversity in major tributaries of river Bedti of Western ghats region of Karnataka, India, *Res. J. Anim. Vet. Fish. Sci.*, **2(8)**, 5-10 **(2014)**

44. Bhat A., Diversity and composition of freshwater fishes in river systems of Central Western ghats, India, *Environ. Biol. Fish.*, **68**, 25-38 **(2003)**

45. Kumar Naik A. S., Kumar J., Mahesh V., Anjaneyappa H. N., Benakappa S., Somashekara S. R., Rajanna K. B. and Hulkoti S. H., Status of fish diversity of Varada river, Karnataka, India, *Environ. Ecol.*, **31(2A)**, 786-792 **(2013)**