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Distribution pattern, threatened status and conservation measures of fishes with relation to water quality and habitat characteristics of Bhavanisagar Reservoir, Tamil Nadu

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Abstract
This study documents the water quality, habitat characteristics and freshwater fish diversity of Bhavanisagar Reservoir, Tamil Nadu. We recorded 52 species represented by 8 orders, 13 families and 38 genera. The Cyprinid family was found to be dominant in the present study. Various diversity indices have been used to assess the fish diversity. The highest species diversity was found out in Bhavanisagar Dam (S1) and lowest species diversity was recorded in Aapakkudal (S7) sites. Fish diversity was also correlated with physicochemical variables and habitat characteristics. Among 52 fish species collected from 10 study sites of the upstream/ downstream areas of Bhavanisagar reservoir, of which 2 species (4%) were found to be critically endangered, 41 species were least concerned (79%), 5 species were near threatened (9%) and 4 species were in vulnerable category (8%). The threat status of fishes found in the Bhavanisagar reservoir strongly suggests the need for effective conservation measures to conserve the fish species richness.

Keywords: Bhavanisagar reservoir, Fish fauna, Water quality, Habitat characteristics, Species diversity indices.

1. Introduction

Fishes exhibit enormous diversity in their morphology, habitats they occupy, and in their biology [1]. Hence, biodiversity and conservation are regarded as the major issues enabling sustainable use of natural resources [2]. It seems necessary and today's most urgent and significant need to protect ichthyofaunal diversity [3] in their natural habitat. Over the last century, river ecosystems have suffered from intense human intervention resulted in habitat loss and degradation and as a consequence, many fish species have become highly endangered, particularly in rivers where heavy demand is placed on fresh waters [4]. The main causes are habitat destruction, defragmentation, industries, private use [5] pollution stress and global climate change impacts [6]. Freshwater fish fauna is one of the most threatened taxonomic groups due to high sensitivity to qualitative alteration of aquatic environment [7]. Fishes are often used as bio-indicator for the assessment of water quality or increasing pollution potential [8]. The fish diversity and associated habitats management are a great challenge [9]. As habitat degradation continues to accelerate on a global scale, maintenance of species richness and biodiversity has become a central issue of conservation biology [10, 11, 12, 13]. Inland aquatic systems are crucial for the conservation of local and global biodiversity [14]. In fact, there is a great diversity in the form and function of these aquatic systems, presenting a wide range of habitats [14, 15, 16]. The influence of habitat heterogeneity on species richness is well appreciated [17, 18], but the relationship between habitat structural complexity and density of species exhibiting different ecological characteristics has received comparatively little attention. The freshwater ichthyofauna diversity of Tamil Nadu was reported by various researchers [19, 20, 21, 22]. The fish diversity of Cauvery river system have been reported [23, 24] including fish diversity of Grand Anicut, Tiruchirappalli. Recently, [25] studied the diversity, distribution, threats and conservation action of fish fauna in Chinnar, Krishnagiri and Stanley reservoirs of Tamil Nadu.

The Rivers and tanks have faced major alterations in the recent years due to increasing urbanization, industrialization and various recreational activities [26]. Reassessment of the fish fauna and identifying the threats, so as to build baseline information for possible conservation action plans are thus a priority [27]. However, the fish diversity in Bhavanisagar reservoir of Tamil Nadu in particular is lacking; no attempt was made to analyse the habitat, physico-chemical characteristics and fish fauna in detail. Hence, the present study was aimed to focus on these measures.

2. Materials and Methods

2.1 Study sites: Bhavani, the second largest river in Tamil Nadu, originates from Silent Valley National Park in Palakkad district of Kerala and flows into Tamil Nadu, covering a distance of 217 km before confluence with Cauvery River at Bhavani town. Bhavanisagar Dam and Reservoir also called as Lower Bhavani Dam, is located on the Bhavani River in Erode district, Tamil Nadu. The Bhavani and Moyar rivers flows together into the Bhavanisagar reservoir after which it becomes the Bhavani River, is a tributary of the Cauvery (Fig. 1). The dam feeds the Lower Bhavani Project Canal and is the second largest dam in Tamil Nadu. The elevation of the river basin ranges from 300 m a.m.s.l. on the plains to 2600 ma.m.s.l. on the Nilgris plateau. Accordingly, the annual rainfall varies from 700 mm on the lowlands to nearly 3000 mm in the hills. Ten study sites were selected from Bhavanisagar Dam (S1) to Bhavani Kooduthurai (S10) with a distance of 10 Km interval on the basis of habitat heterogeneity (pools, riffles, run and backwaters), water quality, depth and disturbances. From the selected sites, samplings during the period October 2013 to September 2014 from a 100-150 m reach in all the sites and all the observations were made during day lights.

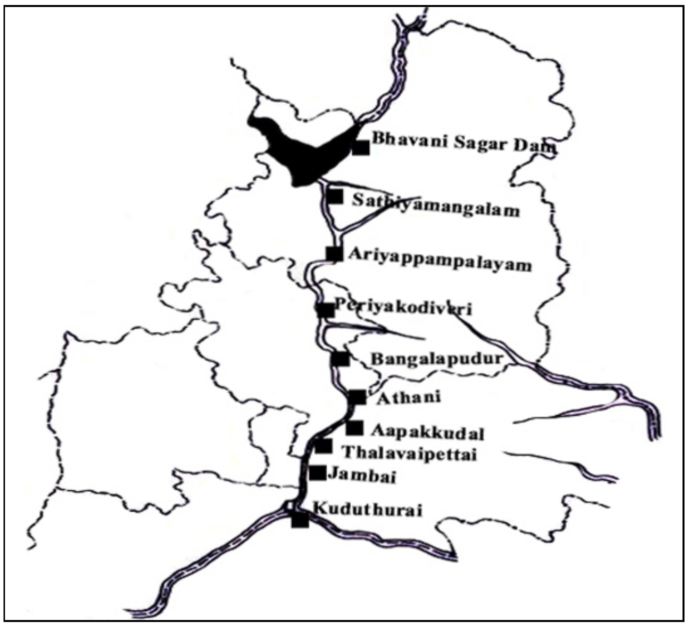

Fig 1: List of study sites in Bhavanisagar Reservoir

2.2 Sampling methods: Habitat parameters were taken using the habitat inventory methods [28, 29]. Water samples were collected in 2L plastic containers and brought to the laboratory for further analysis. Air and water temperatures were measured at sampling time using mercury-in-glass thermometer, pH was estimated using standardized pocket pH meter and the conductivity was measured using the conductivity meter, dissolved oxygen was estimated by [30] method. The total dissolved solids, alkalinity, total hardness, BOD and COD were analyzed by [31] methods. All the essential data like place of collection, date, habitat characters were recorded. Fish samples were collected with the help of gill, cast and drag nets. Five to ten specimens of each species were collected for identification while the rest were released back into the water. The specimens were lively photographed with Canon 1100 Digital SLR camera and were preserved in 4% buffered formaldehyde solution. The collected specimens were transported to Department of Biotechnology-Cum-Laboratory Museum of the Periyar University Museum of Natural History, Salem, Tamil Nadu, India and assigned the specimen catalogue numbers (PUMNH 201-252). The species identification and confirmation were carried out using available literature [32, 33]. The valid species nomenclatural names were adopted as per the Catalogue of Fishes of the California Academy of Sciences [34, 35] and fish status was checked in IUCN red list [36]. Fish species diversity was subjected to diversity analysis using different indices like species richness (S = number of species); Shannon–Weaver Information Index [37]; Simpson Dominance Index [38]; Species Dominance Index [39]; Pielous Evenness [40], Principal Component Analysis and dendrogram analysis were performed using statistical packages PAST [41].

3. Results and Discussion

A total of 52 species representing by 8 orders, 13 families and 38 genera were recorded during the present study. Cypriniformes was the dominant group among all with 57.7% of the assemblage composition followed by Siluriformes with 19.2%, Perciformes with 13.5% and other orders namely Osteoglossiformes, Anguliformes, Mugiliformes, Cyprinodontiformes, and Synbranchiformes forming 1.9% each (Table 1). The distribution pattern fish species between the selected sites are summarized (Table 2).

Most of Cyprinids such as *Salmophasia bacaila, Salmophasia acinaces, Barilius gatensis, Barilius bendelisis, Devario aequipinnatus, Rasbora cauverii, Systomus sarana, Dawkinsia filamentosa, Puntius chola, Puntius dorsalis, Pethia ticto, Pethia conchonius, Labeo fimbriatus, Labeo rohita, Garra*

Table 1: Fish species recorded from the upstream/downstream areas of Bhavanisagar reservoir, Tamil Nadu, India.

S. No	Order	Family	Genera	Species	Percentage (%)
1	Osteoglossiformes	Notopteridae	1	1	1.92
2	Anguliformes	Anguillidae	1	1	1.92
3	Cypriniformes	Cyprinidae	21	29	55.8
		Cobitidae	1	1	1.92
4	Siluriformes	Bagridae	4	7	13.5
		Pangasiidae	1	1	1.92
		Clariidae	2	2	3.84
5	Mugiliformes	Belonidae	1	1	1.92
6	Cyprinodontiformes	Cyprinodontidae	1	1	1.92
7	Synbranchiformes	Mastacembelidae	1	1	1.92
8	Perciformes	Cichlidae	2	3	5.8
		Gobiidae	1	1	1.92
		Channidae	1	3	5.76
Total	8	13	38	52	100

Table 2: Distribution of freshwater fishes in the upstream/downstream areas of Bhavanisagar reservoir, Tamil Nadu, India. (x)=Presence of species; (−) =Absence of species. Least Concern- LC; Near Threatened- NT; Vulnerable-VU; Endangered- EN.

	List of fishes	Specimen key	IUCN Status	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1	*Notopterus notopterus* (Pallas, 1769)	PUMNH 201/ 2013	LC	x	-	-	-	-	-	-	-	-	x
2	*Anguilla bengalensis* (Gray, 1831)	PUMNH 225/ 2013	LC	x	-	x	-	-	-	-	-	x	-
3	*Salmophasia acinaces* (Valenciennes, 1844)	PUMNH 226/ 2013	LC	x	-	x	x	x	x	x	x	-	-
4	*Salmophasia bacaila* (Hamilton, 1822)	PUMNH 221/ 2013	LC	x	x	-	x	x	-	x	-	-	-
5	*Barilius gatensis* (Valenciennes, 1844)	PUMNH 222/ 2013	LC	x	x	x	x	-	-	x	x	x	x
6	*Barilius bendelisis* (Hamilton, 1807)	PUMNH 224 / 2013	LC	x	x	x	x	-	-	-	x	x	-
7	*Devario aequipinnatus* (McClelland,1839)	PUMNH 223/ 2013	LC	x	x	x	x	x	x	-	x	x	x
8	*Rasbora cauverii* (Jerdon, 1849)	PUMNH 251/ 2013	LC	x	x	x	x	x	x	x	-	x	-
9	*Amblypharyngodon mola* (Hamilton, 1822)	PUMNH 250/ 2013	LC	x	x	-	-	-	-	-	x	-	x
10	*Cyprinus carpio* Linnaeus, 1758	PUMNH 252/ 2013	VU	x	x	-	-	-	-	-	-	x	x
11	*Tor khudree* (Sykes, 1839)	PUMNH 202/ 2013	EN	-	-	-	x	x	-	-	x	-	-
12	*Barbodes hexagonolepis* (McClelland, 1839)	PUMNH 248/ 2013	NT	-	x	x	-	x	-	-	-	-	-
13	*Systomus sarana* (Hamilton, 1822)	PUMNH 249/ 2013	LC	x	-	-	x	x	x	x	-	x	-
14	*Dawkinsia filamentosus* (Valenciennes, 1844)	PUMNH 246/ 2013	LC	x	x	x	x	x	-	-	-	x	x
15	*Puntius chola* (Hamilton, 1822)	PUMNH 247/ 2013	LC	x	x	-	x	x	-	x	x	x	x
16	*Puntius dorsalis* (Jerdon, 1849)	PUMNH 227/ 2013	LC	x	-	-	x	-	x	x	x	x	x
17	*Pethia ticto* (Hamilton, 1822)	PUMNH 228/ 2013	LC	x	x	x	-	-	x	-	-	x	-
18	*Pethia conchonius* (Hamilton, 1822)	PUMNH 229/ 2013	LC	x	x	x	-	x	x	x	x	-	-
19	*Barbodes carnaticus* (Jerdon, 1849)	PUMNH 245/ 2013	LC	x	-	-	-	-	-	-	-	-	-
20	*Gonoproktopterus dubius* (Day, 1867)	PUMNH 230/ 2013	EN	x	-	-	x	-	x	-	x	-	-
21	*Osteochilichthys nashii* (Day, 1868)	PUMNH 231/ 2013	LC	-	x	-	x	x	-	x	-	-	-
22	*Osteochilichthys brevidorsalis* (Day, 1873)	PUMNH 203/ 2013	LC	-	x	x	x	x	x	-	-	x	-
23	*Cirrhinius chrrhosus* (Bloch, 1795)	PUMNH 232/ 2013	VU	x	x	x	-	-	x	-	x	-	-
24	*Gibelion catla* (Hamilton, 1822)	PUMNH 233/ 2013	LC	x	-	-	-	x	-	-	-	-	x
25	*Labeo fimbriatus* (Bloch, 1795)	PUMNH 234/ 2013	LC	x	-	-	x	-	-	x	-	-	-
26	*Labeo kontius* (Jerdon, 1849)	PUMNH 235/ 2013	LC	x	-	-	-	-	x	-	x	x	x
27	*Laboe calbasu* (Hamilton, 1822)	PUMNH 236/ 2013	LC	-	x	-	-	x	-	x	-	-	-
28	*Labeo rohita* (Hamilton, 1822)	PUMNH 205/ 2013	LC	-	x	-	x	-	x	-	x	-	-
29	*Schismatorhynchos nukta* (Sykes, 1839)	PUMNH 206 2013	EN	-	x	-	-	-	x	-	-	-	x
30	*Garra mullya* (Sykes, 1839)	PUMNH 207/ 2013	LC	-	x	-	x	x	-	-	x	x	-
31	*Garra gotyla stenorhynchus* (Jerdon, 1849)	PUMNH 237/ 2013	LC	-	-	x	-	-	-	x	-	-	-
32	*Lepidocephalichthys thermalis* (Valenciennes, 1846)	PUMNH 238/ 2013	LC	-	x	-	x	-	x	-	-	-	-
33	*Sperata aor* (Hamilton, 1822)	PUMNH 204/ 2013	LC	x	-	x	-	x	-	-	x	-	x
34	*Sperata seenghala* (Sykes, 1839)	PUMNH 239/ 2013	LC	x	-	-	-	x	-	-	x	-	-
35	*Mystus punctatus* (Jerdon, 1849)	PUMNH 240/ 2013	EN	x	-	x	-	-	x	-	-	-	-
36	*Mystus armatus* (Day, 1865)	PUMNH 208/ 2013	NT	-	-	-	x	-	-	-	-	-	-
37	*Mystus cavasius* (Hamilton, 1822)	PUMNH 209/ 2013	LC	-	x	x	-	-	x	x	x	-	-
38	*Ompok bimaculatus* (Bloch, 1794)	PUMNH 210/ 2013	NT	x	-	-	-	x	-	-	-	-	-
39	*Wallago attu* (Bloch & Schneider, 1801)	PUMNH 211/ 2013	NT	x	-	-	x	-	-	-	-	-	x
40	*Pangasius pangasius* (Hamilton, 1822)	PUMNH 212/ 2013	LC	x	-	-	-	-	-	-	-	-	x
41	*Clarias batrachus* (Linnaeus, 1758)	PUMNH 241/ 2013	LC	x	-	-	-	-	-	-	x	-	-
42	*Heteropneustes fossilis* (Bloch, 1794)	PUMNH 242/ 2013	LC	-	x	-	-	-	-	x	-	-	-
43	*Xenentodon cancila* (Hamilton, 1822)	PUMNH 243/ 2013	LC	x	-	x	-	-	-	-	-	x	x
44	*Aplocheilus lineatus* (Valenciennes, 1846)	PUMNH 244/ 2013	LC	-	x	-	-	x	-	-	-	x	-
45	*Mastacembelus aramatus* (Lacepede, 1800)	PUMNH 213/ 2013	LC	-	-	-	-	-	-	-	-	-	-

46	*Etroplus maculatus* (Bloch, 1795)	PUMNH 214/ 2013	LC	x	-	-	-	-	-	x	-	-	-
47	*Etroplus suratensis* (Bloch, 1790)	PUMNH 215/ 2013	LC	-	-	-	x	-	x	-	x	-	x
48	*Oreochromis mossambicus* (Peters, 1852)	PUMNH 219/ 2013	NT	x	-	x	-	-	-	-	-	-	x
49	*Glossogobius giuris* (Hamilton, 1822)	PUMNH 220/ 2013	LC	-	-	x	x	x	-	-	-	-	x
50	*Channa marulius* (Hamilton, 1822)	PUMNH 216/ 2013	LC	-	-	x	-	x	-	-	-	x	x
51	*Channa punctata* (Bloch, 1793)	PUMNH 217/ 2013	LC	x	-	x	-	-	x	-	-	-	-
52	*Channa striata* (Bloch, 1793)	PUMNH 218/ 2013	LC	x	-	x	x	-	-	x	-	x	-

mullya, Garra gotyla stenorhynchus were widely distributed in the other parts of the Western Ghats. Our study indicates that Cyprinid fishes show a wide range of distribution and composition. The species of *Notopterus notopterus, Anguilla bengalensis, Cyprinus carpio, Laboe calbasu, Sperata seenghala, Sperata aor, Wallago attu, Pangasius pangasius, Clarias batrachus* and *Heteropneustes fossilis* were comparatively rare and confined to the reservoir and lower reaches of the river. The results are in conformity with those of [42, 43, 44].

High species richness was observed from sampling sites like Bhavanisagar Dam (S1) Periyakodiveri (S4) and Sathiyamangalam (S2), and less species richness was recorded at Aapakkudal (S7), and Jambai (S9) sites, respectively. As far as the diversity indices (Table 3) are concerned, the Shannon-Weaver diversity indices of the fishes was found highest at Bhavanisagar Dam (S1) site (3.293) while lowest was at site Aapakkudal (S7) site (2.641). The Simpson dominance indices were high at Bhavanisagar Dam (S1) site (0.954) and low at Aapakkudal (S7) site (0.915). But the Species Dominance index (D) was high at Jambai (S9) site (0.086) and low at Bhavanisagar Dam (S1) site (0.046). The evenness high at Bhavani Kooduthurai (S10) (0.932) and low at Ariyappampalayam (S3) (0.756). Thus, the result values were recorded for fish species richness shown by various diversity indices are positively correlated between the selected sites. Only Species Dominance index had shown negative correlation between Bhavanisagar Dam (S1) and Ariyappampalayam (S4) and Aapakkudal (S7) sites. Low species richness at Aapakkudal (S7) site may be correlated with the physical barrier for the fish movement and the physical stability which is one of the important factors for fish diversity. At Aapakkudal (S7) site, a lot of physical barriers like big log inside the river site and fallen trees were noticed, and this could be the reason for low species richness. The same observations were made by [45, 46, 47].

Table 3: Fish diversity indices of upstream/downstream areas of Bhavanisagar reservoir, Tamil Nadu, India.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Total number of species	34	23	22	23	21	19	16	18	17	19
Total number of individuals	192	124	129	106	92	82	78	81	76	100
Dominance_D	0.046	0.064	0.077	0.052	0.065	0.062	0.077	0.064	0.086	0.060
Simpson_1-D	0.954	0.936	0.927	0.948	0.936	0.938	0.923	0.936	0.915	0.940
Shannon_H	3.293	2.948	2.812	3.042	2.886	2.864	2.663	2.813	2.641	2.874
Evenness_e^H/S	0.792	0.829	0.756	0.910	0.853	0.923	0.896	0.926	0.825	0.932

The present study has shown positive correlation between fish species and physicochemical parameters. For instance, the Aapakkudal (S7) study site have also witnessed low species richness. Here, only 16 fish species were recorded which was the least number among all the study sites. The fish species recorded were *Salmophasia acinaces, Salmophasia bacaila, Barilius gatensis, Rasbora cauverii, Systomus sarana, Puntius chola, Puntius dorsalis, Pethia conchonius, Osteochilichthys nashi, Labeo fimbriatus, Laboe calbasu, Garra gotyla stenorhynchus, Mystus cavasius, Heteropneustes fossilis, Etroplus maculatus* and *Channa striata.*

There are other factors responsible for fish retardation other than physical stability like overfishing, dynamiting, pollution threats, etc. Hence, low fish species richness at Aapakkudal (S7) site might be because of the urban waste and effluents discharged along the river bank. As it is supported by the fact that the lowest DO level (4.8 mg/l) was recorded at this site. The physico-chemical parameters of water was summarized (Table 4).

Table 4: Mean of physicochemical parameters of upstream/downstream areas of Bhavanisagar reservoir, Tamil Nadu, India (Dry season).

	Water quality parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1	Air temperature (°C)	23	24	27	28	27	26	27	29	26	27
2	Water temperature (°C)	22	21	24	25	23	24	24	23	22	23
3	pH	7.1	7	7.2	7.3	7.2	7.5	6.8	7.3	6.9	7.2
4	Dissolved oxygen (mg l^{-1})	10.2	11.2	11.6	7.5	6.5	5.9	4.8	5.3	5.1	6.0
5	Total hardness (mg l^{-1})	44	33	38	44	47	49	98	53	86	61
6	Alkalinity, (mg l^{-1})	21	19	18	29	35	33	77	38	73	44
7	Conductivity (mhos cm^{-1})	58	63	61	48	53	42	98	45	88	68
8	COD (mg l^{-1})	9	9.5	8.8	11	9.5	10.8	16	11	13	12
9	BOD (mg l^{-1})	3.5	4.1	5.3	5.8	6.1	9.6	12.2	9.4	10.2	9.8

The mean pH of the sampling stations ranged between 6.8 mg l^{-1} Aapakkudal (S7) to 7.5 Athani (S6). The pH at Aapakkudal (S7) site showed the acidic nature of water. Mean water temperature was observed to be lower than air temperature which was attributed to less heating of the water body. Dissolved oxygen was high at all sites except Aapakkudal (S7) and Jambai (S9) sites (4.8 and 5.1 mg/l) with a mean of 8.74 mg/l showed good aeration of the river. Total hardness, conductivity, and alkalinity values were under permissive limits except at Aapakkudal (S7) and Jambai (S9) sites. Aapakkudal (S7) site showed high total hardness (98 mg/l), which was considered as hard water. The present results are in conformity with [48]. Also, maximum COD (16 mg/l) and BOD (12.2 mg/l) were recorded at Aapakkudal (S7) site. Increasing trend of BOD and decreasing trend of DO at Aapakkudal (S7) site clearly indicated the increasing load of pollution. High value of COD and BOD indicated high degree of organic pollution [49].

High alkalinity (77 mg/l) and conductivity (98 mg/l) at Aapakkudal (S7) site was probably due to addition of domestic waste from the nearby cities. Therefore, high values of BOD, COD, total hardness, alkalinity and conductivity, and low values of pH and DO at Aapakkudal (S7) site have adverse effect on abundance of fish diversity. That is why least fish richness (n=16) was recorded at this site and such observation was also made by [50].

In addition, habitat characteristics have also shown considerable variation in microhabitat types such as substrate types, depth and riparian cover which were presented in Table 5. It is clear from the study that water at all stations was clear (except at Aapakkudal (S7) and Jambai (S9) sites), with sandy, rocky bottom and the banks were lined by boulders and rocks with very low riparian cover. However, many of the fish habitats such as pools and deep areas were covered with sediments and rocks. The riparian cover is one of the important attributes for fish population to survive. It is having the direct influence on fish habitat as it works as a barrier from predators and food source as some species feed on insects which fall from trees. Therefore, it might be one of the reasons for low fish diversity at Aapakkudal (S7) site where the riparian cover was found least among all the study sites (0%).

Table 5: Habitat characteristics of upstream/downstream areas of Bhavanisagar reservoir, Tamil Nadu, India.

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Latitude	11° 47” N	11° 38” N	11° 33” N	11° 47” N	11° 27” N	11° 25” N	11° 25” N	11° 22” N	11° 22” N	11° 25” N
Longitude	77° 48” E	77° 45” E	77° 44” E	77° 41” E	77° 41” E	77° 40” E	77° 40” E	77° 42” E	77° 43” E	77° 40” E
Altitude	928	877	811	784	713	668	634	640	675	668
Bedrock	10	0	45	0	0	0	5	5	10	10
Boulder	35	55	20	55	25	20	10	25	20	15
Cobble	20	15	15	10	15	15	15	15	15	25
Gravel	26	20	10	20	20	30	25	25	10	20
Sand	8	9	5	10	20	25	15	20	20	20
Leaf litter	1	1	5	5	10	5	10	5	5	5
Fine sand	0	0	0	0	10	5	20	5	20	5
Depth (cm)	76	45	67	45	55	45	75	55	70	55
Riparian cover (%)	40	25	35	25	10	10	0	45	5	45

In order to determine which physico-chemical parameters, habitat characteristics were affected with fish species richness, Principal Component Analysis was performed. The PCA revealed a clear separation of the fish species richness along water quality and habitat characteristics (Fig. 2). A total of 10 components were extracted and the first three components with higher eigenvalue accounted to about 98.46 % of the total variance. The first component axis alone explained 86.33 % of the variance with an eigenvalue of 5.3 with high loadings (> 0. 7). The second and third components explained 8.91% and 3.22% of variance with an eigenvalue of 0.8 and 0.6. Among the 10 sites, the lowest species richness of the ordination represented sites (S7, S9, S8, S10 and S6) with negatively affected with low riparian cover, dissolved oxygen, high amount of fine sand, alkalinity, conductivity, hardness, BOD, COD and acidic nature pH. The highest species richness of the PCA matrix represented sites S5, S3, S2, S4 and S1 were positively correlated with air temperature, water temperature, depth and boulder.

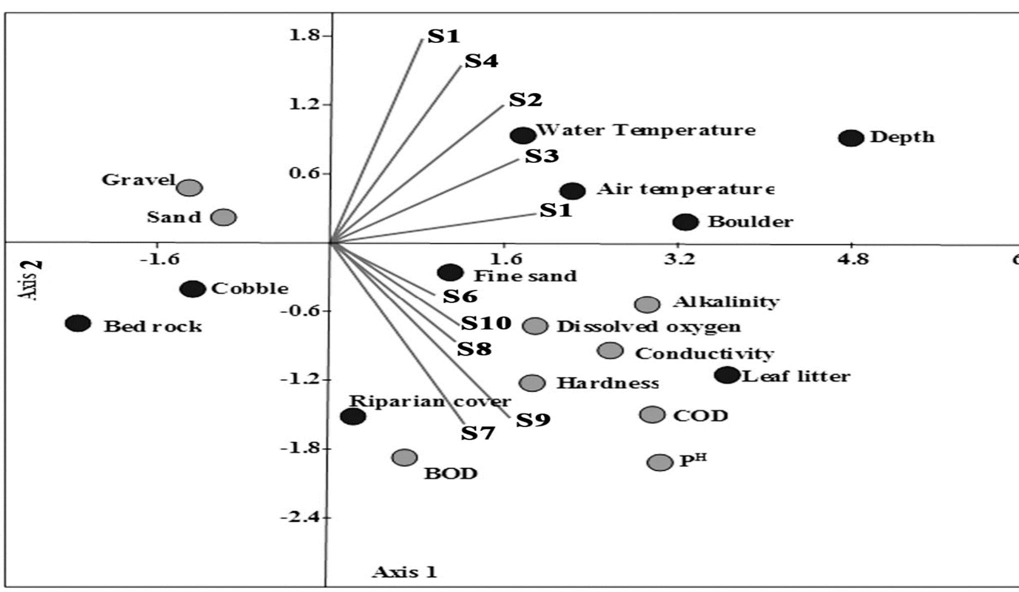

Fig 2: Principal Component Analysis (PCA) based on the fish species richness, physico-chemical parameters and habitat characteristics in 10 study sites of Bhavanisagar reservoir.

The dendrogram analysis among the study sites showed that fish species similarity decreases with the increase in distance between the two sampling sites (Fig. 3). Among the study sites the cluster analysis showed unique in species similarity and showed a unique range of distribution. The study sites showed its uniqueness in species like *Salmophasia bacaila, Barilius gatensis, Barilius bendelisis, Devario aequipinnatus, Rasbora cauverii, Dawkinsia filamentosa, Puntius dorsalis, Pethia ticto, Pethia conchonius, Labeo fimbriatus, Labeo kontius, Labeo rohita, Mystus cavasius, Ompok bimaculatus, Xenentodon cancila, Etroplus maculatus, Etroplus suratensis, Anabas testudineus, Channa marulius* and *Channa punctata.*

Threat status and conservation of fishes, we checked in IUCN red list (IUCN, 2013). A total of 52 fish species collected from 10 study sites of the upstream/ downstream areas of Krishnagiri reservoir, of which 41 species are least concerned (79%) (Fig. 4), 5 species are near threatened (9%), 4 species is in endangered category (8%) and 2 species are in vulnerable category (4%).

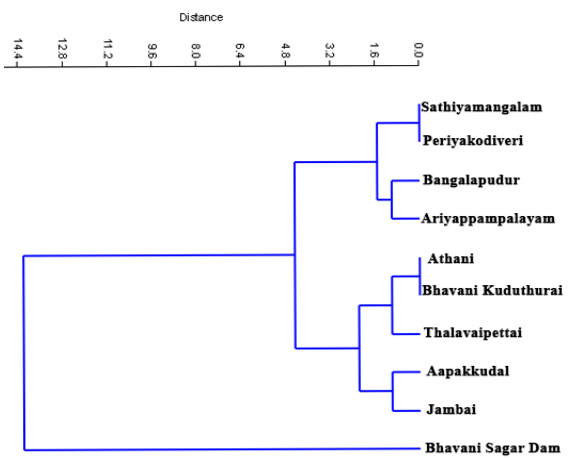

Fig 3: Clusters of localities resulting from dendrogram analysis based on the Jaccard's metric of 10 sites of the upstream/ downstream areas of Bhavani sagar reservoir.

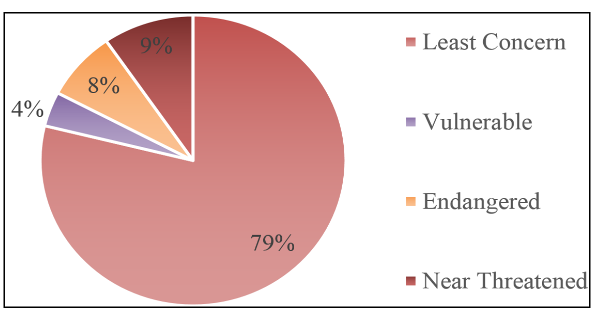

Fig 4: Conservation status of fish species collected from different study sites of upstream and downstream areas of Bhavani sagar reservoir, Tamil Nadu, India.

Variations in species diversity at sampling stations indicate that altered habitats support less biological communities while less disturbed sites are characterized by a diverse fish fauna in a variety of habitats as it is clearly shown by the present study. Several studies have analyzed the fish community structure along an upstream downstream gradient in order to predict species richness based on measurements such as altitude, order, stream gradient and distance from source [51, 52, 53]. These abiotic factors can influence not only species richness but also trophic composition [53, 54]. In many studies, the number of species increased downstream with a marked difference in species richness between the headwater and downstream zones [55].

As habitat degradation continues to accelerate on a global scale, maintenance of species richness and biodiversity has become a central issue of conservation biology [10, 11, 12, 13]. Inland aquatic systems are crucial for the conservation of local and global biodiversity [14]. Unfortunately, most reservoirs occur in lowland areas, often with high human population densities. As a consequence, their environmental value is being dramatically affected, as demonstrated by numerous studies [56, 57]. It is widely accepted that environmental variation plays an important role affecting diversity.

4. Conclusions

Physical stability and anthropogenic activities like overexploitation of fishes and discharge of various types of pollutants have a crucial role in the retardation of fish diversity at Aapakkudal (S7) and Jambai (S9) sites. Therefore, it is obvious that the river is receiving pollution threats at S7 site, which should be checked by taking necessary steps. We need to formulate sustainable strategies to save fish community of this river system as a whole.

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