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Species Diversity and Habitat Inventory of *Puntius sp.* from Various Water Bodies of South India

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Abstract

Freshwater ecosystems contain only about 0.01% of the Earth's water and the system accounts about 45% of fish species known to date. Alteration in the micro and macro habitats in the system severely affects the aquatic life especially fishes and also complicates the fish taxonomy. Among the different kinds of fresh water fishes, the fishes grouped under the genus *Puntius*, belonging to *Cypriniformes* family, have been considered as an important protein source of daily diets of human beings in south India, in particular. The inter-genetic and intra-genetic relationships of the *Puntius* species have not yet been well understood to date and the species are reported to exist in various water bodies of peninsular India. In the present study, a total of 168 individuals of the 17 species of genus *Puntius* have been collected from 31 locations of six river systems (meandering eastward flowing rivers of Bhavani, Moyar, Chalakudy, Periyar, Cauvery and Kabini**)** of Southern Western Ghats. The data analyses suggested that species like *Puntius melanampyx, Puntius carnaticus, Puntius amphibious, Puntius fasciatus, Puntius mahecola* were fiund predominantly in the locations considereded in the present study. The significances of the study and timely measures needed to protect the species have also been concisely discussed.

Keywords: Diversity, Habitat, Principal Component Analysis, *Puntius* species, Southern Western Ghats.

INTRODUCTION

Fishes have more species than all other vertebrate group combined [1, 2] and the fishes divided into 482 families of 57 orders. These numbers are in sharp contrast to numbers of species of amphibians (827), reptiles (449), birds (29,165) and mammals (23,122) found worldwide [3]. Nelson (1994) suggested the number of described living fish species might eventually reach about 28,500 [2]. India harbours a rich and diverse fish fauna with nearly 11% of the total fish species of the world [4]. Study of the distribution of fishes in particular biosphere is very important to understand the ecological significance of the species. Many factors such as altitude, water temperature, habitat type, food availability, predator and ecological barrier etc. are the determining factors for distribution in river/stream habitats. One of the pioneering studies in the distributional ecology of stream fishes recognized the importance of depth as the main factor influencing species diversity and showed that increasing depth caused addition of species downstream in Owego Creek, New York [5]. The stream habitats are classified into various depths, current and substrate categories based on their properties [6]. Fish distribution studied along stream order and longitudinal gradient in big Sandy Creek, Texas exhibits a model classification of the stream habitats [7]. Barila *et al.*, (1981) has been found that species number was weakly correlated with stream order, though it increased regularly downstream within orders. The influence of altitude, stream order and various parameters like mean depth, gradient and maximum width on fish species richness and diversity has been observed in five stream orders of Raystown Branch, Susquehanna river drainage, Pennsylvania and the analyses exhibited a significant correlation between species richness and stream order and endorsed its use as a composite index of habitat structure [8]. Ecologists are interested in measuring diversity since measures of diversity are frequently seen as indicators of the well being of ecological systems. The diversity can be measured either at the community (habitat) or the species level.

The stream habitat was measured in dimensions like length, width, depth, bottom type and current. Stream depth categories were chosen as representative of habitats found in the small streams sampled; 0 - 5 cm corresponded to shallow edges and riffles, 5 - 20 cm to riffles and shallow pools, 20 - 50 cm to pools and > 50 cm to deep pools. Bottom types (substrates) were categorized into physical and biotic structures [6]. History of the Indian freshwater fishes is way back to on the fishes found in the river Ganges and its tributaries [9]. The documentation and listing of the fishes from different part of India was carried out mainly by [10] a comprehensive and authoritative account on the freshwater fishes has been provided by [11, 12]. The further investigations on the freshwater fishes of India especially the Western Ghats was initiated by [13 – 17] and he enunciated the Satpura Hypothesis. These led to the new descriptions, enlisting with elaborate discussions on the endemism and other zoogeographical relevance and several new taxa have been added from Kerala during this. Studies on the endemic fishes from various streams and rivers in the Western Ghats mountain ranges have been compiled recently [18]. Fish diversities in selected streams in northern Karnataka [19] Central Western Ghats [20] have also been reported.

The genus *Puntius* has long been recognized as a "catch-all" genus for a variety of small tropical Asian cyprinids whose inter-relationships are poorly understood [21 – 23]. The genus *Puntius* belonging to *Cyprinidae* family is represented by a large number of species in the Asian tropics [9]. The *cyprinids* species *Puntius* are small indigenous species (SIS) used to be abundantly available in rivers, streams, ponds, beels, ditches, and floodplains in the past in the South Asian countries [24]. However, review of the literature on the diversity of fresh water fishes shows that most of the study was dealt with general diversity and

no study was carried out specific to Genus *Puntius*. In this background, the aim of the present work is to provide information on the diversity and distribution of Genus *Puntius* with special reference to the Southern Western Ghats.

METHODS AND MATERIALS

Collection and Identification

Fishes were collected using cast net, dip net, gill net and drag net from various streams and rivers of Southern Western Ghats. A total of 10 specimens from each species were collected and fishes were photographed before it was preserved in formalin. Further, tissue was collected from each specimen for genetic study and specimens were preserved in 10% formalin for smaller samples and for larger samples formalin has been injected into the abdominal cavity, so that the internal organs are well preserved for further taxonomic studies. The specimens were tagged and the reference numbers were given for specimen identification and transported to lab for further morphometric and meristic character analysis [25 - 28]. Holotype and paratypes of *Puntius* species were examined in Zoological Survey of India, Southern Regional station, Chennai and Kolkata for confirmation of species. Voucher specimens have been made for each species and deposited at the Biodiversity and Molecular Lab, Department of Environmental Sciences, Bharathiar University. Habitat Inventory has been done based on the novel methods [6, 29 - 31].

Water Quality and Stream Order

Water samples were collected in 2 liter cleaned PVC container from each site and brought to the laboratory for further analysis. Water temperature and conductivity were measured in the field. Water quality parameters were estimated by using international standard methods [32]. Stream order classification was based on Horton's approach [33], modified by Strahler [34].

Statistical analysis

Species diversities (H') [35], Evenness index (E) and Dominance index (D) [36] have been analyzed to exhibit the present diversity, abundance and dominant status of the *Puntius* species in the Southern Western Ghats. Since the species abundance and their relative frequencies were subjected to cluster analysis, a complete linkage cluster dendrogram was drawn based on Pearson correlation. The contribution of the variables and its influence for the species diversity has been analyzed using Principal Component Analysis [37]. The above statistical analysis was performed using window based computer software XLSTAT and SPSS.

RESULTS

Puntius species were collected from the Southern Western Ghats streams and rivers. The Western Ghats is a mountain range that runs almost parallel to the western coast of Indian peninsula. It is a UNESCO World Heritage Site and is one of the eight "hotspots" of biological diversity in the world. It is also called as "The Great Escarpment of India". The range of Western Ghats runs from north to south along the western edge of the Deccan Plateau, and separates the plateau from a narrow coastal plain, called Konkan, along the Arabian Sea. A total of thirty nine world heritage sites including national parks, wildlife sanctuaries and reserve forests: twenty in Kerala, ten in Karnataka, five in Tamil Nadu and four in Maharashtra adds fame to the Western Ghats (Fig. 1). Seventeen *Puntius* species were collected from the long and meandering eastward flowing river systems of Southern Western Ghats, especially from Bhavani River System, Moyar River System, Chalakudy River System, Periyar River System, Cauvery River System and Nugu River System. The study sites and their characteristics are presented in Table 1 and Fig. 2. The study sites and the species collected from the sites are presented in Table 2.

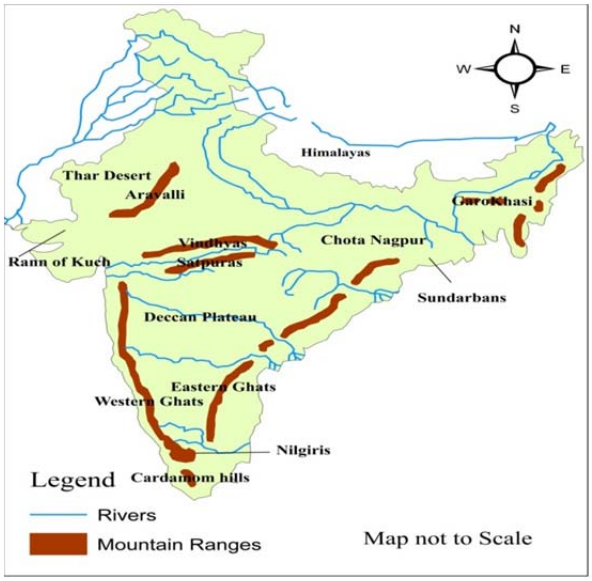

Fig. 1: The mountain ranges of peninsular India

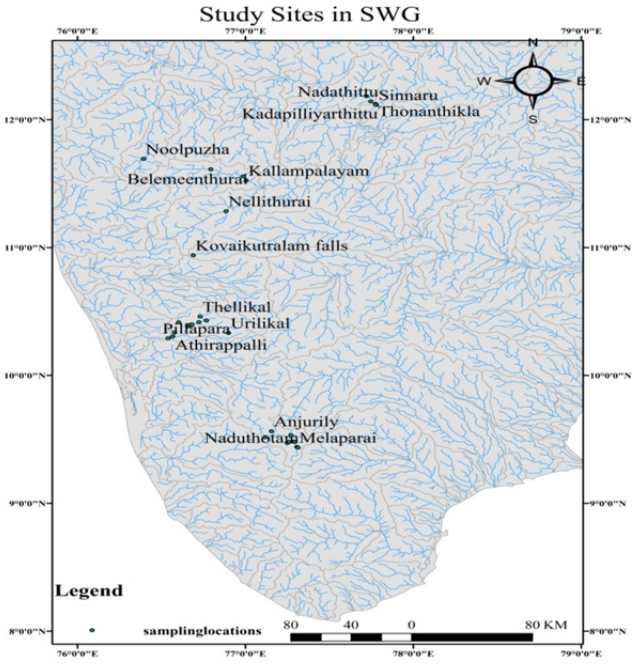

Fig. 2: Collection locations of six river systems.

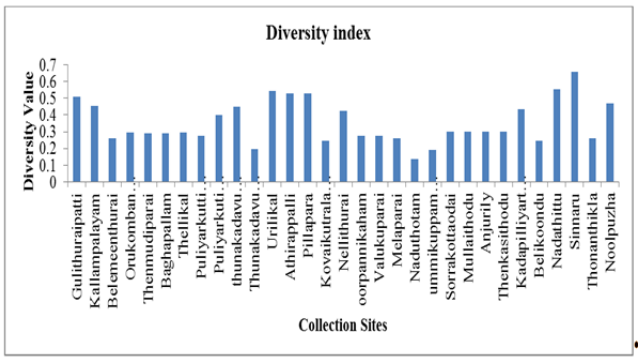

Fig. 3: Species diversity of genus *Puntius* in the 31 sites

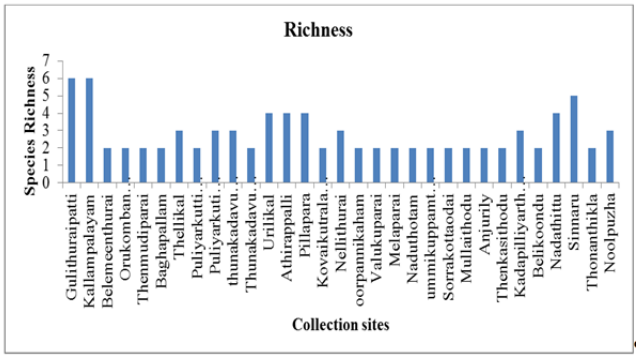

Fig. 4: Species richness of genus *Puntius* the 31 sites

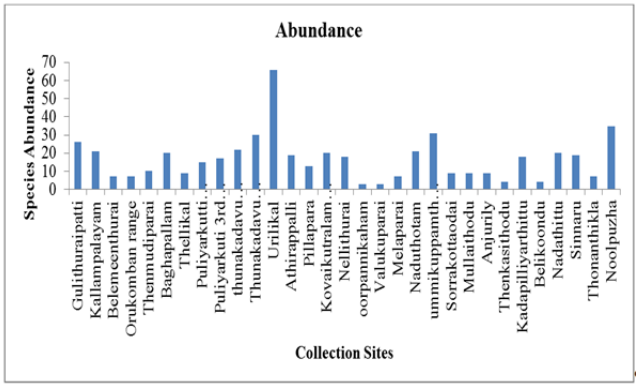

Fig. 5: Species abundance of genus *Puntius* in the 31 sites

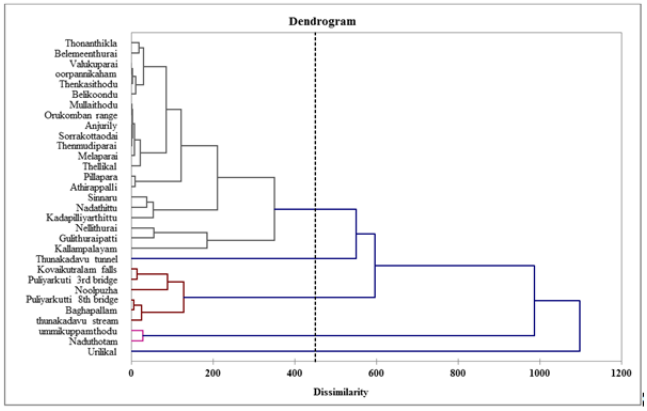

Fig. 6: Cluster dendrogram shows the dissimilarity between the 31 sites

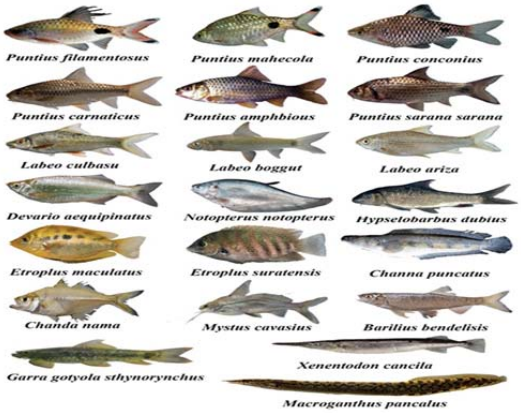

Fig. 7: Fishes collected from various water bodies of SWG.

Species Diversity, Species Richness and Abundance of genus *Puntius*

In the present study, 168 individuals of the 17 species of genus *Puntius* have been collected from 31 sites of six river systems of Southern Western Ghats. Species like *Puntius melanampyx, Puntius carnaticus, Puntius amphibious, Puntius fasciatus, Puntius mahecola,* were commonly found in all the six river systems. Among the 31 sites high species diversity of genus *Puntius* was recorded at Sinnaru of Cauvery River system (H'- 0.659) and low diversity was recorded at Naduthotam, Periyar River System recorded (H'- 0.137) (Fig. 3). The maximum species richness was recorded at Gulithuraipatti and Kallampalayam (S – 6), (Fig. 4). The maximum species abundance 66 was recorded at Urilikal and lowest abundance 3 was recorded at Oorpannikaham and Valukuparai (Fig. 5). The maximum dominance (D - 5.182) was recorded at Sinnaru and lowest dominance (D - 1.221) was recorded at Naduthotam. In species richness and abundance there were wide variations among the present collection sites. Herein, altitude also plays a major role in species diversity and its abundance. Colinvaux proposed the theory that diversity changes with altitude on mountainsides, being lowest at higher elevations [38]. The present finding supports the above theory the results express that species diversity and abundance is high at high altitudes.

Species composition

Similarities between any two the sites were very less among 31 sites of six river systems. Cluster analyses showed that totally 5 clusters were grouped and species having similar composition have clustered in a same cluster (Table 3, Fig. 6).

Table 1: Study sites and their habitat characteristics

S. No	Study site	Latitude and longitude	Altitude	Forest type	Stream order	Stream Width (m)	Stream Depth (m)	Area (m^2)	Volume (m^3)	Mean Velocity* (m/sec)
Moyar River System										
1	Gulithuraipatti	11° 36' N and 76° 47' E	312	Thorn forest	4	10	6	1000	6000	4
2	Kallampalayam	11° 31' N and 77° 0' E	300	Thorn forest	4	13	8	1300	10400	4
3	Belemeenthurai	11° 36' N and 76° 47' E	520	Dry deciduous	4	19	1.75	1900	3325	4
Chalakudy River System										
4	Orukomban range	10° 22' N and 76° 39' E	450	Dry deciduous	4	6	0.5	600	300	3
5	Thenmudiparai	10° 24' N and 76° 36' E	510	Dry deciduous	5	25	1.5	2500	3750	3
6	Baghapallam	10° 27' N and 76° 43' E	748	Dry deciduous	5	8	0.5	800	400	3
7	Thellikal	10° 27' N and 76° 44' E	840	Dry deciduous	4	4	1.0	400	400	3
8	Puliyarkutti 8th bridge	10° 23' N and 76° 40' E	527	Dry deciduous	4	19.2	1.2	1920	2304	3
9	Puliyarkutti 3rd bridge	10° 23' N and 76° 41' E	512	Dry deciduous	4	37	1.5	3700	5550	3
10	Thunakadavu stream	10° 25' N and 76° 46' E	510	Dry deciduous	4	13.6	0.5	1360	680	3
11	Thunakadavu tunnel	10° 20' N and 76° 34' E	520	Dry deciduous	5	15	10	1500	15000	5
12	Urilikal	10° 19' N and 76° 53' E	3238	Dry deciduous	2	7	1.5	700	1050	2
13	Athirappalli	10° 18' E and 76° 34' N	202	Semi evergreen	4	8	3	800	2400	4
14	Pillapara	11° 36' N and 76°47' E	267	Semi evergreen	4	5	2	500	1000	4
Bhavani River System										
15	Kovaikutralam falls	10° 56' N and 76°41' E	560	Semi evergreen	2	5	1.2	500	600	4
16	Nellithurai	11° 17' N and 76°53' E	380	Thorn forest	4	27	1.1	2700	2970	5
Periyar River System										
17	Oorpannikaham	09° 28' N and 77°16' E	884	Evergreen	4	12	2.1	1200	2520	2
18	Valukuparai	09° 28' N and 77°17' E	869	Evergreen	4	7.5	0.3	750	225	3
19	Melaparai	09° 26' E and 77° 18' N	965	Evergreen	4	11	4.2	1100	4620	3
20	Naduthotam	09° 26' N and 77° 19' E	950	Evergreen	4	7.5	0.3	750	225	3
21	Ummikuppamthodu	09° 28' N and 77° 14' E	943	Evergreen	4	5	3.0	500	1500	4
22	Sorrakottaodai	09° 28' N and 77° 15' E	879	Evergreen	4	7	1.5	700	1050	3
23	Mullaithodu	09° 31' N and 77° 16' E	869	Evergreen	4	10	0.6	1000	600	3
24	Anjurily	11° 36' N and 76°47' E	912	Evergreen	4	20	5	2000	10000	2
25	Thenkasithodu	11° 36' N and 76°47' E	872	Evergreen	4	11.3	0.5	1130	565	2
Cauvery River System										
26	Kadapilliyarthittu	12° 07' N and 77° 46' E	1137	Dry deciduous	4	75	1.5	7500	11250	2
27	Belikoondu	12° 11' N and 77° 43' E	267	Dry deciduous	4	80	10	8000	80000	5
28	Nadathittu	12° 08' E and 77° 44' N	262	Dry deciduous	4	70	6	7000	42000	3
29	Sinnaru	12° 06' N and 77° 46' E	225	Dry deciduous	4	55	0.5	5500	2750	3
30	Thonanthikla	12° 07' N and 76° 46' E	341	Dry deciduous	4	25	1	2500	2500	4
Nugu River System										
31	Noolpuzha	11° 41' N and 76° 23' E	2810	Semi evergreen	3	25	4.1	2500	10250	4

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

From the cluster dendrogram it is clearly noticed that most of the study sites are clustered together because of the similarity of species composition in those sites. Some of the sites, where human disturbances are prevalent also fall in the same cluster. Certain sites remain separate, because only species composition in that particular site is not present in the other location. There are two main reasons for this separate clustering: due to the rare species forms; and due to low water temperature. When the compositions of the fish communities at different sites were compared, five groups of clusters have been obtained.

Water Quality

Water Quality parameters were recorded and presented in Table 4. It is found that the parameters value lies between the IS: 10500 Permissible limits. The acidic or alkaline nature of the water will be decided based on the pH level. Water pH ranges were from 6.5 to 8.5, Kadapilliyarthittu was recorded with pH level is high (pH - 9) and Anjurily, Athirapalli, Urilikal recorded low pH level (pH – 7.2) compared to the other sites. Low conductivity value 27.8 mS was recorded in Puliyarkutti river 8th bridge and Puliyarkutti river 3rd bridge sites and high conductivity

value 85.2 mS recorded in Noolpuzha of Nugu river system.

Total dissolved solids (TDS) are a measure of inorganic salts dissolved in water. This dissolved solid comes from both natural and human sources. Mitchell and Stapp in 1992 have suggested changes in TDS concentrations that can be harmful. If TDS concentrations are too high or too low, the growth of much aquatic life can be limited. Thenkasithodu witnessed a low value of TDS content as 13.7 mg/l and Urilikal recorded a high value of TDS as 51.9 mg/l. A minimum resistivity value of 2.58 was measured at Kadapilliyarthittu and a maximum 45.6 was measured at Thenkasithodu. A high level of DO was recorded at Thenkasithodu as 6.11mg/l and a low level of DO was recorded at Belikoondu as 0.63 mg/l. Low value of salinity was recorded at sites viz., Thenkasithodu, Anjurily, Sorrakottaodai, Naduthotam, Nellithurai, Kovaikutralam falls, Puliyarkutti River 8th bridge and Puliyarkutti River 3rd bridge as 0.01 ppt and a high level of salinity was noted at Kadapilliyarthittu as 0.18 ppt. Maximum water temperature was recorded at Pillapara as 33.6 °C and a minimum water temperature was noted at Thenkasithodu as 18.9 °C.

Table 2: Study site and Species collected from river systems of Southern Western Ghats

S. No	Study site	Species collected
Moyar River System		
1	Gulithuraipatti	*P. carnaticus, P.amphibious, P. sarana sarana, P. dorsalis and P.filamentosus*
2	Kallampalayam	*P.carnaticus, P.amphibious, P.sarana sarana, P. dorsalis, P.chola and P.ticto*
3	Belemeenthurai	*P.carnaticus*
Chalakudy River System		
4	Orukomban range	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
5	Thenmudiparai	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
6	Baghapallam	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
7	Thellikal	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
8	Puliyarkutti river 8th bridge	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
9	Puliyarkutti river 3rd bridge	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
10	Thunakadavu stream	*P. carnaticus, P.mahecola P.melanampyx and P. fasciatus*
11	Thunakadavu tunnel	*P.mahecola*
12	Urilikal	*P. fasciatus, P.melanampyx, P.sophore and P. bimaculatus*
13	Athirappalli	*P. melanampyx, P. mahecola, P.denisonii and P. chalakudiensis*
14	Pillapara	*P. melanampyx, P. mahecola, P.denisonii and P. chalakudiensis*
Bhavani River System		
15	Kovaikutralam falls	*P. melanampyx and P.fasciatus*
16	Nellithurai	*P. sarana sarana, P.sarana spirulus and P. mahecola*
Periyar River System		
17	Oorpannikaham	P.fasciatus *and P.melanampyx*
18	Valukuparai	P.fasciatus *and P.melanampyx*
19	Melaparai	P.fasciatus *and P.melanampyx*
20	Naduthotam	*P.fasciatus and P.ophicephalus*
21	Ummikuppamthodu	*P.fasciatus and P.ophicephalus*
22	Sorrakottaodai	P.fasciatus *and P.melanampyx*
23	Mullaithodu	P.fasciatus *and P.melanampyx*
24	Anjurily	P.fasciatus *and P.melanampyx*
25	Thenkasithodu	*P. bimaculatus*
Cauvery River System		
26	Kadapilliyarthittu	*P.carnaticus, P.mahecola and P.conconius*
27	Belikoondu	*P.mahecola and P.conconius*
28	Nadathittu	*P.carnaticus, P.filamentosus, P.mahecola and P.conconius*
29	Sinnaru	*P.carnaticus, P. amphibious, P. filamentosus, P.sarana sarana, P.conconius*
30	Thonanthikla	*P.filamentosus and P. carnaticus*
Nugu River System		
31	Noolpuzha	*P. sarana sarana, P.sarana spirulus, P. melanampyx, P. fasciatus and P.bimaculatus*

Table 3: *Puntius* species composition among the 31 sites six river systems

Cluster no	Cluster between	Study sites
1	1 - 21	Thonanthikla, Belemeenthurai, Valukuparai, Oorpannikaham, Thenkasithodu, Belikoondu, Mullaithodu, Orukomban range, Anjurily, Sorrakottaodai, Thenmudiparai, Melaparai, Thellikal, Pillapara, Athirapalli, Sinnaru, Nadathittu, Kadapilliyarthittu, Nellithurai, Gulithuraipatti and Kallampalayam
2	22	Thunakadavu Tunnel
3	23 - 28	Kovaikutralam, Puliyarkutti 3rd bridge, Noolpuzha, Puliyarkutti river 8th bridge, Baghapallam and Thunakadavu stream
4	29 -30	Ummikuppamthodu and Naduthotam
5	31	Urilikal

Habitat Structure

Stream habitat was measured in dimensions like length, width, depth, bottom type and current. Among streams sampled, some were very small. Large proportions (> 50%) of the habitat sampled included very shallow (< 1 centimeter) water. Typically, such areas are not habitable by fishes and most fish concentrate in dispersed pools indicating that habitat measures in up-stream areas should be restricted to the pools themselves [6].

Substratum Types

For the present study, the fish species diversity, habitat quality assessments of the river systems have been taken as the major criteria. The results exhibit that the study area is well flourished with flora and fauna. It proves that habitat provides the perfect level of food, shelter suitable for the fishes and other aquatic organisms. The habitat assessment of the study area says that there are four habitat types (pool, riffle, run and glide) with six substratum type (Fine sand, debris, Silt, Bedrocks, Gravel, Rubbles and boulders). The shore line is also Sandy border rigid with Rocks and Sandy border rigid. This makes up a good habitat for the aquatic organisms. Moreover the water quality, substratum type and vegetation provide a good and healthy habitat and high food resource availability which plays a major key role for species diversity and abundance in the Moyar river system. The river habitat is utilized by the tribal people for catching the fishes for their source of protein food. In the present study, in regard to the substratum type, Rubble & Boulders were dominant with 80% in Mullaithodu. In Anjurily gravel was the dominant substratum representing 70%. Moreover substratum types like sand and silt are equally represented in all the study sites. Debris is the biological matter that occupies the stream habitat as a major part in providing good shelter and feeding habitat for the fishes. Mostly the bottom feeders like *Garra, Nemachelius, Travanchoria* use these debris and bed rock substratum as their habitat in a total stream channel with all other substratum types. Nadathittu of Cauvery River, Naduthotam of Periyar river, Kovaikutralam of Bhavani River and Thunakadavu of Chalakudy river system have their base substratum as natural bedrock, which provides them a strong rigid bottom.

Stream width and volume were high at Belikoondu of Cauvery river system (80 m, 80000 m^3) followed by Nadathittu (70 m, 42000 m^3), Kadapilliyarthittu (75 m, 11250 m^3), Kallampalayam (13 m, 10400 m^3), Noolpuzha (25 m, 10250 m^3). The lowest stream width and volume were recorded at Thellikal (4 m, 400 m^3). Among the 31 sites very fast flowing water was noted at Nellithurai, Thunakadavu tunnel and Belikoondu. Fast flow and Moderate flow water was noted in most of all the river systems. Slow flow of water in the channels was recorded at Thenkasithodu, Kadapilliyarthittu, Oorpannikaham and Urilikal.

Table 4: Water quality of 31 study sites of six river systems

Index	pH	Conductivity (mS)	TDS (ppm)	Resistivity (KΩ)	DO (mg/L)	Salinity (ppt)	Water temperature (°C)
Gulithuraipatti	8.4	57.8	20.37	24.2	3.5	0.03	23.8
Kallampalayam	7.9	45.2	28.5	21.9	2.5	0.02	24.1
Belemeenthurai	8.4	59.2	37.7	16.4	1.3	0.03	24.5
Orukomban range	7.5	33.9	26.5	22.4	3.5	0.02	23.4
Thenmudiparai	8	45.2	28.5	21.9	2.5	0.02	24.1
Baghapallam	8	57.8	38.0	16.8	2.4	0.03	21.7
Thellikal	8.8	59.2	37.7	16.4	1.3	0.03	24.5
Puliyarkutti 8th bridge	7.79	27.8	18.0	34.8	5.4	0.01	23.5
Puliyarkutti 3rd bridge	7.79	27.8	18.0	34.8	5.4	0.01	23.5
Thunakadavu stream	5.9	38.3	28.3	22.2	5.09	0.02	21.4
Thunakadavu tunnel	5.9	38.3	28.3	22.2	5.09	0.02	21.4
Urilikal	7.2	78.7	51.9	12.9	1.4	0.03	24.1
Athirappalli	7.2	35.2	47.5	3.97	0.73	0.02	32.7
Pillapara	7.6	34.0	19.5	29.9	0.89	0.02	33.6
Kovaikutralam falls	7.5	31.3	20.1	32.3	3.2	0.01	22.5
Nellithurai	7.3	30.3	20.3	31.5	2.3	0.01	25.5
Oorpannikaham	8.3	50.3	32.3	20.0	1.2	0.02	24.8
Valukuparai	7.7	66.9	43.8	15.1	0.7	0.03	24.8
Melaparai	9	44.7	28.8	22.5	1.3	0.02	26.1
Naduthotam	7.5	46.2	30.4	20.6	0.7	0.01	25.9
Ummikuppamthodu	7.7	64.9	43.2	17.1	1.2	0.03	24.8
Sorrakottaodai	8	34.2	21.9	29.5	1.1	0.01	23.1
Mullaithodu	8.1	78.6	51.4	12.5	0.9	0.04	24.2
Anjurily	7.2	21.5	13.6	47.5	4.86	0.01	19.2
Thenkasithodu	5.2	22.0	13.7	45.6	6.11	0.01	18.9
Kadapilliyarthittu	9.6	39.1	26.3	2.58	0.72	0.18	30.5
Belikoondu	9.4	39.8	26.3	2.63	0.63	0.17	32.7
Nadathittu	9.4	39.8	26.3	2.63	0.63	0.17	32.7
Sinnaru	9.2	39.5	26.3	2.65	3.11	0.11	30.2
Thonanthikla	9.2	39.5	26.3	2.65	3.11	0.11	30.2
Noolpuzha	7.32	85.2	51.7	11.8	3.62	0.04	23.2

Table 5: Substratum types of 31 study sites of six river systems

Index	Rubble & Boulders	Gravel	Sand	Silt	Debris	Bedrock
Gulithuraipatti	10	60	20	10	0	0
Kallampalayam	0	60	10	10	20	0
Belemeenthurai	70	10	15	0	5	0
Orukomban range	30	20	10	0	15	25
Thenmudiparai	0	35	20	20	5	20
Baghapallam	0	25	25	5	5	40
Thellikal	0	40	20	20	20	0
Puliyarkutti river 8th bridge	30	10	20	0	10	30
Puliyarkuti 3rd bridge	40	20	10	0	10	20
Thunakadavu stream	20	40	15	0	25	0
Thunakadavu tunnel	40	0	0	0	0	60
Urilikal	40	20	20	0	10	10
Athirappalli	60	10	10	0	0	20
Pillapara	60	10	10	0	0	20
Kovaikutralam falls	10	0	20	0	10	60
Nellithurai	40	10	40	0	10	0
Oorpannikaham	10	60	5	0	0	25
Valukuparai	70	10	0	0	10	10
Melaparai	10	0	80	0	10	0
Naduthotam	20	10	10	0	0	60
Ummikuppamthodu	20	10	60	0	10	0
Sorrakottaodai	5	10	20	30	35	0
Mullaithodu	80	10	0	0	10	0
Anjurily	0	70	15	0	15	0
Thenkasithodu	15	15	10	0	0	60
Kadapilliyarthittu	70	10	15	0	5	0
Belikoondu	10	60	20	0	10	0
Nadathittu	10	0	0	0	10	80
Sinnaru	10	50	25	15	0	0
Thonanthikla	10	60	5	0	0	25
Noolpuzha	10	60	25	0	5	0

Ecological Structures Influence Characterizations

Principal component analysis was used to illustrate the influence of the variables and its importance for the ecological structure of the river system and the fish species. The various habitat characteristics like water quality, channel morphology, and the substratum type influencing the *Puntius* species distribution analysis results explains that species abundance and richness are mainly due to influencing factors like Altitude (6.940), Area (21.449) and Volume (58.428) (Table. 5, 6 & 7). All other characters play a supportive role to express the variations among the study sites. Based on the contributions study sites like Belikoondu, Kallampalayam, Sorrakottaodai, Anjurily, Thenkasithodu, Belemeenthurai, Kovaikutralam, Naduthotam, Nadathittu, Kadapilliyarthittu and Sinnaru exhibits more variations than comparing to the other study sites. The results obtained concludes that altitude plays a major role in species diversity and species abundance, which supports the proposed the theory that diversity changes with altitude on mountainsides, being lowest at higher elevations [38]. The present finding supported the above theory as the results expressed that species diversity and abundance is high at high altitudes. Among the 31 sites, high species diversity of genus *Puntius* was recorded at Sinnaru of Cauvery River system (H'- 0.659) because of the altitude, area of the channel and the volume of flow as well. The maximum *Puntius* species richness was recorded at Gulithuraipatti and Kallampalayam (S – 6), due to the channel flow, altitude and the submerged substratum types with muddy water flow. The maximum *Puntius* species abundance 66 was recorded at Urilikal due to the low area of the channel and the maximum percentage of the rocky boulder substratum. The maximum dominance of *Puntius* species (D - 5.182) was recorded at Sinnaru influenced by the vast channel area. Rest of the sites was low due to the less percentage of influence made by the habitat structures.

DISCUSSION

Silas in his faunal account discussed the extension of range of *Salmostoma acinaces* (*Chela argentea* Day), Barbodes carnaticus (*Barbus* (*Puntius*) *carnaticus*), *Osteochilus* (*Osteochilichthys*) *thomassi* and *Batasio travancoria* and listed 2 endemic species described by Herre viz. *Homoloptera Montana* and *Glyptothorax housei.* Moreover, he reported 5 species from the Cochin part of the anamalai hills viz. *Barilius bakeri, Puntius denisoni, Travancoria jonesi, Noemacheilus triangularis* and *Batasio travancoria.* Rema Devi reported 59 species from Anamalai hill of which 30 species were new additions to the IGWLS and 20 to the Anamalai hills, incuding one new species *Heteropneustes longipectoralis*. *Punitus bimaculatus* (*B. puckeli*) earlier considered as a juvenile of *P. dorsalis* has been collected from these hills. Interestingly this species was found to be the most dominant *Puntius*

species in the hill ranges of the Eastern Ghats especially Javadi hills. *Puntius punctatus* earlier considered as a synonym of *Punitus ticto* has been kept as a seprate species and both these species have been collected from Anamalai hills [28].

Table 6: Channel Morphology of 31 study sites of six river systems

Index	Stream Width (m)	Stream Depth (m)	Area (m^2)	Volume (m^3)	Mean Velocity (m/sec)
Gulithuraipatti	10	6	1000	6000	4
Kallampalayam	13	8	1300	10400	4
Belemeenthurai	19	1.75	1900	3325	4
Orukomban range	6	0.5	600	300	3
Thenmudiparai	25	1.5	2500	3750	3
Baghapallam	8	0.5	800	400	3
Thellikal	4	1	400	400	3
Puliyarkutti 8th bridge	19.2	1.2	1920	2304	3
Puliyarkutti 3rd bridge	37	1.5	3700	5550	3
Thunakadavu stream	13.6	0.5	1360	680	3
Thunakadavu tunnel	15	10	1500	15000	5
Urilikal	7	1.5	700	1050	2
Athirappalli	8	3	800	2400	4
Pillapara	5	2	500	1000	4
Kovaikutralam falls	5	1.2	500	600	4
Nellithurai	27	1.1	2700	2970	5
Oorpannikaham	12	2.1	1200	2520	2
Valukuparai	7.5	0.3	750	225	3
Melaparai	11	4.2	1100	4620	3
Naduthotam	7.5	0.3	750	225	3
Ummikuppamthodu	5	3	500	1500	4
Sorrakottaodai	7	1.5	700	1050	3
Mullaithodu	10	0.6	1000	600	3
Anjurily	20	5	2000	10000	2
Thenkasithodu	11.3	0.5	1130	565	2
Kadapilliyarthittu	75	1.5	7500	11250	2
Belikoondu	80	10	8000	80000	5
Nadathittu	70	6	7000	42000	3
Sinnaru	55	0.5	5500	2750	3
Thonanthikla	25	1	2500	2500	4
Noolpuzha	25	4.1	2500	10250	4

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

Table 7: Contribution of the variables is given in overall percentage after varimax rotation for habitat characters.

Variables	D1	D2
Altitude	6.940	45.277
pH	0.849	0.147
Conductivity (mS)	0.424	0.002
TDS (ppm)	0.568	0.031
Resistivity (KΩ)	0.715	0.075
DO (mg/L)	0.900	0.180
Salinity (ppt)	0.923	0.196
Water temperature (°C)	0.695	0.069
Rubble & Boulders	0.676	0.060
Gravel	0.740	0.098
Sand	0.764	0.127
Silt	0.884	0.167
Derbies	0.828	0.120
Bedrock	0.714	0.037
Stream order	0.885	0.170
Stream Width (m)	0.819	0.155
Stream Depth (m)	0.909	0.196
Area (m2)	21.449	20.245
Volume (m3)	58.428	32.473
Mean Velocity (m/sec)	0.891	0.177

Diversity of *Puntius* Species at the Anamalais is very high except for a few areas such as the Aliyar river basin. The lack of diversity in the Aliyar river basin is due to the fact that most of the streams in the area are non-perennial and are prone to disturbance/contamination by the local tribal people. This diversity is attributed to the controlled fishing activity by locals and protection by Forest officials. The physical environment like forest vegetation, riparian vegetation, water temperature, habitat type, and in-stream cover (which provide hiding places for fish) play a major role in species diversity and richness. The lowest DO recorded at sampling sites is due to organic-rich domestic waste let into the river by the tourists in the river system [39]. Simpson proposed the heterogeneity theory, which holds that the more diverse the physical environment, the more complex its flora and fauna. The greater the variation in topography relief, the more complex the structure of the fauna; similarly the more types of habitats the community contains, the more kinds of species it will hold. This theory is supported by the fact that forest with marked vertical structure holds more species. This hypothesis is true in the present study on fishes. Altitude also plays a major role in species diversity. Colinvaux proposed the theory of diversity that changes with altitude on mountainsides – diversity is lowest at high elevation and *vice versa*. The present finding supported the above theory. *Puntius ophicephalus* was rediscovered from Periyar River by which the total number of fish species raised to 38 [40]. In the present study 64 species were collected from 31 study sites of six river systems of Southern Western Ghats. Species like *Puntius melanampyx, Puntius carnaticus, Puntius amphibious, Puntius fasciatus, Puntius mahecola, Devario aequipinnatus, Garra mullya, Travancoria jonesi, Nemacheilus guntheri* were commonly found in all the six river systems.

A total of 168 individuals of the 17 species of genus *Puntius* have been collected for the study from 31 study sites of six river systems of Southern Western Ghats. Smith in 1990 stated that habitat selection of the fishes could be influenced by the body structure, food and shelter and by physiological process. Moreover the fish analyses the characters of the rivers and streams and further they respond to the characters and helps themselves for the survival of the fittest. Hence, it is reliable that the micro and macro habitats play a key role in the morphology and physiological characters and as well modifications of the species. The fish prefers the habitat based on the nature of the rivers/stream substratum type. As Odum stated that the flow of the water in the channel is an important factor for the distribution of fishes [41], the species like *Barilius, Hypselobarbus, Puntius, Travancoria, Rasbora* and *Tor* prefer fast flow. The nature of the substratum and the flow rate seem to be moderaltely interrelated in governing the distribution of the fishes. This induces the dominance of the cyprinid species to be well flourished in all the river systems, of the Southern Western Ghats. It is clear that Ecological structure plays a key role in representing river systems of Southern Western Ghats, which is flourished with rich species diversity and abundance.

SUMMARY

The morphological-based fish taxonomy is more inconclusive because the micro and macro habitat have influenced the morphological variations within the species. In the present study, the *Puntius* species were collected by using different mesh size of gill nets, cast net and dip nets from the long and meandering eastward flowing river systems of Bhavani, Moyar, Chalakudy, Periyar, Cauvery and Kabini**.** A total of the 168 individuals of the 17 species of genus *Puntius* have been collected for the study from the 31 study sites of the six river systems of the Southern Western Ghats. The data analyses suggested that species like *Puntius melanampyx, Puntius carnaticus, Puntius amphibious, Puntius fasciatus, Puntius mahecola* were found to be the dominant species in the locations considered in the present task. Interestingly, among the 31 sites, Belikoondu, Kallampalayam, Sorrakottaodai, Anjurily, Thenkasithodu, Belemeenthurai, Kovaikutralam, Naduthotam, Nadathittu, Kadapilliyarthittu and Sinnaru exhibited high variations in species abundance and as well species richness. Importantly, the present study clearly documented that altitudes play a major role in species diversities and as well in species abundance. The *Puntid* species, a healthy fish food, are in peril in Southern Western Ghats and the comprehensive listing of *Puntius* species distribution and continuous monitoring is the most critical need of protection in the present scenario. It is very apparent to mention that the use of explosives, poisons and fishing of juveniles could be the primary causes to the sharp decline of the *Puntius* population in the study areas. Establishment of sanctuaries, preservation of genetic materials, awareness programmes and enforcement of laws are some of the short and long term remedial measures for the effecient conservation of *Puntius* population in Southern Western Ghats. Socal workers, fishermen and local people must also be educated about the importance of conservation of fish fauna in their area in general, so that the personnel in turn can also make awareness among the people in an ecological spirit.

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REFERENCES

1. Matthews W J (1998) Patterns in freshwater fish ecology. Inter Thom Pub. Thom Sci, New York.
2. Nelson J S (1994) Fishes of the World, 3rd Ed. Wiley, New York. pp. 600.
3. Orr R T (1971) Vertebrate Biology, 3rd ed. W.B. Saunders Co. Philadelphia.
4. Anon (1996) Annual Report, National Bureau of Fish Genetic Resources, Lucknow.
5. Sheldon A S (1968) Species diversity and longitudinal succession in stream fishes. *Ecol* 49: 193 - 198.
6. Gorman O T, Karr J R (1978) Habitat structure and stream fish community. *Ecol* 59: 507 - 515.
7. Evans J W, Noble R.L (1978) The longitudinal distribution of fishes in an East Texas stream. *Amer Midl Natur* 101(2): 333 - 343.

8. Barila T Y, Williams R D, Stauffer J R (1981). The influence of stream order and selected stream bed parameters on fish diversity in Raystown Branch, Susquehanna river drainage, Pennsylvania. *J App Eco*. 18: 125 - 131.
9. Hamilton, Buchanan F (1822) An Account of the Fishes of River Ganges and its Branches. George Ramsay and Co., London. pp. vii
10. Jerdon T C (1848) On the freshwater fishes of southern India. Mad J Lit Sci 15(1848): 141 - 149.
11. Day F (1865) On the fishes of Cochin, on the Malabar Coast of India. Part II. *Proc Zool Soc of Lon.* 1: 286 - 318.
12. Day F (1878) The fishes of India, Burma and Ceylon. 4th Ed. New Delhi, pp. 778.
13. Hora S L (1921) Notes on fishes in the Indian Museum on a new species of *Nemacheilus* from the Nilgiri Hills. *Rec of Ind Mus* 22: 19 - 21.
14. Hora S L (1937). Notes on fishes in the Indian Museum, on three collections of fish from Mysore and Coorg, South India. *Rec of Ind Mus.* 39: 5 - 28.
15. Hora S L (1941) Homalopterid fishes from Peninsular India. *Rec of Ind Mus*. XLIII: 211 - 232.
16. Hora S L, Misra K S (1942) Fish of Poona, Part II. *J Bom Nat His Soc* 43: 218 - 228.
17. Hora S L (1949) Satpura hypothesis of the distribution of Malayan fauna and flora and flora of peninsular India. *Proceed Nat Ins Sci India* 15: 309 - 314.
18. Ponniah A G, Gopalakrishnan A (2000) Endemic Fish diversity of the Western Ghats. National Bureau of Fish Genetic Resources, Lucknow, U.P. pp. 347.
19. Arunachalam M, Madhusoodanan K, Nair C, Vijverberg J, Kortmulder K (1997) Food and habitat partitioning among fishes in stream pools of south Indian River. *Inter J Eco Envi Sci.* 23: 271 – 395
20. Arunachalam M (2000) Assemblage structure of stream fishes in the Western Ghats (India). *Hydrobio.* 430: 1 - 31.
21. Pethiyagoda R (2005) A Review of the barbs of the *Puntius filamentosus* group of southern India and Srilanka. Raff Bull Zoo 12: 127 – 144.
22. Kullander, Fang (2005) Two new species of *Puntius* from Northern Myanmar. *Amer soc Icthyol.* 2: 290 - 302.
23. Kullander S O (2008) Five new species of *Puntius* from Myanmar (Teleostei: Cyprinidae). *Ichthyol Explor Fres Wat.* 19: 59-84.
24. Shantakumar M, Viswanath W (2006) Inter- relationship of *Puntius* Hamilton - Buchanan (cyprinidae: Cyprininae) found in Manipur, India. *Zoo's Print*. 21(6): 2279 - 2283.
25. Talwar P K, Jhingran A G (1991) Inland fishes of India and adjacent countries. *Vol. I,* Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi, pp. 541.
26. Jayaram K C (1999) The Freshwater Fishes of the Indian Region. Nerendra Publishing House, New Delhi. pp. xxvii
27. Jayaram K.C (2010) The Freshwater Fishes of Indian Region, 2nd Ed. Narendra Publications, New Delhi. pp. 119.
28. Menon A G K (1999) Check list - Fresh water fishes of India. Rec Zool Sur India, Occasional Paper. 175: 1 - 366.
29. Armantrout N B (1990) Aquatic habitat inventory. Bureau of Land Management, Eugene District, U.S.A. pp. 32.
30. Manimekalan A, Arunachalam M, Sankaranarayanan A, Johnson J A, Soranam R (2000) New record of fishes from the Western Ghats of Maharastra. *J Bom Nat His Soc* 97(2): 292 - 294.
31. Arunachalam M (1999) Methods for fish habitat inventory in Streams/river. Proc. Workshop. Germplasam Inventory. Gene Banking Freshwater Fish *National Bureau Fish* Genetic Resource, Lucknow (in press).
32. APHA (1995) Standard methods. 19th Edition. American Public Health Association Washington, D.C.
33. Horton R E (1945) Erosional development of streams and their drainage basins. Bull Geolog Soc Amer 56: 275 - 370.
34. Kuehne R A (1962) A classification of streams, illustrated by fish distribution in an Eastern Kentucky creek. *Ecol* 43(4): 608 - 614.
35. Shannon C E, Weaver W (1949). The mathematical theory of communications. Urbaba, University of IIinois Press.
36. Simpson G G (1949) Measurement of diversity, Nat 136. pp. 688.
37. Willis S C, Winemiller K O, Fernandez H L (2005) Habitat structural complexity and morphological diversity of fish assemblages in a Neotropical floodplain river, *Oecologia*. 142: 284 - 295.
38. Colinvaux P A (1930) Ecology congress cataloging in publication data.
39. Arunkumar A A, Manimekalan A, Manikandan V, Velmurugan P. (2015). Fish species richness and habitat quality mapping with geographical information system across Cauvery River in Tamil Nadu, India. *J Aridlan Agri*, 1: 43-54.
40. Menon, A.G.K., 1999. Check list - Fresh water fishes of India. Records of the Zoological Survey of India, Occasional Paper. 175: 1 - 366.
41. Odum H T (1945) Primary production in flowing water. *Limn and Oceano* 1: 102 - 117.