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Fish Assemblages And Stream Habitat Types In South Indian Streams

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Abstract

Based on the habitat types, thirty species of cyprinids in nine streams located in the Western Ghat mountain ranges, hotspot of biodiversity have been classified into six guilds. Shallow pools (<60cm deep and velocities <30 cm/s) were preferred by juveniles and adults of big sized barbs such as *Hypselobarbus micropogon, Tor khudree* and *Neolissochilus wynaadensis*. Slow riffles (< 60 cm deep and velocities 30-59 cm/s) were preferred by juveniles of surface dwellers such as *Barilius canarensis, B. gatensis, Devario aequipinnatus, Salmophasia boopis, Salmophasia acinaces* and *Chela labuca*; bottom and substrate dwellers such as *Garramullya* and *Garra stenorhynchus*. Fast riffles (< 60 cm deep and velocities ≥ 60 cm/s) were preferred by the surface dwelling species and species of *Garra*. Almost all the cyprinid species preferred the medium pool (60-149 cm deep and velocities <30 cm/s). Big sized barbs and torines (game fish) were confined to deep pools (≥150 cm deep). Among the nine streams raceway is identified in one stream (60-149cm deep and velocities ≥30 cm/s) which was preferred by juveniles and adults of *Garra stenorhynchus* and *Barilius gatensis*. Guild structures of cyprinid species are consistent in almost all the streams.

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Key words: habitat types, fish guild, streams, Peninsular India

Introduction

Associations of stream fishes and their relationship to habitat features are of intriguing problems for fisheries biologists. Identifying habitat conditions and the requirements by fishes in streams will help to improve habitat conditions, enhance stream features and to make policy making decisions in future restoration activities. There are two approaches in studying fish abundance with quantification of macro habitats (Gorman and Karr 1978; Schlosser 1982; Angermeier 1987; Aadland 1993; Persinger *et al.*, 2010) because habitats within the channel may be influenced by a variety of conditions such as hydraulics, water quality, substrate types, fish cover, biotic interactions both interspecific and intraspecific and also the food availability. The other one is the microhabitat

approach in which the specific habitat conditions will be identified for each species. This model has been widely used in stream fishes of northern latitude (Shirvell and Dungey 1983; Moyle and Baltz 1985; Heggenes 1990; Quist *et al.*, 2005, 2006; Tesfay *et al.*, 2019) and this model has also been applied to New Zealand Rivers (Hayes and Jowett 1994). Leonard and Orth (1988) used microhabitat information from habitat guild representatives to identify stream flow requirements for protecting an entire fish community. There were attempts to study the microhabitat with standing stock (Stalnaker 1979; Conder and Annear 1987; Pajak and Neves 1982; Shirvell 1989). However, modeling with microhabitats to understand the fish habitat relationships often resulted with insufficient result or even misleading information (Mathur *et al.*, 1985; Bozek and Rahel 1991; Oakes *et al.*, 2005). To overcome this, microhabitat and macro habitat approaches have been used (Aadland *et al.*, 1989; Bisson *et al.*, 1988; Heggenes *et al.*, 1990; Ault and White 1994). Present study addresses both micro and macro habitats availability and usage in selected south Indian streams.

Materials and methods

Nine study steams were selected in four river basins from the peninsular states of Karnataka, Kerala and Tamil Nadu in the Western Ghats mountain ranges, a 1600 km long and unbroken chain along the west coast of Peninsular India (Table 1). Habitat use data were collected during May 2022 to May 2023 and from a 100 m reach in all the sites and all the observations were made during day lights (8-5 hours). Sites were selected based on their habitat heterogeneity (with pools, riffles, runs and backwaters) (Arunachalam *et al.*, 2005). Each site was studied and mapped in detail and were divided into 31-79 cells (Table 2) (15.72 - 21.92 m^2). Habitat types were defined as pools, channel margins, raceways, riffles, backwater and run. Pools are topographically low areas with flat-water surface asymmetrical cross sections and relatively low mean velocities. Backwaters had flat-water surfaces and low or zero velocities and were sheltered from the stream current by protrusion of the bedrock or big boulder and the bank. Riffles were topographically high areas that had irregular water surfaces and relatively high velocities. Runs were straight, relatively deeper areas with moderate to high velocities. Channel margins were all areas within 2 m of the bank. Approximately the same numbers of cells were sampled from each habitat during the sampling period. Segregation of stream habitats was based on Aadland (1993) and this method was so suitable in the stream sites selected in the Peninsular India and the habitat guild was followed using Arunachalam *et al.*, (2005) and Sivakumar (2007). Shallow pools were those areas with mean column velocities less than 30 cm/s and depths less than 60 cm. Medium pools were those areas with velocities less than 30 cm/s and depths 60 - 149 cm. Deep pools were those areas 150 cm deep or deeper. Raceways were 60-149 cm deep with velocity of 30 cm/s and greater. Slow riffles were less than 60 cm deep with a velocity range of 30 - 59 cm/s. Fast riffles were less than 60 cm deep with a velocity of 60 cm/s or more. Cluster analysis was used with K means approach to group species. Habitat use category was calculated as number fish species caught in each habitat type and habitat availability was the total area sampled in each habitat type. Densities per habitat type were averaged by weighting on the basis of sample size (numbers of species in each stream). Adults and juveniles of big sized barbs such as *Hypselobarbus jerdoni*, *Hypselobarbus carnaticus* and *Tor khudree* were separated as juveniles and adults whereas in *H. kurali and H. micropogon,* adults were only identified. All the samplings were performed during base flow and low flow conditions between September and May.

Table 1 Stream profiles in selected sites

Streams	River basin	Water Tempt. °C	Altitude (m)	Latitude	Longitude	Stream order	Gradient (%)	Riparian cover(%)	Mean flow (cm/s)	Mean depth (cm)	Mean width (m)	Discharge (m^3 sec^{-1})
Iyyappanpara thode	Kabini / Cauveri	23.5	773	11°55'17.8"	76°05'7.1"	2	1	85	12.55	38.93	4.81	0.17
Kanlindhi Puzha	Kabini / Cauveri	20.9	924	11°54'29.7"	76°59'9.8"	3	2	35	52.54	64.53	11.77	3.72
Thampuratti para	Chaliyar	29.0	15	11°16'46.8"	76°21'0.1"	3	2	24	14.67	45.11	10.20	0.56
Chemmanar	Bhavani / Cauveri	17.0	1000	*	*	2	2	80	25.38	29.15	6.10	0.07
Mulli	Bhavani / Cauveri	24.0	720	10°25'22.3"	76°43'57.8"	2	1	25	8.01	25.97	7.77	0.17
Suruli falls	Vaigai	20.1	490	8°51'39.08"	77°18'40.2"	2	3	40	26.43	34.58	5.56	0.41
Addahole	Nethravathi	29.2	154	12°41'35.3"	75°38'24.3"	4	1	0	15.77	47	15.35	1.02
Lokapavani	Cauveri	24.3	618	12°31'10.9"	76°43'00"	3	2	70	23.7	55.78	9.44	0.98
Kabilanadhi	Nethravathi	29.6	189	12°55'6.3"	75°30'37.4"	4	1	0	16.31	76.46	14.09	1.01

*** Position could not be located by GPS because of cloudy weather**

Table 2 Number of cells (N) and area (m2) sampled in shallow pools (depth<60 cm, velocity <30 cm/s), slow riffle (depth <60 cm,velocity 30-59 cm/s), Fast riffles (depth <60 cm, velocity ≥60 cm/s) raceways (depth 60-149 cm, velocity ≥30 cm/s), medium pool (depth 60-149 cm, velocity <30 cm/s), and deep pools (depth ≥150 cm) in the nine study streams/Rivers. Also shown are the total number of fish species and the total number of fish sampled in each river.

Habitat type/Streams	Iyappan Para		Kalindhi		Thampuratti		Chemmanar		Mulli		Suruli		Addahole		Lokapavani		Kabilanadhi		All streams	
	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N
Shallow pool	347	21			640	30	185	10	700	32	376.4	19	1040	52	219	11	830	42	4337.4	217
Slow riffle	73	5	320	16	152.5	7	352	18	90	5	139.5	13	246.5	14	392.5	17	90	5	1856	100
Fast riffle			205	13	12	2					95	5					4	1	316	21
Raceway			343	19															343	19
Medium Pool	67.5	5	340	19	273.5	14	75	4			40	3	276	11	353	16	340	17	1765	89
Deep pool																	168	14	168	14
All	487.5	31	1208	67	1078	53	612	32	790	37	650.9	40	1562.5	77	964.5	44	1432	79	8785.4	460
Total number of species	7		12		15		3		10		7		14		11		11		57	
Total no fish collected	51		94		57		24		75		98		85		84		62		630	

Depth, velocity and substrates were recorded at each 20 m² sampling cell. Velocity was measured with flow meter. Depth and mean water column velocity measurements were taken equidistantly at the upstream to downstream end of transects. Visual estimates on the proportion of substrates in each transect were performed. Substrate categories were bedrock (>508 mm diameter), boulder (256-508 mm), cobble (>64-256 mm), gravel (3-64 mm), sand (<3 mm), Leaf litter (organic), fine sand <1 mm.

Underwater observation methods have been used to compare the fish catch data because it provides a representative sample of fish all over the habitat types. This method has been proved explicitly or implicitly that the number of encounters (observations) is proportional to abundance of fish in all habitat types examined (Moyle and Baltz 1985; Cunjak and Power 1986, Morantz *et al.*, 1987).

This method has been considered reliable within a range of habitats but may be unreliable in more extreme habitat types (Heggenes 1990). Underwater observations by snorkeling has also been used for density estimates of fish species in different habitat types as this method has gaining popularity in recent years (Fausch and White 1981) because of its usefulness in natural environments under a variety of conditions.

Results

A total of 47 species representing 8 families were collected in the nine streams (Table 3, 4) however, cyprinids were considered for this study because of the dominance in the assemblages with a range of 80.7 to 100 %. In the assemblages 8 species are endangered (Camp Report 1997) which included endemics such as *Barilius canarensis* endemic to south Canara district (Nethravathi river basin), *Nelolissochilus wynaadensis*, *Garra stenorhynchus*, *Garra mcclellandi* and *Hypselobarbus micropogon* endemic to Cauvery river basin and *Puntius ophicephalus* is endemic to Periyar and Vaigai river basins (Arunachalam *et al.*, 2004). Species such as *Devario malabaricus* and *Hypselobarbus denisoni* are endemic to Kerala part of Western Ghats and all the species of *Hypselobarbus* are endemic to Western Ghats (Arunachalam *et al.*, 2016). Juveniles of *Hypselobarbus jerdoni* and *Tor khudree* (Table 5) were usually found along the shallow margin with cobbles and sand. Vegetation, root undercut and boulder edges were the major cover types for these two species. Slow riffle (Table 5) habitats were occupied by juveniles of big sized barbs such *Hypselobarbus jerdoni*, *Tor khudree* and *Hypselobarbus carnaticus*, and surface dwellers such as *Barilius spp.*, *Devario spp.* and *Rasbora daniconius* and the bottom dwellers species of *Garra* were confined to this habitat, slow riffles had the substrate types predominantly of bedrock and boulders. Fast riffles (Fig. 1) were mainly occupied by the surface dwellers such as *Barilius canarensis*, *Barilius gatensis*, *Devario aequipinnatus* and *Devario malabaricus* and the bottom and substrate dwellers such as *Garra stenorhynchus* and *Garra mullya.* Fast riffles had mostly bedrock and boulders (Fig. 2).

Table 3 Fish list of nine Study streams/rivers of Western Ghats

Fishes/ Streams	1	2	3	4	5	6	7	8	9
Hypselobarbus carniticus (LRnt)	6	15			10			3	
Hypselobarbus kurali (EN)							1		5
Hypselobarbus micropogon (NA)		3							
Hypselobarbus jerdoni (NA)									4
Neolissochilus wynadensis (CR)		4							
Tor khudree (VU)							3		6
Osteochilichthys brevidorsalis(EN)								6	
Osteochilichthys nashii (NA)							1		9
Puntius mahecola (NA)			2						3
Puntius bimaculatus (NA)	3							1	
Puntius dorsalis (EN)					4				
Puntius ophicephalus (EN)						9			

Puntius new		4							
Pethia conchonius (VU)		3							
Pethia setnai(NA)							1		
Pethia ticto ticto (LRnt)			1						
Haludaria fasciatus (EN)	3								
Haludaria melanampyx (LRlc)		4	2	8					
Dawkinsia filamentosus (NA)			9						2
Sahyadria denisoni (EN)			1						
Systomus sarana subnasutus (VU)								1	
Salmophasia boopis (NA)							3		
Barilius canarensis(NA)							25		25
Barilius gatensis (NA)	2	23	11	5	16	29		16	
Devario aequipinnatus (LRnt)		3		11	25	33		15	3
Devario malabaricus (CR)	7		9						
Rasbora daniconius(LRnt)	14		5			2			1
Garra stenorhynchus (EN)		18			5			15	
Garra mcclellandi(NA)					2				
Garra mullya (NA)	16	15	6		5	13	39	24	3
Balitora mysorensis(NA)							3		
Bhavania australis(EN)			4				1		
Nemacheilus menoni(NA)							1		
Schistura denisoni denisoni(NA)					1	10		1	
Schistura nilgiriensis(NA)		1							
Mesonemacheilus guentheri(LRlc)		1							
Mesonemacheilus triangularis(LRlc)			1				2		
Oreonectes evezardi(NA)					1				
Lepidocephalus thermalis(NA)					6	2			
Mystus armatus (NA)								1	
Mystus cavasius (LRnt)								1	
Mystus bleekeri (NA)			3						
Xenentodon cancila (LRnt)							3		
Aplocheilus lineatus (NA)			1						
Sicyopterus graseus (NA)									1
Mastacembelus armatus (NA)			1						
Tetraodon travancoria			1				2		

Table 4 Densities (number/100 m^2) of cyprinids in shallow pools, slow riffle, fast riffle, raceways, medium pools, and deep pools in the Western Ghats streams. (NA- Not available habitat)

Species	Shallow pool	Slowriffle	Fast riffle	Raceway	Medium pool	Deeppool	Number of fish Observed
Iyappanparathode							
Puntius bimaculatus	3.46	0.00	NA	NA	0.00	NA	12
Hypselobarbus carnaticus	4.03	6.85	NA	NA	8.89	NA	25
Haludaria fasciatus	3.46	0.00	NA	NA	0.00	NA	12
Barilius gatensis	1.44	6.85	NA	NA	0.00	NA	10
Devario malabaricus	4.61	6.85	NA	NA	10.37	NA	28
Rabora daniconius	11.24	2.74	NA	NA	14.81	NA	51
Garra mullya	13.54	0.00	NA	NA	11.85	NA	55
Kalindhipuzha							
Hypselobarbus micropogon	NA	0.00	0.00	0.58	3.24	NA	32
Neolissochilus wynaadensis	NA	0.00	0.00	0.87	2.94	NA	13
Hypselobarbus carnaticus	NA	0.00	0.00	2.33	10.88	NA	45
Pethia conchonius	NA	0.00	0.00	0.00	3.53	NA	12
Haludaria melanampyx	NA	0.00	0.00	0.00	3.24	NA	11

Barilius gatensis	NA	15.00	6.34	1.17	0.00	NA	65
Devario aequipinnatus	NA	2.81	0.98	0.00	0.59	NA	13
Garra stenorhynchus	NA	12.50	4.88	4.37	0.00	NA	65
Garra mullya	NA	7.50	3.90	0.87	0.88	NA	38
Thamburatti para							
Puntius mahecola	1.72	0.00	0.00	NA	0.00	NA	11
Sahyadria denisoni	0.31	0.00	0.00	NA	1.10	NA	5
Dawkinsia filamentosus	2.03	1.31	0.00	NA	7.31	NA	35
Haludaria melanampyx	1.25	0.00	0.00	NA	0.00	NA	8
Pethia ticto	0.63	0.00	0.00	NA	0.73	NA	6
Barilius gatensis	1.09	22.30	25.00	NA	0.00	NA	44
Devario malabaricus	1.25	12.46	33.33	NA	1.10	NA	34
Rasbora daniconius	3.13	0.00	0.00	NA	0.00	NA	20
Garra mullya	1.56	9.18	0.00	NA	0.00	NA	24
Chemmanar							
Haludaria melanampyx	17.30	0.00	NA	NA	0	NA	32
Barilius gatensis	3.24	4.55	NA	NA	0	NA	22
Devario aequipinnatus	4.86	9.38	NA	NA	4	NA	45
Mulli							
Hypselobarbus carnaticus	4.00	2.22	NA	NA	NA	NA	30
Puntius dorsalis	1.86	0.00	NA	NA	NA	NA	13
Barilius gatensis	2.00	23.33	NA	NA	NA	NA	35
Devario aequipinnatus	4.29	33.33	NA	NA	NA	NA	60
Garra stenorhynchus	1.57	12.22	NA	NA	NA	NA	22
Garra mcclellandi	0.57	7.78	NA	NA	NA	NA	11
Garra mullya	1.86	8.89	NA	NA	NA	NA	21

Table 4- Continued.

Species	Shallow pool	Slow riffle	Fast riffle	Race way	Medium pool	Deep pool	No. of fish observed
Suruli falls							
Puntius ophicephalus	4.25	1.43	0.00	NA	50.00	NA	38
Barilius gatensis	1.33	18.64	16.84	NA	7.50	NA	50
Devario aequipinnatus	2.39	38.71	4.21	NA	0.00	NA	67
Rasbora daniconius	1.33	1.43	0.00	NA	7.50	NA	10
Garra mullya	3.45	15.05	2.11	NA	10.00	NA	40
Addahole							
Hypselobarbus kurali	0.00	0.00	NA	NA	1.81	NA	5
Osteochilichthys nashii	0.00	0.00	NA	NA	1.81	NA	5
Pethia setnai	0.48	0.00	NA	NA	0.00	NA	5
Tor khudree (J)	0.00	4.06	NA	NA	0.00	NA	10
Tor khudree (A)	0.00	0.00	NA	NA	1.45	NA	4
Barilius canarensis	0.58	7.30	NA	NA	0.00	NA	24
Salmophasia boopis	0	0	NA	NA	5.43	NA	15
Garra new *sp.*	5.38	0.00	NA	NA	0.00	NA	56
Garra mullya	0.77	1.62	NA	NA	0.00	NA	12
Lokapavani							
Osteochilichthys brevidorsalis	1.83	0.00	NA	NA	5.67	NA	24
Puntius bimaculatus	2.28	0.00	NA	NA	0.00	NA	5
Hypselobarbus carnaticus (J)	0.91	1.02	NA	NA	0.00	NA	6
Hypselobarbus carnaticus (A)	0.00	0.00	NA	NA	2.83	NA	10
Systomus sarana subnasutus	0.00	0.00	NA	NA	1.42	NA	5
Barilius gatensis	0.91	10.45	NA	NA	1.42	NA	48
Devario aequipinnatus	1.83	9.68	NA	NA	1.42	NA	47
Garra stenorhynchus	3.65	8.41	NA	NA	1.13	NA	45

Garra mullya	9.13	8.92	NA	NA	2.83	NA	65
Kabilanadhi							
Hypselobarbus kurali	0.00	0.00	0	NA	4.12	3.57	32
Hypselobarbus jerdoni (J)	0.24	3.33	0	NA	0.00	0.00	5
Hypselobarbus jerdoni (A)	0.00	0.00	0	NA	2.06	3.57	13
Osteochilichthys nashii	0.36	0.00	0	NA	5.59	9.52	38
Puntius mahecola	1.45	0.00	0	NA	0.59	0.00	14
Dawkinsia filamentosus	1.08	0.00	0	NA	0.88	0.00	12
Tor khudree (J)	1.08	0.00	0	NA	0.59	0.00	11
Tor khudree (A)		0.00	0	NA	2.06	19.64	40
Barilius canarensis	3.61	32.22	150	NA	0.00	0.00	65
Devario aequipinnatus	0.72	6.67	50	NA	0.00	0.00	14
Rasbora daniconius	0.48	2.22	0	NA	0.00	0.00	6
Garra mullya	0.60	6.67	0	NA	0.59	0.00	13

Table 5 Habitat preference guilds of fishes in nine streams/rivers; species name and abbreviation, sample size, mean cell depth, mean column velocity (cm/sec) and depth (cm) of habitat used by each fish species. Coefficients of variation (cv) are in parentheses.

Species	Abbreviation	Size	Mean cell depth (cv)	Mean velocityused (cv)	Mean depthused (cv)
Shallow pool (velocity < 30cm/s, depth < 60cm)					
Hypselobarbus jerdoni (J)	HjJ	2	31 (4.56)	26.19 (9.12)	14.5 (4.88)
Osteochilichthys brevidorsalis	Ob	7	59.86 (9.52)	15.29 (74.64)	45.71 (9.17)
Puntius mahecola	Pa	23	39.17 (33.98)	15.72 (57.62)	20.04 (31.86)
Puntius bimaculatus	Pb	29	34.24 (36.58)	12.06 (66.70)	16.59 (34.58)
Hypselobarbus carnaticus (A)	PcaA	42	38.83 (37.09)	5.83 (50.18)	23.24 (40.44)
Hypselobarbus carnaticus (J)	Pcaj	2	42.50 (8.32)	23.10 (3.45)	21.50 (9.87)
Sahyadaria denisoni	Pde	2	68.50 (3.10)	7.18 (8.32)	34.50 (6.15)
Puntius dorsalis	Pdo	13	31.38 (32.53)	4.94 (28.76)	16.23 (37.24)
Haludaria fasciatus	Pfa	12	35.42 (27.31)	10.63 (30.58)	18.08 (24.78)
Dawkinsia filamentosus	Pf	13	38.36 (33.40)	15.47 (67.37)	18.82 (25.54)
Haludaria melanampyx	Pm	40	33.53 (30.09)	12.61 (38.25)	19.18 (35.79)
Puntius ophicephalus	Po	16	52.25 (15.37)	17.38 (87.90)	8.63 (25.71)
Pethia setnai	Pse	5	23.40 (21.50)	5.07 (20.41)	11.80 (20.23)
Pethia ticto ticto	Pt	4	49.00 (25.87)	8.77 (23.32)	24.25 (17.94)
Tor khudree	Tkj	9	41.25 (43.56)	20.11 (45.69)	20.50 (41.87)
Barilius canarensis	Bc	36	42.97 (22.07)	25.08 (20.08)	11.81 (21.41)
Barilius gatensis	Bg	39	33.85 (45.11)	18.99 (46.08)	8.49 (33.20)
Devario aequipinnatus	Da	58	32.62 (49.46)	15.92 (67.13)	7.74 (38.30)
Devario malabaricus	Dm	24	32.25 (35.97)	16.86 (55.71)	9.67 (23.96)
Rasbora daniconius	Rd	68	38.57 (41.47)	11.24 (64.19)	9.21 (26.51)
Garra stenorhynchus	Gg	19	45.32 (24.30)	15.48 (82.14)	43.11 (26.06)
Garra mcclellandi	Gmc	4	47.25 (22.49)	4.51 (35.36)	45.25 (23.62)
Garra mullya	Gm	116	40.48 (32.77)	15.52 (58.97)	39.30 (33.70)
Garra new sp.	Gns	56	58.07 (25.57)	18.13 (66.59)	57.00 (25.61)
Slow-riffle guild (velocity 30-59cm/s, depth < 60cm)					
Hypselobarbus jerdoni	HjJ	3	27.67 (16.69)	34.55 (40.29)	14.3 (8.06)
Hypselobarbus carnaticus	PcJ	11	15.45 (28.41)	31.81 (25.52)	8.55 (32.83)
Dawkinsia filamentous	Pf	2	38.5 (23.88)	32.96 (3.63)	18.5 (26.76)
Puntius ophicephalus	Po	2	26.5 (29.35)	31.26 (7.64)	6 (0)
Tor khudree	TkJ	10	40.20 (15.83)	33.23 (54.31)	17.20 (20.56)
Barilius canarensis	Bc	47	34.02 (31.62)	36.83 (31.09)	10.15 (21.55)
Barilius gatensis	Bg	191	31.99 (45.04)	37.74 (21.65)	8.58 (34.06)
Devario aequipinnatus	Da	150	26.29 (41.01)	35.10 (22.86)	7.45 (41.32)

Devario malabaricus	Dm	24	24.08 (41.83)	30.81 (5.83)	7.38 (31.94)
Rasboro daniconius	Rd	6	24.67 (40.59)	35.14 (20.09)	7.83 (33.70)
Garra stenorhynchus	Gg	84	36.10 (39.07)	39.30 (23.55)	35.39 (37.63)
Garra mcclellandi	Gmc	7	12.57 (24.67)	32.83 (6.70)	12.43 (24.07)
Garra mullya	Gm	112	32.13 (46.05)	38.32 (27.93)	31.32 (45.47)

Table 5- Continued.

Species	Abbreviation	Size	Mean cell depth (cv)	Mean velocityused (cv)	Mean depthused (cv)
Fast riffle guild (velocity ≥ 60cm/s, depth < 60cm)					
Barilius canarensis	Bc	6	48.5 (7.91)	48.5 (39.25)	12.17 (68.85)
Barilius gatensis	Bg	32	34 (58.74)	71.46 (24.92)	7.84 (40.97)
Devario aequipinnatus	Da	8	37.88 (60.73)	61.59 (12.67)	7.88 (54.91)
Devario malabaricus	Dm	4	24.5 (12.24)	73.52 (4.60)	7 (11.66)
Garra stenorhynchus	Gg	10	57.5 (11.77)	71.92 (8.97)	56 (9.22)
Garra mullya	Gm	10	46.3 (37.96)	77.67 (21.40)	45.8 (37.46)
Raceway guild (velocity ≥ 30cm/s, depth 60-149 cm)					
Hypselobarbus micropogon	Hm	2	57.5 (6.15)	33.19 (15.41)	55.5 (6.37)
Neolissochilus wynaadensis	Nw	3	80 (12.50)	41.93 (4.27)	63.33 (12.06)
Hypselobarbus carnaticus	PcaJ	8	66.25 (15.49)	37.82 (15.27)	49.69 (14.02)
Barilius gatensis	Bg	4	61.50 (20.93)	47.61 (50.74)	8.75 (34.13)
Garra stenorhynchus	Gg	15	59.00 (15.09)	52.92 (32.01)	58.20 (15.60)
Garra mullya	Gm	3	65.00 (7.69)	60.87 (16.15)	65.00 (7.69)
Medium pool guild (velocity<30cm/s, depth 60-149cm)					
Hypselobarbus kurali	Hk	19	120 (17.58)	5.026 (68.52)	115.95 (17.36)
Hypselobarbus micropogon	Hm	11	74.55 (11.79)	25.36 (30.53)	69.18 (12.45)
Hypselobarbus jerdoni	HjA	7	136.14 (9.12)	4.225 (48.99)	129.43 (8.44)
Neolissochilus wynaadensis	Nw	10	81.5 (9.61)	25.47 (34.42)	61.3 (12.42)
Osteochilichthys brevidorsalis	Ob	20	89.9 (22.51)	16.22 (53.71)	70.85 (26.70)
Osteochilichthys nashi	On	24	115 (15.66)	4.33 (84.82)	103 (17.56)
Puntius mahecola	Pa	2	80 (0)	7.61 (15.71)	49 (25.98)
Hypselobarbus carnaticus	PcaA	53	84.91 (18.01)	23.20 (46.85)	62.74(21.66)
Pethia conchonius	Pco	12	80 (13.85)	28.4 (29.71)	39.75 (25.11)
Sahyadria denisoni	Pde	3	80 (6.25)	8.73 (14.78)	40 (5)
Dawkinsia filamentosus	Pf	23	69.93 (18.29)	9.30 (18.39)	33.70 (21.18)
Haludaria melanampyx	Pm	11	68.09 (13.06)	16.11 (30.30)	37.27 (12.36)
Puntius ophicephalus	Po	20	58.75 (18.90)	12.29 (3.51)	9.85 (19.28)
Systomus sarana subnasutus	Psa	5	103.2 (3.31)	10.14 (49.07)	78.6 (2.48)
Pethia ticto	Pt	2	60 (0)	10.14(0)	26 (0)
Tor khudree (J)	TkJ	2	80 (0)	8.45 (0)	50.00 (0.00)
Tor khudree (A)	TkA	11	126 (13.05)	4.69 (73.19)	101.00 (9.59)
Salmophasia boopis	Sb	15	97.8 (16.29)	6.93 (50.32)	10.40 (17.35)
Barilius gatensis	Bg	8	67.38 (z35.85)	18.48 (46.46)	11.50 (17.39)
Devario aequipinnatus	Da	10	76.80 (23.46)	21.26 (49.54)	12.80 (12.10)
Devario malabaricus	Dm	10	72.7 (20.79)	6.76 (16.67)	11.5 (11.04)
Rasbora daniconius	Rd	13	71.85 (21.50)	7.93 (32.42)	11.69 (12.77)
Garra stenorhynchus	Gg	4	54.00 (19.25)	1.13 (115.47)	52.50 (18.76)
Garra mullya	Gm	27	76.22 (28.71)	12.15 (63.51)	75.63 (27.53)
Deep-pool guild (depth ≥150cm)					
Hypselobarbus kurali	Hk		153.33 (6.07)	0.28 (154.92)	149.67 (4.74)
Hypselobarbus Jerdoni (A)	HjA	6	161.7 (9.91)	1.27 (124.72)	154.33 (9.98)
Osteochilichthys nashii	On	16	183.75 (12.82)	1.21 (50.6)	146.25 (16.87)
Tor Khudree (A)	TkA	33	191.52 (14.83)	1.51 (57.24)	147.08 (15.57)

Fig. 1 Mean depth and velocities used by fish species –life stage combinations collected in the study streams/Rivers of Western Ghats (Life stage abbreviations follow species abbreviations given in Table 5).

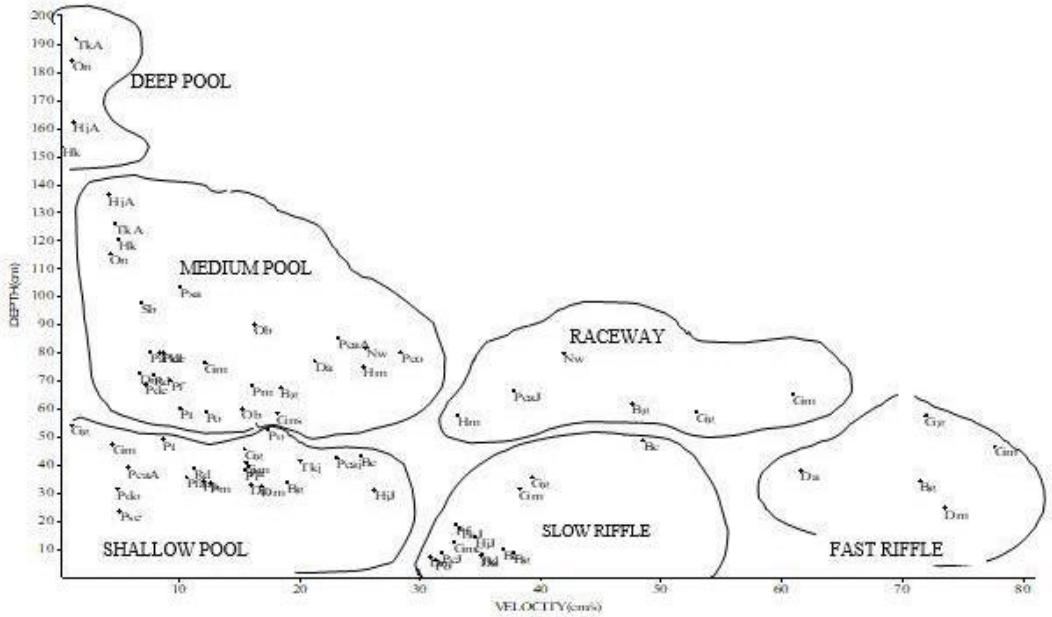
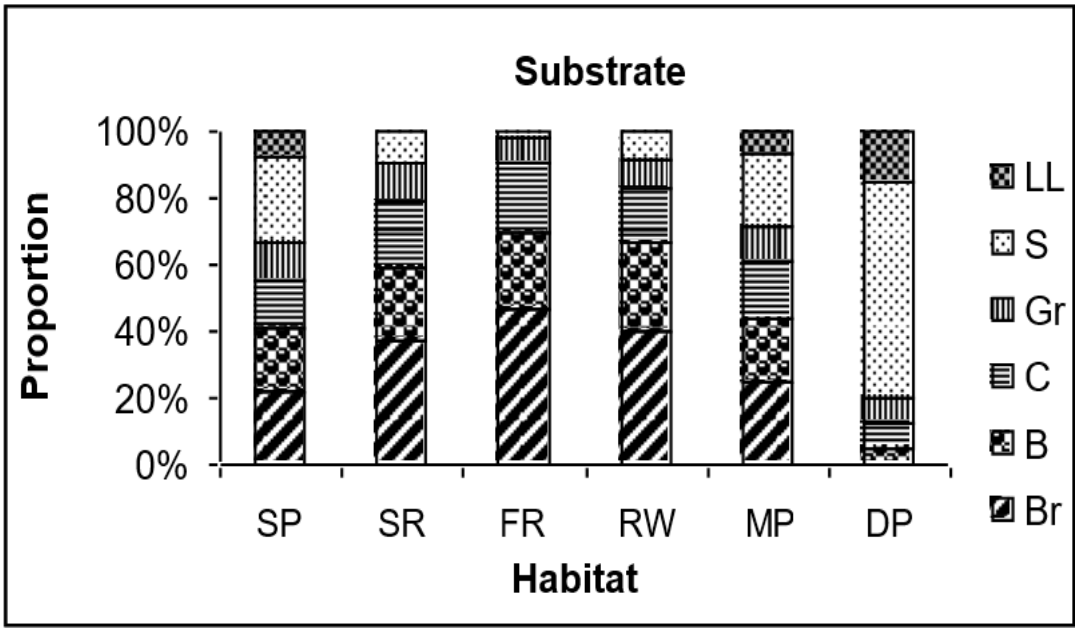


Fig. 2 Proportion of substrates in the habitat of nine study streams/rivers



Habitat
SP- Shallow pool, SR- Slow riffle, FR- Fast riffle, RW- Raceway,MP- Medium pool, DP- Deep pool.

Substrate
LL- Leaf litter, S- Sand, Gr- Gravel, C- Cobble, B- Boulder, Br- Bedrock
Raceway was consisted mainly of the juveniles of big sized barbs and torines and by the bottom dwellers of *Garra* species. Raceway habitats consisted mainly of bedrock and boulders.

Almost all the members of the cyprinids were confined to medium pool (Table 5). Adults and juveniles of the big sized barbs and torines such as *Hypselobarbus kurali*, *H. micropogon*, *Hypselobarbus jerdoni*, *Tor khudree*, *Hypselobarbus carnaticus* and *Neolissochilus wynaadensi*s were in medium pool (Fig. 1). Medium pools had the substrate types of bedrock, boulders and sand. Deep pool habitat was occupied by species such as *Hypselobarbus jerdoni*, *Osteochilichthys nashii* and adults *Tor khudree*. Substrate types (Fig.2) in the habitat were predominately sand (65%0 and leaf litter (15%).

Discussion.

In all the streams from the peninsular states, fish species prefer similar habitats. Medium pools was the most preferred habitats for the big sized barbs and torines, shallow pools were preferred by the species of *Puntius* and *Osteochilichthys nashii*. Surface dwellers were consistently higher in slow and fast riffles. Based on the water column depth, *Devario aequipinnatus, Barilius bakeri and Rasbora daniconius* were considered as surface dwellers in stream pools of a south Indian river (Arunachalam *et al.,* 1997; Sivakumar 2007). This is true as *Barilius canarensis* a surface water dweller is abundant in slow riffles in Addahole and Kabialnadhi streams in Karnataka part, *Barilius gatensis* also shows its abundance in slow riffle in Lokapavani stream. Also a similar trend has been noticed in the occurrence of *Barilius gatensis* in all the study streams in Tamil Nadu and Kerala states. Except the occurrence of the adult of *Tor khudree* (Mahseer) and the big sized carps such as *Hypselobarbus jerdoni* (adults) and *Hypselobarbus kurali* in deep pools in one stream in Kabila nadhi in Karnataka, no other fish species are found in the deep pool habitats in streams of Tamil Nadu and Kerala states. The big sized barb, *Hypselobarbus kurali* always prefers sandy substrates with leaf letter cover and the consistency of this habitat preference in deep pools in almost all the streams in Peninsular Indian states has been noted (underwater observation of the feeding position of cyprinids by Sivakumar).

Guild structure of cyprinid fishes in streams of Western Ghats already proposed (Sivakumar 2007) is more or less consistent with the species occurrence to specific habitats in the present study however; the earlier study is based on the macro habitat preferences of each species. Consistency of surface dwelling species such as *Devario aequipinnatus, Devario malabaricus, Barilius gatensis, Barilius canarensis, Rasbora daniconius* and *Salmophasia boopis* in the shallow riffles and shallow pools and the pattern of occurrence of column dwelling species such as *Dawkinsia filamentosus, Puntius ophicephalus, Systomus sarana subnasutus, Osteochilichthys brevis dorsalis, Osteochilichthys nashi* in the middle and bottom dwelling species belonging to the genera *Tor, Neolissochilus, Hypselobarbus,* (Arunachalam *et al.,* 2017) and the substrate dwelling species such *Garra mullya, Garra mcclellandi, Garra stenorhynchus* and a new species of *Garra* from Add a hole in Karnataka exhibit the pattern of habitat segregation as in tropical moist forest streams in Sri Lanka (Moyle and Senanayake 1984; Wikramanayake and Moyle 1989; Wickramanayake 1990; Vijverberg *et al.,* 2017) and in South Indian streams (Arunachalam 2000; Arunachalam *et al.,* 2005; Sivakumar 2007).

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