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Habitat utilization and preference of cyprinid fishes in the Western Ghats streams of South India

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Abstract

Freshwater ecosystems in the tropical regions are facing significant threats due to anthropogenic disturbances and habitat alterations. Tropical freshwater habitats comprise a fraction of the Earth's water and surface and are crucial for biodiversity as they house 40% of global fish diversity. This study focused on the biodiversity and habitat utilization of dominant cyprinid fish species across 21 streams in the Western Ghats. Field assessments indicated varying habitat characteristics and preferences among cyprinid species, with shallow pools and slow riffles being important for fish reproduction and survival. Over 2,700 fishes were collected, and species such as *Hypselobarbus* and *Puntius* favoured specific habitat types based on size and ecological needs. The analysis of habitat features showed strong associations with fish density, thus highlighting the diverse stream conditions for fish populations. Conservation measures are critical for threatened cyprinid species, as overfishing poses a threat to their survival. The necessity for immediate action by competent authorities and conservationists is emphasized to protect the vital ecosystems having the diverse fish species which ensures freshwater biodiversity sustenance in the Western Ghats.

Keywords: Western Ghats, Biodiversity, Cyprinids, Utilization coefficient, Habitat types

INTRODUCTION

Freshwater ecosystems may well be the most endangered ecosystems in the world. Yet surface freshwater habitats contain only around 0.01% of the worlds water and cover only about 0.8% of the Earth's surface (Gleick, 1996). Rapidly increasing demands on freshwater systems make it essential that resources are exploited in a sustainable manner (Jenkins, 2003). Tropical freshwater ecosystems are particularly vulnerable but poorly understood. There is a pressing need to assess the effects of anthropogenic disturbance on fish and other aquatic communities and to develop effective conservation strategies for rivers at risk. To do this it is first necessary to provide an accurate assessment of the biodiversity they harbour. Fish communities are particularly at risk from habitat alterations, changing flow pattern and changes in water quality and these impacts have very restricted distribution ranges of several species (Ponnaiah and Gopalakrishnan, 2001). Over 10,000 fish species live in freshwater (Lundberg *et al.,* 2000); approximately 40% of global fish

diversity and one quarter of global vertebrate diversity. Between 1976 and 1994 an average of 309 new fish species, approximately 1% of known fishes, were formally described or resurrected from synonymy each year (Stiassny, 1999) and this trend is continuing (Lundberg *et al.,* 2000). Regional discovery rates of new freshwater species also vary. About 2,546 species of fishes are known from the Indian waters (Kotwal and Banerjee, 1998). A dozen countries are identified as mega diversity countries and India are one among them (McNeely *et al.,* 1990). The Western Ghats is a chain of low- lying mountain ranges along the west-cost of the Indian subcontinent that is recognized as a global biodiversity hotspot (Bossuyt, 2004) The freshwater fish diversity in the hill streams of Western Ghats is unique because of the different geomorphic conditions, land setting and water velocity. The anthropogenic activities have changed the ecological structure of the hill stream fishes (Armantrout, 1998). Declines in biodiversity are far greater in freshwater than in the most affected terrestrial ecosystems (Sala *et al.,* 2000). The approach in studying fish abundance with quantification of habitats (Angermeier, 1987) 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 inter specific and intraspecific and also the food availability. Therefore, this study aimed to assess the macrohabitat types and habitat utilization by the dominant cyprinid fish species in the 21 selected streams and rivers in the Southern Western Ghats regions.

MATERIALS AND METHODS

Study Areas

Twenty-one study streams/rivers were selected in fifteen river basins in Kerala, Karnataka and Tamil Nadu parts of Western Ghats. The representative river basins are: Thunga, Bhadra, Seethanadhi, Cauvery, Sowparniga and Kali in Karnataka; Kabini, Valapattanam, Kallada, Amaravathi, Karamana in Kerala; Bhavani, Tamirabarani, Chittar, Nambiyar in Tamil Nadu (Table 1). Sampling was to understand the habitat utilization of the cyprinid fishes and was assessed by prescribed methods (Schlosser, 1987).

Table 1. Details of study sites and profiles of selected streams/rivers in sanctuaries and National Parks of Western Ghats

Streams/rivers	River basin	Altitude (m)	Latitude	Longitude	Stream order	Gradient (%)	Riparian cover (%)
Korkanhalla	Thunga	652	13° 20’22. 3”	75° 10’19. 4”	3	2	23.75
Vimalanadhi	Thunga	680	13° 19’49. 7”	75° 06’15. 7”	3	1	63.00
Halkaprae	Bhadra	778	13° 12’36. 6”	75° 11’05. 5”	4	4	28.23
Jakanmaki	Seethanadhi	091	13° 23’59. 4”	75° 03’8. 4”	2	1	61.81
Abby falls	Cauvery	962	12° 25’	75° 47’	2	2	39.44
Anajeri	Sowparniga	073	13° 49’51. 9”	74° 48’10. 3”	4	1	35.25
Syntheri rock	Kali	437	15° 05’04. 1”	74° 31’29. 2”	4	2	09.29
Manjal	Kabini	840	11° 42’08. 7”	76° 22’04. 6”	3	2	64.17
Kurichithode	Kabini	820	11° 37’58”	76° 22’45. 9”	4	3	62.08
Thirunelli	Kabini	687	11° 53’2. 4”	76° 04’37”	4	1	40.50
Chavachithode	Valapattanam	184	11° 55’38. 6”	75° 51’25. 1”	3	1	10.00
Uruliyar	Kallada	123	08° 52’37. 4”	77° 11’42. 0”	2	3	19.29
Chinnar	Amaravathi	480	10° 21’01. 9”	77°14’15. 2”	3	2	19.44
Thodayar	Karamana	120	08° 39’29. 9”	77° 09’09. 7”	3	2	67.80
Kakkanhalla	Bhavani	350	11° 37’	76° 34’	2	7	60.00
Theppakad	Bhavani	645	11° 35’	76° 35’	4	1	65.55
Sigur falls	Bhavani	950	11° 45’43. 0”	76° 46’00. 4”	4	6	63.18
Gadana	Tamiraparani	155	08° 47’59. 3”	77° 18’0. 1”	2	6	10.83
Kallar and Kuttiyar	Chittar	122	08° 29’00. 6”	77° 19’37. 8”	3	1	50.82
Narakad	Nambiyar	400	08° 26’	77° 32’	2	3	77.44
Ramanadhi	Tamiraparani	160	08° 50’57. 1”	77° 18’38. 2”	2	1	07.67

Assessments of Habitats

Assessments of habitat and habitat inventory were carried out using the methods described by Armantrout (1990), Arunachalam (1995) and Sivakumar *et al.*, (2024). Inventory was carried out at a fixed point, which is designated as 0. This reference point can be readily recognizable by others with permanent features like confluence of tributaries, bridge, culvert or any other manmade structures. The inventory was done in one habitat at a time moving upstream. Different habitat

types such as shallow pools, medium pool, deep pool, shallow riffle, fast riffle and raceway were recorded within 100 m stretch, based on Arunachalam (1999). Macrohabitat controls the longitudinal distribution of fishes along various environmental gradients. General stream features such as channel gradient, stream depth, stream width, riparian cover and bank stability are the macrohabitat features. Generally, stream habitat characteristics were measured in each study stream. Habitat use data were collected from a 100 m reach in all the sites and all the (including underwater) observations were made during daylights between 8 am to 4 pm. Sites were selected based on their habitat heterogeneity (with pools and riffles). Each stream was studied and mapped in detail and were divided into 31-79 cells (15. 72 - 21. 92 m^2). 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 the methods by Arunachalam (2000). Riparian cover was measured using a spherical densiometer. Gradient was determined by averaging three repeated measurements with a clinometer. Measurements of habitat structure were followed using Gorman and Karr (1978) with modifications based on the Indian conditions with depth, current, and substrates. 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). Intensive sampling was done to get minimum 10 individuals of each species in all the sites. The habitat specific coefficient was calculated for individual fish species using the electivity index of Ivelev (1961) based on Schlosser (1991) as follows:

$$\text{Utilization coefficient} = \frac{\text{Habitat specific density-Average total density}}{\text{Average total density}}$$

Statistical Analysis

Habitat utilization theoretically commences from minus one (indicates non-use of the habitat) to positive value (higher positive value indicated most preferred habitat). Habitat use guild was proposed on the basis of fish catch, underwater observation and habitat utilization coefficient. Habitat based Principal Components analysis (SPSS, version 11 and PAST) was used to illustrate the habitat preference of fishes based on associations using relative frequency of occurrence based on underwater observations. Principal Component analysis was done for species richness and abundance with habitat parameters such as altitude, stream order, gradient and riparian cover.

RESULTS

Structural characteristics of Western Ghats streams

Stream habitat variables such as mean stream wetted width, mean stream depth and mean flow were varied among the study streams (Tables 2,3,4). In Karnataka part the mean wetted width was from 6.1 m (Halkaprae) - 16. 2 m (Abby falls) and the mean depth was ranged from 27 cm (Halkaprae) - 76. 8 cm (Abby falls). The mean flow and water discharge were low in Vimalanadhi stream (4.1 cm/s) and high in Syntheri rock (41. 5 cm/s). In Kerala part, the mean wetted width varied from 5.66 m (Uruliyar) to 29.05 m (Chinnar) and the mean depth were from 35.8 cm (Thodaiyar) to 102.6 cm (Chinnar). High mean velocity was recorded in Thodaiyar (37.1 cm/s) stream. Mean wetted width (6.4 m) was lowest in Narakad stream and highest in Theppacad (25.68 m) of Tamil Nadu region. Deepest habitats among sites were recorded in Theppacad and Gadana. High mean velocity (54.46cm/s) was recorded in Sigur falls and was low in Ramanadhi stream (8.02 cm/s) (Fig. 1). Relation between macrohabitat stream features and fish assemblages were examined by Principal component analysis (Fig. 2). Results of Principal component analysis of macrohabitat factors and fish abundance and richness showed that fish densities were not much influenced by stream gradient whereas it had strong association with altitude and stream order. High fish densities were evident in shallow pool area in small streams like Syntheri rock, Gadana and Narakad. Whereas in Vimalanadhi, Anajeri, Chavachithode, and Ramanadhi, the cyprinids were abundant in slow and fast riffles. High densities were recorded in medium pool area in Manjal, Kurichithode with Noolpuzha and Uruliyar streams (Tables 5,6,7).

Table 2. Number of cells (N) and area (m^2) 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 pools (depth 60-149 cm, velocity <30 cm/s) and deep pools (depth ≥150 cm) in the seven study streams/rivers in Karnataka

Streams/rivers	Korkanhalla		Vimalanadhi		Halkaprae		Jakamaki		Abby falls		Anajeri		Syntheri rock		All streams	
Habitat types	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N
Shallow pool	112.5	4	1052.5	107	378	23	571.8	28	545	29	892.5	49	80	5	3632.3	245
Slow riffle	509	37	12.5	3	201	16	100	8	108	5	12	2	423.5	30	1366	101
Fast riffle	27	2			60	6					12	2	85.5	9	184.5	19
Raceway	40.5	3													40.5	3
Medium Pool	80	4					72	6	1250	40	942	62	168	7	2512	119
Deep pool																
All	769	50	1065	110	639	45	743.8	42	1903	74	1858.5	115	757	51	7735.3	487

Table 3. Number of cells (N) and area (m^2) 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 pools (depth 60-149 cm, velocity <30 cm/s) and deep pools (depth ≥150 cm) in the seven study streams/rivers of Kerala

Streams/rivers	Manjal		Kurichithode		Thirunelli		Chavachithode		Uruliyar		Chinnar		Thodaiyar		All streams	
Habitat types	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N
Shallow pool	423	19	303	21			538	25	332.5	18			828	25	2424.5	108
Slow riffle	278.5	21	288.5	20	370	19	63	4	64.25	6			132	5	1196.25	75
Fast riffle					175	9			31.5	4	1080	15	357	16	1643.5	44
Raceway			117	7	590	30					1836	26	90	3	2633	66
Medium Pool	107	8	120	6	860	42	1181	48	129.25	16	3618	49			6015.25	169
Deep pool	240	8							35	3	2880	40			3155	51
All	1048.5	56	828.5	54	1995	100	1782	77	592.5	47	9414	130	1407	49	17067.5	513

Table 4. Number of cells (N) and area (m^2) 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 pools (depth 60-149 cm, velocity <30 cm/s) and deep pools (depth ≥150 cm) in the seven study streams/rivers in Tamil Nadu

Streams/rivers	Kakkanhalla		Theppakad		Sigur falls		Gadana		Kallar and Kuttiyar		Narakad		Ramanadhi		All streams	
Habitat types	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N	Area	N
Shallow pool	740	37	440	22			70	4	396	20	36	2	870	54	2552	139
Slow riffle	162.5	10	310	21	808	46	112.5	9	221.5	18	117.5	8	84	4	1816	116
Fast riffle	86	5	55	6	806.5	53	47	3			30	1			1024.5	68
Raceway			145	7	468	13	12.5	2	50	3					675.5	25
Medium Pool			250	13			325.5	19	272	13	360	17			1207.5	62
Deep pool			1460	74			220	11			68	5			1748	90
All	988.5	52	2660	143	2082.5	112	787.5	48	939.5	54	611.5	33	954	58	9023.5	500

Figure 1. Average discharge of the study streams/rivers of Western Ghats

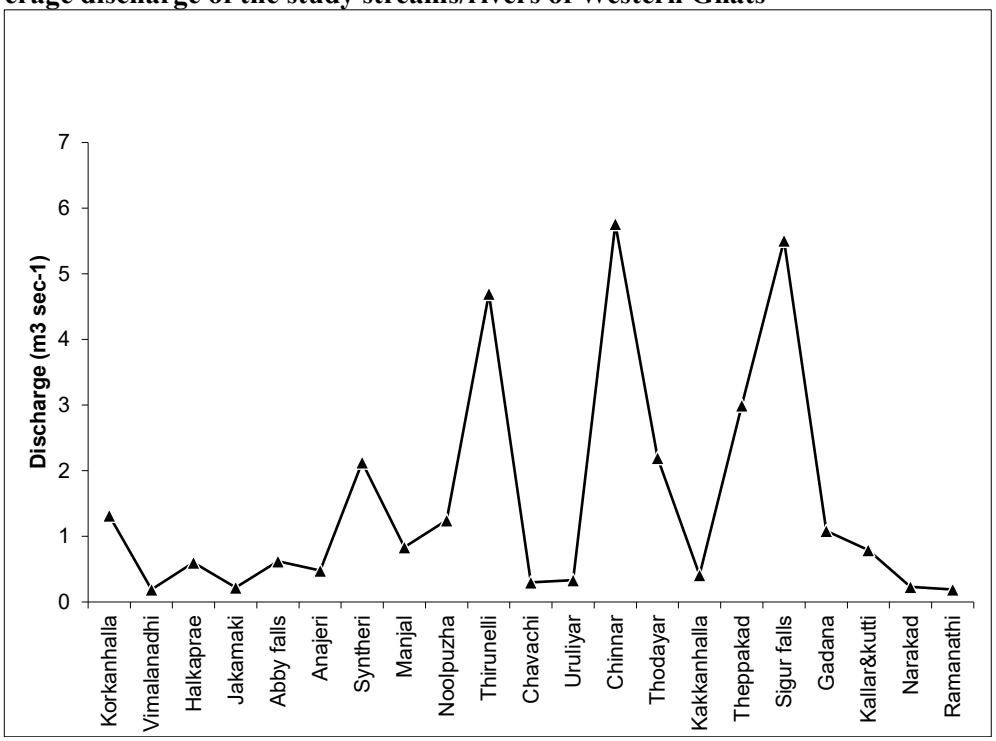


Figure 2. Principal component plot of species abundance and species richness with macrohabitat variables in Western Ghats streams

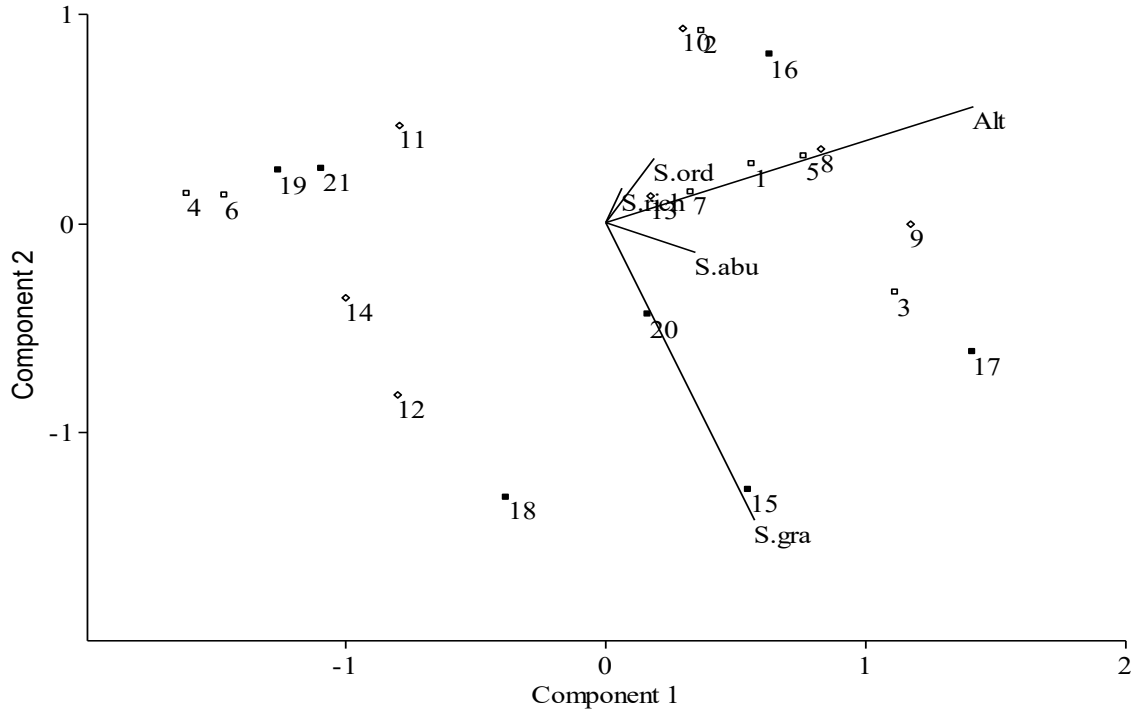


Table 5. Densities (number/100 m^2) of cyprinids in shallow pools, slow riffle, fast riffle, raceways, medium pools, and deep pools in the study streams of Karnataka part

Species	Shallow pool	Slow riffle	Fast riffle	Race way	Medium pool	Deep pool	Number of fish Observed
Korkanhalla							
Osteochilichthys nashii	2	3	0	44	6	NA	40
Dawkinsia arulius	4	1	0	7	3	NA	15
Puntius sahyadriensis	4	0	0	0	0	NA	5
Salmophasia boopis	3	0	0	5	6	NA	12
Barilius canarensis	4	4	111	25	0	NA	63
Rasbora daniconius	7	1	0	2	15	NA	24
Garra bicornuta	4	1	0	0	4	NA	11
Garra mullya	7	3	4	10	4	NA	32
Vimalanadhi							
Osteochilichthys nashii	3	40	NA	NA	NA	NA	36
Dawkinsia arulius	1	40	NA	NA	NA	NA	20
Pethia conchonius	1	16	NA	NA	NA	NA	10
Waikhomia sahyadriensis	1	0	NA	NA	NA	NA	15
Salmophasia boopis	5	80	NA	NA	NA	NA	65
Barilius gatensis	0	40	NA	NA	NA	NA	10
Danio aequipinnatus	1	32	NA	NA	NA	NA	12
Rasbora daniconius	2	16	NA	NA	NA	NA	20
Garra mullya	5	40	NA	NA	NA	NA	55
Halkaprae							
Osteochilichthys nashii	8	7	5	NA	NA	NA	50
Puntius melanostigma	4	5	3	NA	NA	NA	27
Salmophasia boopis	1	1	0	NA	NA	NA	6
Barilius canarensis	3	22	17	NA	NA	NA	65
Barilius gatensis	0	12	22	NA	NA	NA	38
Danio aequipinnatus	3	10	25	NA	NA	NA	45
Garra mullya	17	10	25	NA	NA	NA	100
Jekinmaki							
Puntius mahecola	1	1	NA	NA	4	NA	12
Haludaria fasciatus	2	0	NA	NA	0	NA	10
Dawkinsia filamentosa	1	2	NA	NA	7	NA	10
Haludaria melanampyx	2	0	NA	NA	0	NA	13
Salmophasia boopis	0	0	NA	NA	6	NA	6
Barilius barna	0	4	NA	NA	1	NA	6
Danio aequipinnatus	4	20	NA	NA	21	NA	60
Rasbora daniconius	4	1	NA	NA	3	NA	27
Garra mullya	2	8	NA	NA	3	NA	20
Abby falls							
Neolissochilus wynaadensis(A)	0	0	NA	NA	0	NA	5
Neolissochilus wynaadensis(J)	1	5	NA	NA	0	NA	8
Neolissochilus actirostris (J)	3	28	NA	NA	0	NA	50
Neolissochilus actirostris (A)	0	0	NA	NA	1	NA	10
Osteochilichthys nashii	0	3	NA	NA	0	NA	6
Puntius bimaculatus	1	0	NA	NA	0	NA	5
Pethia conchonius	1	0	NA	NA	0	NA	5
Barilius canarensis	2	11	NA	NA	0	NA	24
Barilius gatensis	2	17	NA	NA	0	NA	30
Danio aequipinnatus	1	5	NA	NA	1	NA	24
Garra mullya	1	4	NA	NA	0	NA	14
Anajeri							
Puntius amphibius	2	8	8	NA	0	NA	21
Haludaria fasciatus	1	0	0	NA	0	NA	5
Dawkinsia filamentosa	4	67	17	NA	6	NA	100
Haludaria melanampyx	1	0	0	NA	0	NA	5
Systomus sarana subnasutus	0	8	0	NA	1	NA	10
Pethia setnai	1	0	0	NA	0	NA	15

Salmophasia boopis	1	50	17	NA	2	NA	40
Barilius barna	1	250	158	NA	1	NA	65
Danio aequipinnatus	1	83	67	NA	1	NA	36
Rasbora daniconius	1	0	0	NA	0	NA	12
Garra mullya	2	67	33	NA	1	NA	36
Syntheri rock							
Hypselobarbus kolus	8	1	2	NA	11	NA	30
Hypselobarbus jerdoni	10	2	6	NA	8	NA	34
Osteochilichthys nashii	3	0	0	NA	7	NA	16
Dawkinsia filamentosa	4	0	1	NA	10	NA	23
Waikhomia sahyadriensis	15	0	1	NA	0	NA	15
Dawkinsia singhala	4	0	0	NA	1	NA	6
Tor khudree	8	1	2	NA	5	NA	20
Tor mosal	3	0	0	NA	1	NA	6
Salmophasia boopis	13	6	18	NA	24	NA	90
Danio aequipinnatus	9	2	5	NA	6	NA	30
Garra mullya	29	8	6	NA	15	NA	88

*(A) – Adult, (J) – Juvenile

Table 6. Densities (number/100 m^2) of cyprinids in shallow pools, slow riffles, fast riffles, raceways, medium pools, and deep pools in the study streams of Kerala part

Species	Shallow pool	Slow riffle	Fast riffle	Race way	Medium pool	Deep pool	Number of fish Observed
Manjal							
Hypselobarbus dubius	0	0	NA	NA	4	1	6
Osteochilichthys nashii	1	0	NA	NA	4	1	12
Hypselobarbus carnaticus(A)	0	0	NA	NA	5	1	9
Hypselobarbus carnaticus(J)	0	1	NA	NA	0	0	5
Puntius chola	4	2	NA	NA	33	10	80
Haludaria fasciatus	1	0	NA	NA	0	0	5
Puntius melanostigma	1	0	NA	NA	7	3	20
Chela laubuca	2	2	NA	NA	28	10	70
Salmophasia sardinella	0	0	NA	NA	5	0	5
Barilius gatensis	2	7	NA	NA	1	0	32
Danio aequipinnatus	5	9	NA	NA	9	4	68
Rasbora daniconius	2	0	NA	NA	9	2	24
Garra gotyla stenorhynchus	1	1	NA	NA	2	0	12
Garra mullya	8	7	NA	NA	19	2	80
Kurichithode with Noolpuzha							
Hypselobarbus dubius(A)	0	0	NA	3	5	NA	10
Hypselobarbus dubius(J)	1	2	NA	1	0	NA	10
Hypselobarbus micropogon (A)	0	0	NA	10	13	NA	28
Hypselobarbus micropogon(J)	4	4	NA	4	0	NA	28
Hypselobarbus jerdoni	0	0	NA	4	0	NA	5
Osteochilichthys nashii	1	0	NA	2	6	NA	12
Puntius mahecola	1	0	NA	1	0	NA	5
Hypselobarbus carnaticus (A)	1	0	NA	4	3	NA	12
Hypselobarbus carnaticus (J)	1	2	NA	2	0	NA	10
Puntius chola	2	0	NA	1	7	NA	15
Haludaria fasciatus	6	0	NA	0	3	NA	20
Salmophasia boopis	3	1	NA	4	11	NA	30
Barilius gatensis	5	16	NA	21	4	NA	90
Danio aequipinnatus	10	7	NA	19	21	NA	96
Garra gotyla stenorhynchus	7	5	NA	9	13	NA	60
Garra mullya	10	5	NA	9	17	NA	75
Thirunelli							
Hypselobarbus micropogon (A)	NA	0	0	0	0	NA	5
Hypselobarbus micropogon (J)	NA	1	1	1	1	NA	13
Neolissochilus wynaadensis	NA	1	0	1	1	NA	17

Hypselobarbus carnaticus (A)	NA	1	1	1	2	NA	24
Hypselobarbus carnaticus (J)	NA	4	1	2	0	NA	30
Pethia conchonius	NA	3	0	1	0	NA	15
Barilius gatensis	NA	3	7	1	1	NA	40
Danio aequipinnatus	NA	1	2	1	0	NA	16
Garra gotyla stenorhynchus	NA	5	9	1	2	NA	60
Garra mullya	NA	4	6	2	2	NA	50
Chavachithode							
Haludaria fasciatus	4	5	NA	NA	0	NA	26
Puntius pradhani	5	5	NA	NA	0	NA	28
Dawkinsia filamentosa	1	5	NA	NA	1	NA	24
Tor khudree (J)	0	13	NA	NA	0	NA	12
Salmophasia boopis	0	0	NA	NA	1	NA	10
Barilius bakeri	1	40	NA	NA	0	NA	36
Barilius gatensis	2	48	NA	NA	1	NA	48
Danio aequipinnatus	3	21	NA	NA	2	NA	45
Rasbora daniconius	1	0	NA	NA	0	NA	6
Garra mullya	5	24	NA	NA	2	NA	68
Uruliyar							
Hypselobarbus kurali (A)	2	0	0	NA	10	29	28
Hypselobarbus kurali (J)	2	8	6	NA	0	0	13
Haludaria fasciatus	3	3	0	NA	0	0	12
Dawkinsia filamentosa	1	3	0	NA	7	11	18
Tor khudree	1	3	0	NA	4	14	16
Barilius bakeri	3	31	63	NA	15	29	80
Danio aequipinnatus	2	8	16	NA	5	17	28
Rasbora daniconius	5	5	3	NA	5	0	26
Garra mullya	12	47	48	NA	19	29	120
Chinnar							
Hypselobarbus carnaticus(A)	NA	NA	0	1	0	0	24
Tor khudree	NA	NA	0	0	0	0	9
Barilius bendelisis	NA	NA	0	0	0	0	6
Barilius gatensis	NA	NA	1	0	0	0	12
Danio aequipinnatus	NA	NA	0	0	0	0	22
Garra gotyla stenorhynchus	NA	NA	1	1	1	0	75
Garra mullya	NA	NA	2	1	0	0	60
Thodayar							
Hypselobarbus kurali (A)	1	0	0	17	NA	NA	24
Hypselobarbus kurali (J)	1	5	1	6	NA	NA	20
Haludaria fasciatus	1	0	0	0	NA	NA	5
Dawkinsia filamentosa	2	4	1	39	NA	NA	60
Barilius bakeri	0	5	1	0	NA	NA	9
Danio aequipinnatus	1	10	3	13	NA	NA	45
Rasbora daniconius	2	5	1	20	NA	NA	47
Garra mullya	1	2	1	2	NA	NA	12

*(A) – Adult, (J) – Juvenile

Table 7. Densities (number/100 m^2) of cyprinids in shallow pools, slow riffles, fast riffles, raceways, medium pools, and deep pools in the study streams of Tamil Nadu part

Species	Shallow pool	Slow riffle	Fast riffle	Race way	Medium pool	Deep pool	Number of fish Observed
Kakkenhalla							
Hypselobarbus carnaticus	4	4	7	NA	NA	NA	45
Puntius dorsalis	1	1	2	NA	NA	NA	9
Tor khudree	1	2	1	NA	NA	NA	12
Danio aequipinnatus	9	31	23	NA	NA	NA	140
Rasbora daniconius	2	2	0	NA	NA	NA	15
Garra gotyla stenorhynchus	5	6	6	NA	NA	NA	50
Garra mullya	2	1	3	NA	NA	NA	20

Theppakad							
Puntius bimaculatus	1	0	0	1	0	0	9
Hypselobarbus carnaticus (A)	0	1	2	8	4	0	30
Pethia ticto	1	0	0	0	0	0	5
Barilius gatensis	0	4	45	8	1	0	55
Danio aequipinnatus	1	2	18	14	10	0	69
Rasbora daniconius	1	0	0	0	1	0	9
Garra gotyla stenorhynchus	3	3	9	4	1	0	36
Garra mullya	3	4	11	4	2	0	44
Sigur falls							
Hypselobarbus dubius	NA	0	0	1	NA	NA	10
Hypselobarbus micropogon	NA	0	0	1	NA	NA	10
Labeo rohita	NA	0	0	1	NA	NA	8
Hypselobarbus carnaticus	NA	1	0	4	NA	NA	33
Puntius dorsalis	NA	1	0	3	NA	NA	20
Tor remadevii	NA	0	0	1	NA	NA	6
Chela laubuca	NA	1	0	2	NA	NA	20
Salmophasia acinaces	NA	4	3	5	NA	NA	85
Barilius gatensis	NA	2	4	4	NA	NA	70
Garra mullya	NA	3	1	2	NA	NA	40
Gadana							
Neolissochilus tamiraparaniensis (A)	6	2	0	48	4	2	28
Neolissochilus tamiraparaniensis(J)	14	12	26	48	1	0	45
Puntius mahecola	19	1	2	104	2	0	35
Dawkinsia tambraparniei	4	7	4	16	0	0	15
Puntius bimaculatus	21	4	4	16	0	0	24
Puntius dorsalis	9	0	0	32	1	0	12
Danio aequipinnatus	17	9	17	48	1	2	44
Rasbora daniconius	29	2	0	16	1	1	31
Garra mullya	21	9	17	40	1	2	45
Kallar and Kuttiyar							
Dawkinsia filamentosa	1	0	NA	60	4	NA	55
Pethia ticto	0	1	NA	0	0	NA	8
Danio aequipinnatus	1	2	NA	44	3	NA	52
Rasbora daniconius	1	0	NA	0	1	NA	30
Garra mullya	1	2	NA	16	1	NA	28
Narakad							
Dawkinsia tambraparniei	14	13	17	NA	7	15	60
Systomus sarana subnasutus	8	2	0	NA	4	15	30
Danio aequipinnatus	19	9	33	NA	2	7	40
Rasbora daniconius	53	8	7	NA	2	0	38
Garra kalakadensis	28	21	67	NA	6	7	80
Ramanadhi							
Puntius bimaculatus	3	6	NA	NA	NA	NA	30
Dawkinsia filamentosa	6	14	NA	NA	NA	NA	60
Danio aequipinnatus	1	24	NA	NA	NA	NA	32
Rasbora daniconius	3	6	NA	NA	NA	NA	30
Garra mullya	3	24	NA	NA	NA	NA	42

*(A) – Adult, (J) – Juvenile

Habitat utilization of cyprinids

A total surface area of 33826.3 m² and 1500 number of cells have been surveyed in Western Ghats streams representing 21 streams in 15 rivers and also 2739 fishes were collected in all these habitats. Slow riffles and shallow pools had more fishes than in other habitats. The dominant cyprinids utilized slow riffle shallow pool and raceway habitats (Figs. 3-8). The big sized barbs like *Hypselobarbus kolus, Hypselobarbus dubius, Hypselobarbus jerdoni* and *Neolissochilus wyanadensis* exclusively used medium pool habitats, and *Hypselobarbus kurali, Hypselobarbus micropogan, Neolissochilus tamiraparaniensis, Labeo rohita,* and *Hypselobarbus carnaticus* predominantly utilized raceway habitats. Small sized barbs like *Puntius mahecola, Puntius dorsalis, Dawkinsia filamentosa, Salmophasia acinaces* and *Rasbora daniconius* mostly used

raceway habitats and *Puntius dorsalis* and *Rasbora daniconius* were also found in shallow pool. Shallow pool habitats were the mostly preferred for species such as *Puntius bimaculatus, Haludaria melanampyx, Waikhomia sahayadarensis, Pethia setnai, Dawkinsia singhala, Pethia ticto, Puntius pradhani*, *Danio aequipinnatus, Dawkinsia tambraparani, Pethia conchonius, Tor khudree, Barilius bakeri, Barilius gatensis, Barilius barna, Garra bicarnuta* and *Garra mullya* exclusively used the slow riffle habitat and rarely used fast riffle and raceway habitats. *Salmophasia boopis, Barilius canarensis, Dawkinsia tambaraparinei, Barilius bendelesis, Garra gotyla stenorhynchus* and *Garra kalakadensis* preferred fast riffle.

Figure 3. Specific utilization coefficient of cyprinids of Western Ghats

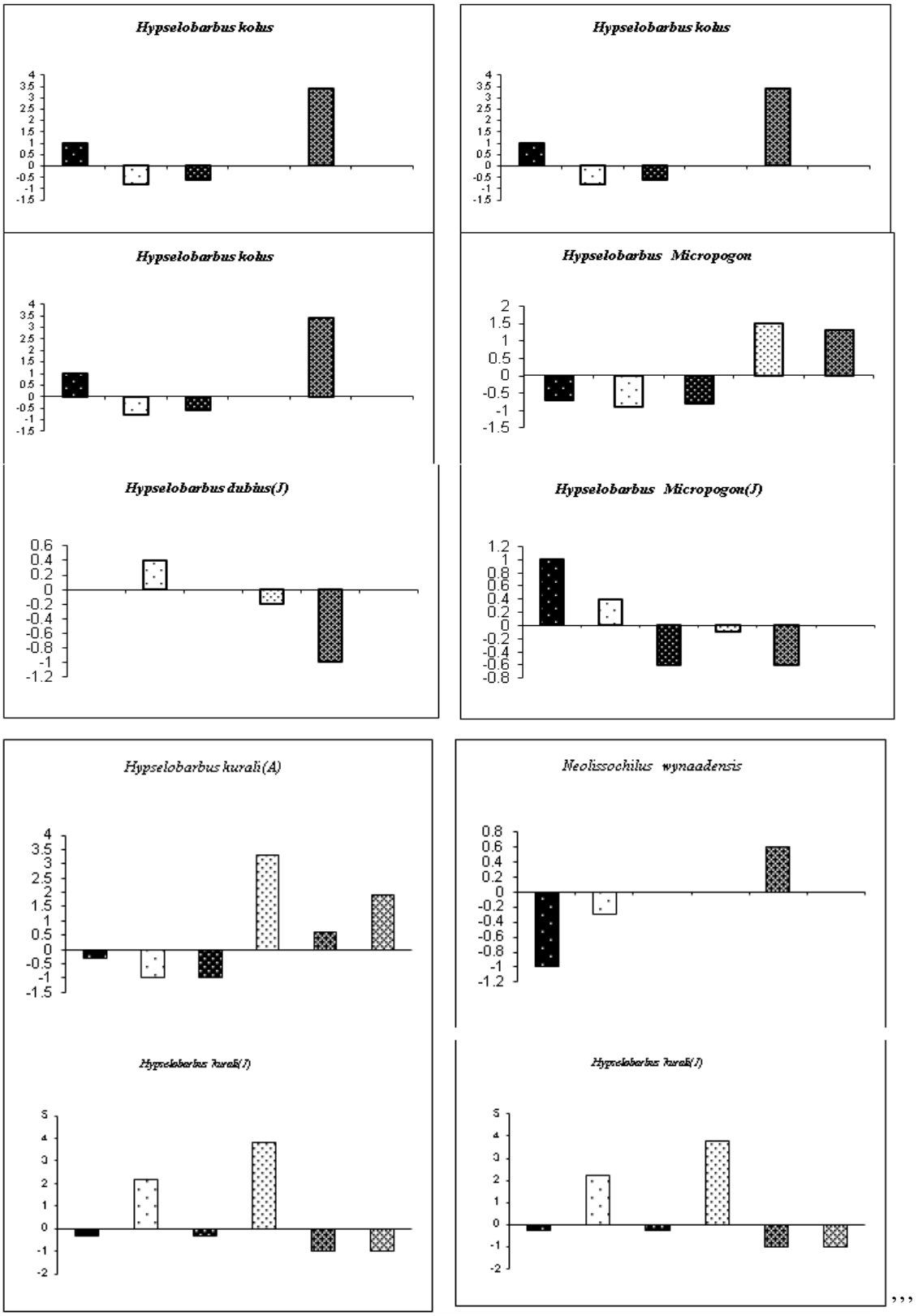


Figure 4. Specific utilization coefficient of cyprinids of Western Ghats

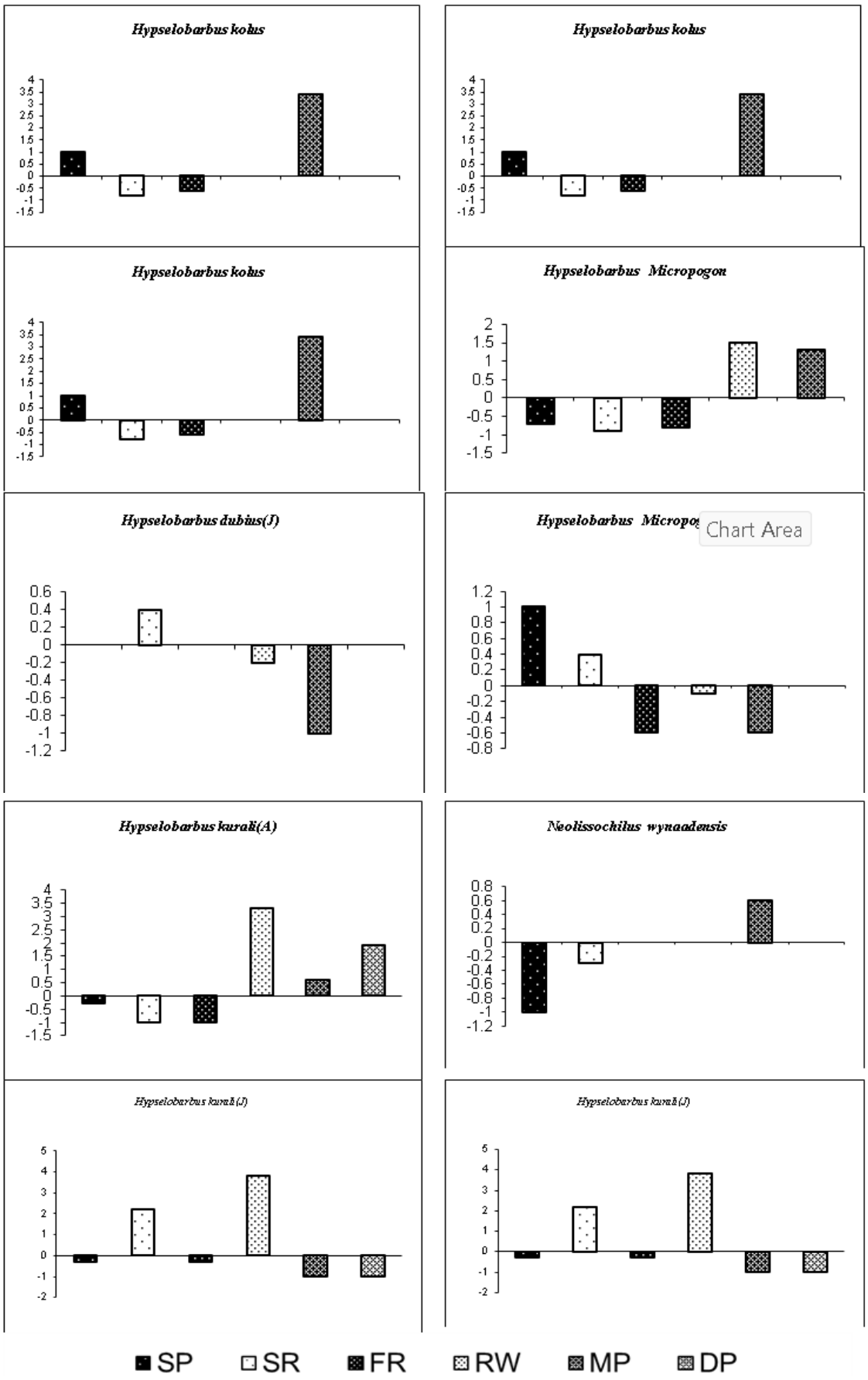


Figure 5. Specific utilization coefficient of cyprinids of Western Ghats

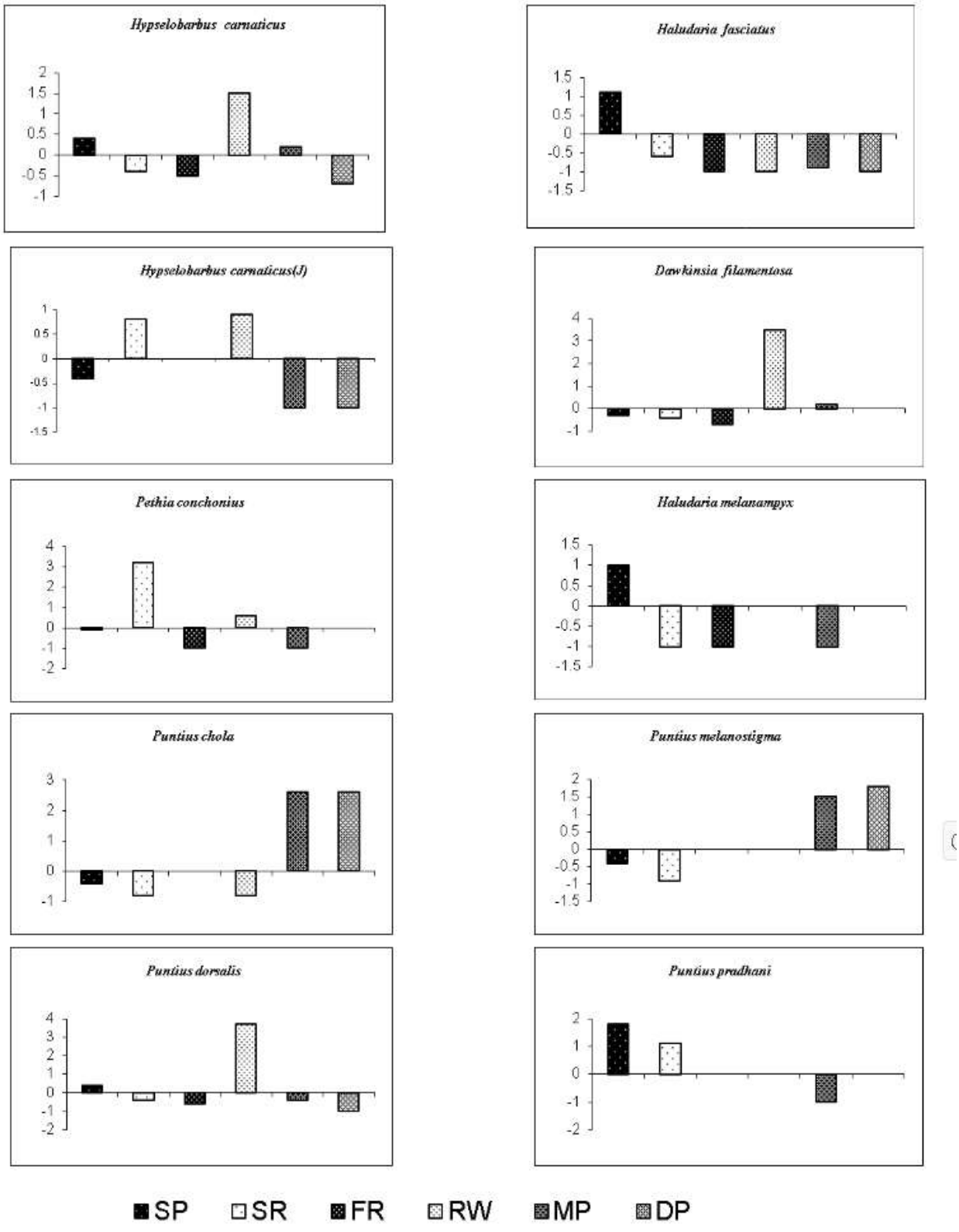


Figure 6. Specific utilization coefficient of cyprinids of Western Ghats

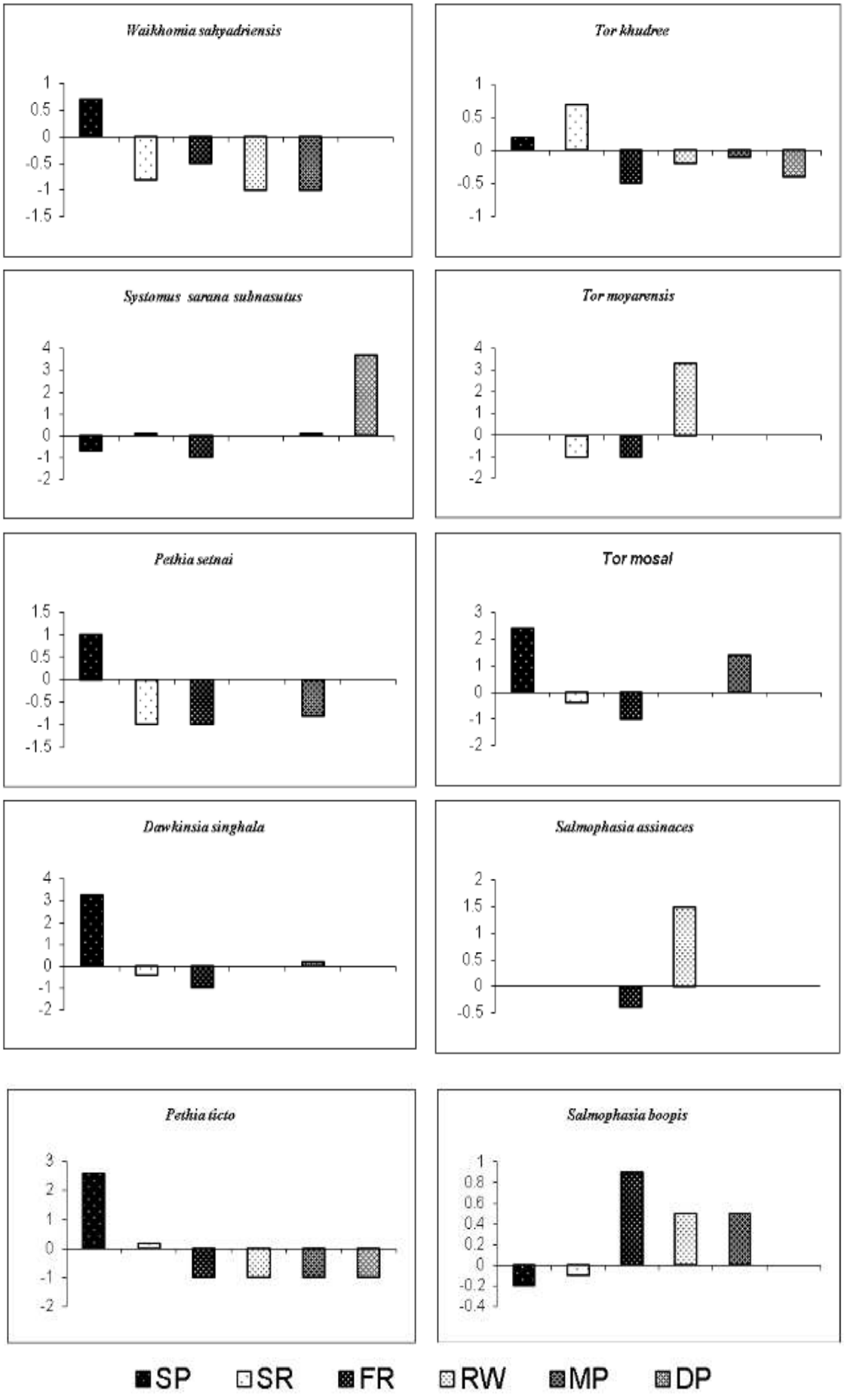


Figure 7. Specific utilization coefficient of cyprinids of Western Ghats

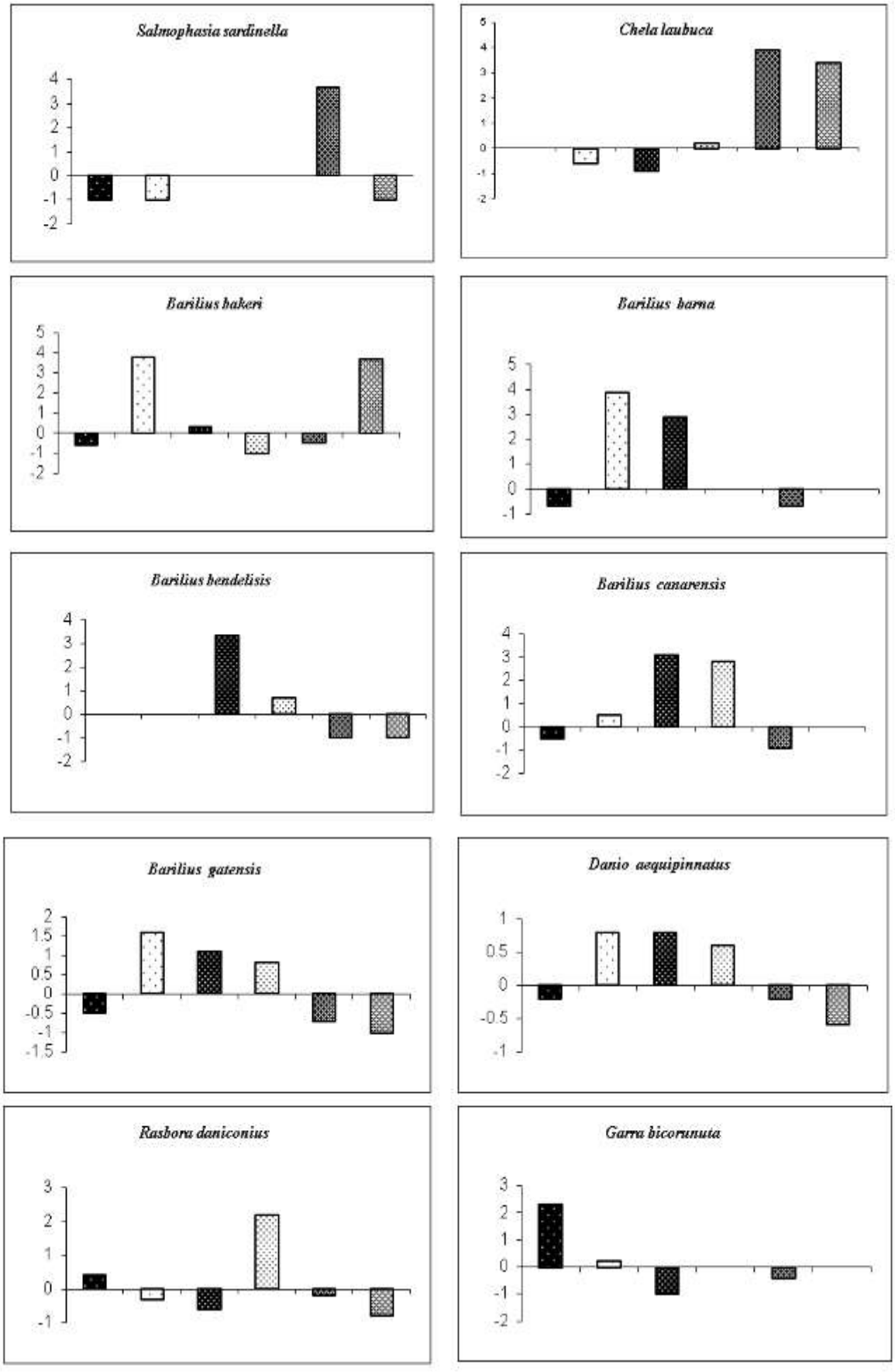
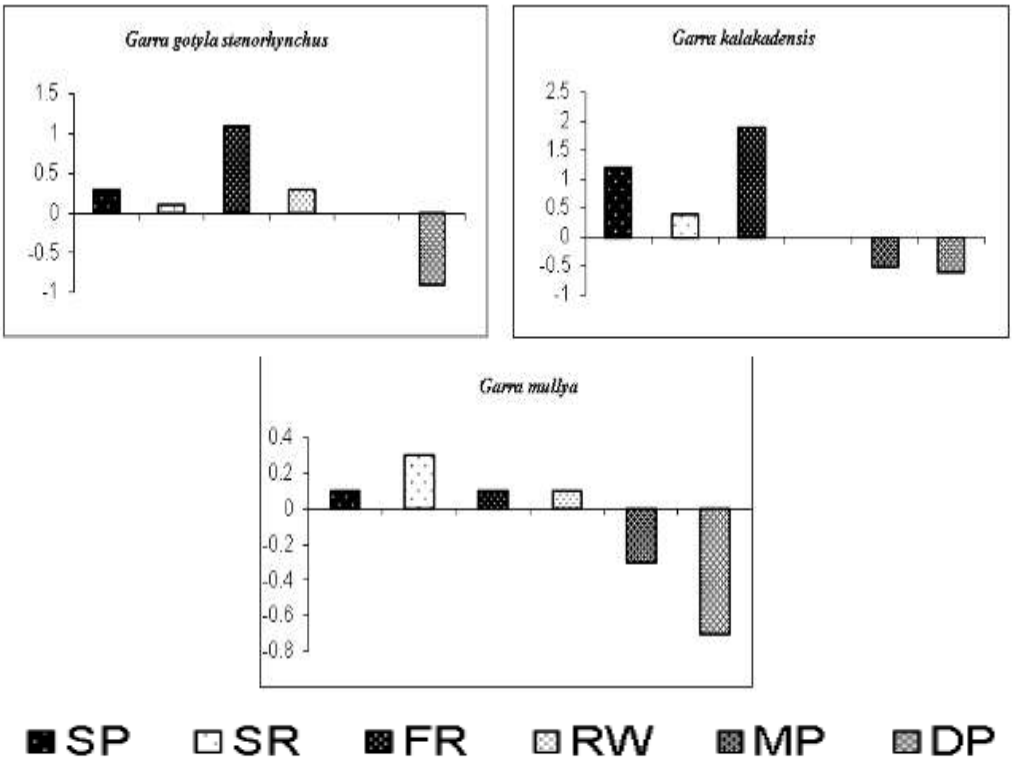


Figure 8. Specific utilization coefficient of cyprinids of Western Ghats



DISCUSSION

Identifying habitat preference and the ecological requirements of fishes will help to improve the stream habitat features and restoration of fish habitat. Fish habitat is defined as "Habitat for fish is a place or for migratory fishes, a set of places in which a fish, a fish population or fish assemblages can find the physical and chemical features needed for life, such as suitable water quality, migration routes, spawning grounds, feeding sites, resting sites and shelter from enemies and adverse weather" (Orth and White, 1993). The concept of a guild – an assemblage of organism using a particular resource or group of resources in a functionally similar manner (Giller, 1987), ignores to a large extent in taxonomic affinities of species within the community, and it has been found to be a useful tool in broad scale comparisons of communities (Wiens, 1983). Recognizing patterns of habitat use by fish is a major goal of fish ecologist because the information helps scholars to predict potential impacts associated with development schemes and habitat alterations (Braaten and Berry, 1997). Fish exhibit random use of habitat, then it may be difficult to predict species or community response to anthropogenic disturbances. Although several studies have found relationships between habitat composition and fish distribution and abundance in small streams, (McClendan and Rabeni, 1987; Angermeier, 1987; Sivakumar *et al*., 2024) patterns of habitat use by fish may not be easily recognized in streams where environmental variables are extreme (Angermeier and Schlosser, 1989).

Conservative measures

The habitat preferences help in understanding and identifying critical habitats for fish survival and reproduction, especially when environmental changes happen which are caused by human activities. The cyprinid fish species recorded in their habitats through this investigation in the 21 streams of the 15 rivers of the Western Ghats were mainly of food and ornamental importance. A majority of the cyprinid fish species observed are listed as 'Least Concern' on the IUCN Red List of Threatened Species, they are *Hypselobarbus jerdoni*, *Hypselobarbus kurali*, *Labeo rohita*, *Hypselobarbus carnaticus*, *Puntius dorsalis*, *Dawkinsia filamentosa*, *Salmophasia acinaces*, *Rasbora daniconius*, *Puntius bimaculatus*, *Waikhomia sahayadarensis*, *Pethia ticto*, *Danio aequipinnatus*, *Pethia conchonius*, *Tor khudree*, *Barilius bakeri*, *Barilius gatensis*, *Barilius barna*, *Barilius barila Garra mullya*, *Salmophasia boopis*, and *Garra gotyla stenorhynchus*. The cyprinid species listed as 'Endangered' were *Hypselobarbus dubius*, *Hypselobarbus micropogon*, *Dawkinsia tambraparniei*, *Barilius canarensis* and *Garra kalakadensis*. The cyprinid species listed as 'Data deficient' were *Puntius mahecola* and *Haludaria melanampyx*, while the species listed as 'Vulnerable' were

Hypselobarbus kolus and *Pethia setnai*. The species listed as 'Critically endangered' was the *Neolissochilus wyanadensis*, and 'Near Threatened' was the *Garra bicornuta*. The cyprinid species that have been recorded and listed as near threatened, endangered, vulnerable and data deficient need special attention and protection for conservation. As the biggest threat to these freshwater cyprinid fishes in the three studied states of the Western Ghats is overfishing, and this can take a toll on the population number. This also calls for immediate conservation measures that can support cyprinid fish diversity, as they form the majority when compared to any other species in the aquatic habitats of the Western Ghats. Further, the involvement of the fisheries and forest departments in the respective states, along with fish conservationists, can aid in the protection and conservation of the studied habitats and the cyprinid species listed as threatened and endangered. The cyprinid fish fauna in the studied and representative river basins of Thunga, Bhadra, Seethanadhi, Cauvery, Sowparniga and Kali in Karnataka; Kabini, Valapattanam, Kallada, Amaravathi and Karamana in Kerala; and Bhavani, Tamirabarani, Chittar and Nambiyar in Tamil Nadu are highly diverse, and the setting up of a state and local-level management body is also vital for habitat conservation for the cyprinid fish biodiversity in the Western Ghats.

CONFLICT OF INTEREST

The authors declare no conflicts of interest in this manuscript.

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