CHAPTER V

HABITAT CONDITIONS OF HILLSTREAM, ENDEMIC, AND THREATENED SPECIES

5.1 Introduction

The habitat of an organism has specific characteristics, and the specific mixture of biotic and abiotic characteristics determines the quality of habitat for the organism (Enger and Smith, 1991). Within its habitat an organism obtains all the food, shelter, water, and other materials needs essential to its survival. To survive within a particular habitat, organisms have adaptations that enable them to carry out their life processes. Aquatic habitats include both marine or saltwater and freshwater environments.

A river and its watershed are normally considered as physically and chemically a single system. But considerable differences can occur in water velocities, volumes and depths, as well as in channel geometry. Physical nature of the channel, bed material and concentration of suspended particulate material are associated with these factors. All these things make a river system, a wide and diverse range of habitats for fishes. Such diversity of habitat is typical of most river systems.

Passing from head-water to estuary there is in general a reduction in substratum particle size and a tendency towards increasing stability of the bed material. In the upper reaches of rivers, rocks and boulders provide both cover and shelter from the current, while in the lower reaches this function is taken by macrophytes and the deep sides of the water course, as well as by sand and mud banks. Fallen trees and tree roots also provide shelter in such areas.

The eroding and the sedimenting areas are considered as typical of rivers rising in hilly area. Because of topographical features, such as the hardness of the bed-rock and faulting, these two states repeatedly occurring along the length of the stream.

In the upper streams and small rivers topographical effects occur on a minor scale, leading to the frequent alteration of shallow pebble rapids with fast current, and deeper areas with slower currents. Berg (1948) of opinion that ecological

grouping of running waters was not possible, and that only physically similar reaches could be compared meaningfully.

The most important physical aspects related to fish are, the volume (some times depth), the velocity, the temperature and the hydrogen ion activity (p^H) (Whitton, 1975). The volume of flow affects the movement and migration of fishes as well as the sites at which individual fishes and populations of fishes of different sizes can occur. Current velocity is more important to fishes because of the effect it has in grading the river bed material and in maintaining high levels of dissolved oxygen. Temperature has an important influence on physical and physiological activities of fishes. Under most natural conditions variation in P^H has little effect on fishes. The other aspect of the physical environment important to fish are light.

Basically the physical qualities of the environment are the more important than chemical ones in governing the distribution of fishes in rivers. Chemical composition of fishes reflect the chemical composition of water. The most important chemical quality which affects the distribution of fishes is the concentration of dissolved oxygen. It can influence survival, growth, swimming performance and larval development, and migration.

Habitat loss is a significant threat to Earth's biodiversity. Most scientists and world conservation groups agree that habitat loss is the single greatest cause of species extinction today. A 1994 study by the World Conservation Monitoring Center determined that 36% of all animal extinctions are caused by habitat destruction (Kellert, 1997). Keeping this in mind this chapter discusses the present habitat conditions of hillstream, endemic, and endangered fishes of southern Kerala.

5.2 Methods

5.2.1 Habitat information

Habitat for fish includes all the physical, chemical, and biological features of the environment needed to sustain life (Murphy and Willis, 1996). The present habitat analysis is based on the following aquatic habitat variables

Morphometric variables – Stream or wetted width (small streams measured with a tape, and larger ones measured with a range finder). Mean depth measurements are taken with a method recommended by Platts *et al.* (1983). Altitude was measured using a Altimeter

Physicochemical variables – The following variables are measured adopting standard analytical methods : Temperature (Diel digital thermometer), P^H (digital P^H scan meter), Dissolved Oxygen (Merck Oxygen kit). Transparency was noted as bottom visible (bv) and bottom not visible (bnv). Flow rate was measured with a electronic flow meter.

Vegetation – Riparian vegetation was noted as Grasses, Shrubs, and Trees, Dominant aquatic vegetation was also noted. The canopy density measured with a densimeter, and represented as percentage . Land use pattern was represented as settlement area, reserve forests, plantation (teak, rubber, coffee, tea, eucaliptus etc.), and paddy field.

Stream habitat types- Hawkins *et al.* (1993) classification was followed as fast water and slow water with sub-divisions. This classification was mostly dependent on substrate types. Modified Wentworth classification (based on particle size) was employed for grading substrate (Cummins, 1962). Particle size <0.0039 mm as mud, silt (0.0039- 0.0625 mm), sand (0.0625- 2 mm), gravel (2- 16 mm), cobble (16- 256 mm), boulder (> 256 mm), and bedrock.

5.2.2 Species diversity

Specimens were collected by using cast net. Five castings were done in each collection site. The specimens collected during pre-monsoon period was used for diversity studies. Diversity index (Shannon, 1948) was calculated using the equation, $H = -\Sigma^S Pi \log_2 Pi$ where Pi is the proportion of individuals in the i^{th} species and S is the species richness (the number of species sampled at each sampling zone).

5.3. Results

5.3.1 Habitat information

The freshwater fish habitat includes the integrated physical, chemical, and biological characteristics of streams. The habitat conditions of hillstream, endemic, and threatened species recorded from southern Kerala are summarised below. Multiple correlation analysis results is presented in Table 5.1. Some of the collection sites are shown in plates 29 to 44.

Notopterus notopterus (Pallas)

Kundai and Trikur areas of Karuvannur river. Both the collection sites are in low land areas. Wetted width and mean depth of stream was almost same, below 10 meters in width and less than 40 cm. in depth, in both locations. Water temperature recorded was 28°C, and dissolved oxygen ranged between 5.2 in Kundai and 6 mg/l in Trikur area. Bottom was not fully visible in both the areas, but more transparent in Kundai area. Water was slightly alkaline in both. The streams were slow moving (flow rate less than 15 cm/s) and major substrates constitutes mud and sand with little gravel. Riparian vegetation was mostly grasses and shrubs. The land use pattern is rubber plantation in Kundai and agricultural lands with settlements in Trikur area.

It inhabit fresh and brackish waters (Day, 1875; and Talwar and Jhingran, 1991). This species is found in clear streams but appears to thrive well in lentic waters.

Anguilla bicolor Mcclelland

Pooyamkutty area of Periyar river. The area is in midlands with an altitude 90 m above msl. Stream width was nearly 100 meters and mean depth was 60 cm. The stream is characterized by fast flowing water and fully transparent. The water temperature was 27°C, dissolved oxygen 6.2 mg/l and water was slightly acidic in nature. The most dominant substrate is bedrock (about 75%) with little sand and mud. Grasses, shrubs, trees, and bamboo constitutes the riparian vegetation; and land use is reserve forest

Table 5.1 Correlation analysis results of various parameters studied

		Altitude (m)	Depth (cm)	H'	Flow (cm/s)	Oxygen (mg/l)	pH	Temperature ^{0}C	Width (m)
Pearson	Altitude (m)	1.000	-.172**	-.164*	.049	.414**	-.045	-667**	-247**
Correlation	Depth (cm)	-.172**	1.000	.105	-.061	-.191**	.024	.223**	.396**
	H'	-.164*	.105	1.000	.006	-.145*	-.051	.214**	.181**
	Flow (cm/s)	.049	-.061	.006	1.000	.175**	.117	-.050	-.045
	Oxygen (mg/l)	.414**	-.191**	-.145*	.175**	1.000	.018	-.531**	-206**
	pH	-.045	.024	-.051	.117	.018	1.000	-.026	.003
	Temperature (^{0}C)	-.667**	.223**	.214**	-.050	-.531**	-.026	1.000	.323**
	Width(m)	-.247**	.396**	.181**	-.045	-.206**	.003	.323**	1.000

** Correlation is significant at the 0.01 level (2 – tailed)

* Correlation is significant at the 0.05 level (2 – tailed)

Fig. 5. Variation between temperature and oxygen in various collection sites

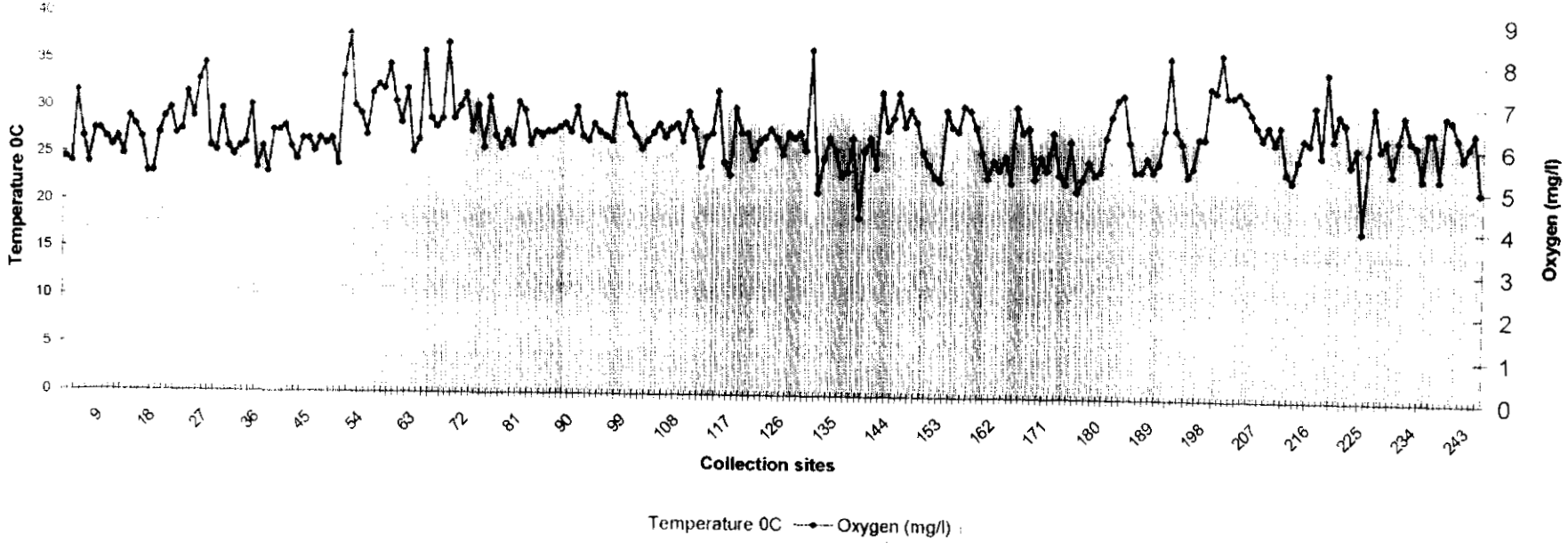
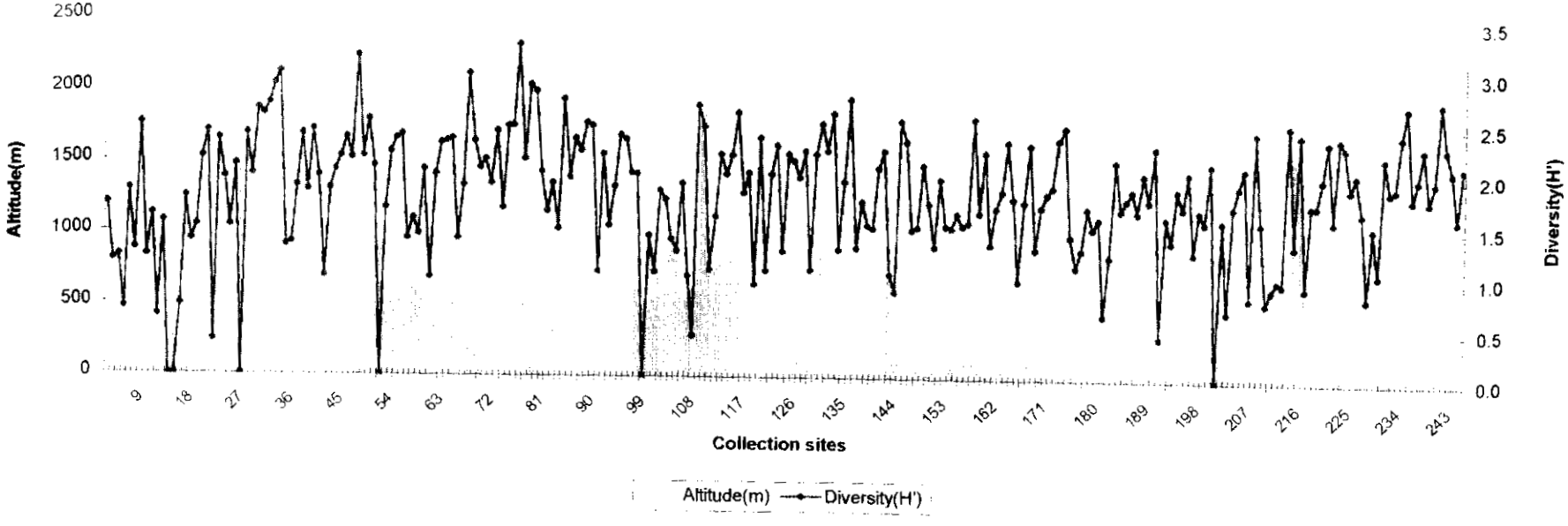


Fig. 5.2 Variation between altitude and diversity in various collection sites



According to Day (1878), it was inhabited in coastal areas. It inhabits lowland freshwaters, and occurs in estuaries and in the sea during early life and near maturity.

***Pisodonophis boro* (Ham.)**

Mulamkuzhy area of Periyar river and Mallesseri area of Achancoil river. Both locations are in lowland areas. In Periyar river, the species was collected from a small stream coming from the Mahogany grove at Mulamkuzhi. The site was dominated by mud as the major substrate (60%), followed by sand and detritus. The physicochemical parameters showed a minimal value of dissolved oxygen (4.2 mg/l) compared to the nearby main river (6.1 mg/l). Water temperature was 26.9^{0}C and the flow rate 15 cm/sec. The riparian vegetation was dominated by grasses and shrubs; Mahogany grove on one side and agricultural lands on the other. The bottom of stream was not visible with turbid waters. Water was slightly alkaline in both the collection localities.

Mallesseri area has a width of 70 meters and depth 15 cm. The flow rate was 55 cm/sec with almost transparent water. The dissolved oxygen was high (5.8 mg/l) compared to Mulamkuzhy. Sand and gravel constitutes the major substrates, with small amounts of mud and cobble. The riparian vegetation was grasses and shrubs; with human settlements and agricultural lands.

It mainly inhabits seas, estuaries, and lagoons (Day, 1865; Talwar and Jhingran, 1991; and Jayaram, 1999). Some times ascending large rivers to far above tidal reach.

***Hypselobarbus curmuca* (Ham.)**

Midland and highland areas of almost all the rivers in southern Kerala, often comes down in lowland areas. It prefers running waters with deep pools and ditches. The major substrates were cobbles, boulders, bedrock, and little sand and gravel. They were abundant in pools of Parambikulam wildlife sanctuary with good shade and sandy bottom. More abundantly observed at the base of the falls and cascades, but was rarely seen along the banks of rivers. Most of the collection localities were in

reserve forest areas with shrubs and trees as the reparian vegetation. Temperature varied from 23 to 29° C and dissolved oxygen values ranged from 5.2 to 7.4 ppm.

It lives and breeds in streams of hilly terrain usually in deep cool and shady parts, but comes down to tidal reaches to feed. Breeding occurs in small streams with sandy and weedy bottom (Talwar and Jhingran, 1991).

Hypselobarbus micropogon periyarensis (Raj)

Prefers deep water bodies especially streams just flowing into large pools. Collected from Idukki reservoir; and streams of Idukki wildlife sanctuary with bedrock, boulders and cobble substratum. Well oxygenated and low temperature is the preferred condition.

Hypselobarbus kolus (Sykes)

Hillstreams of Bharathapuzha, Chalakudy, Periyar, Muvattupuzha and Karamana rivers Mostly occurs in running waters of highland and highrange areas with pools and ditches. The major substrates were cobbles, bedrock, boulders and gravel. Most abundant in Bharathapuzha and Chalakudy rivers. The other habitat conditions are almost similar to those of *H.curmuca*. According to Day (1875), its habitat was central Provinces, Deccan, and throughout the Kistna, Tamboodra, and Godavery rivers.

Hypselobarbus jerdoni (Day)

Midlands of Bharathapuzha, Chalakudy, Periyar and Meenachil rivers. Moderately gradient streams with bedrock, boulders and cobbles as the major substrates. Land use was reserve forests in all the collection sites except in Meenachil river. In Meenachil river, rubber plantation form the land use with mixed agricultural lands Water was clear and temperature ranged between 25 to 29^{0}C. Dissolved oxygen value was greater than 6.5 ppm and slightly acidic water.

It inhabits running waters of the Western Ghats, near the coast (Talwar and Jhingran, 1991).

***Hypselobarbus thomassi* (Day)**

Malayattur and Pooyamkutty areas of Periyar river. These areas were in lowland and midland regions respectively. The main substrates were sand, gravel and cobble in Pooyamkutty. Stream was shallow with moderate current velocity and moderate turbulence (Low gradient riffles). Temperature was 26^0C with slightly acidic water. Land use pattern was reserve forest with bamboos and trees as riparian vegetation

In Malayattur the river was shallow, slow moving with some pools. The dominant substrate was sand, followed by gravel. Some areas were occupied by; bedrock bottom. Land use was settlements with mixed agricultural lands.

According to Talwar and Jhingran (1991) the species occur in upper reaches of the tributaries of the Cauvery river system.

***Labeo calbasu* (Ham.)**

Kappayam and Bhutathankettu areas of Periyar river, and Thattekkad Bird sanctuary. Of these Kappayam is in highland region and rest are in midland area. Kappayam area was a moderately gradient with fast flowing water having considerable turbulence. Cobbles, boulders, bedrock and gravel was the dominant substrates with little sand and mud. Deep pools were also observed in the area. Water was almost clear with slightly acidic nature. Water temperature was 21^0C with high value of dissolved oxygen (7.5 ppm). The landuse was reserve forest, with shrubs, trees and bamboo as riparian vegetation.

Bhutathankettu and Thattekkad areas are settlements with mixed agricultural lands and teak plantation. The dominant substrates were cobbles, gravel and sand. Bottom was not visible and slightly acidic water (p^H = 6.8). Water temperature ranged between 29 to 31^0C and dissolved oxygen content was greater than 6 ppm. Both areas are slow moving shallow stream with some deep pools.

It inhabits rivers and ponds and thrives better in tanks than in running waters. They can tolerate slightly brackish water and does not normally breed in ponds (Talwar and Jhingran, 1991).

***Labeo dussumieri* (Val.)**

Midland and Highland areas of Periyar and Pamba rivers. Common in Vellathooval - Ponmudi areas and Mattupetty reservoir of Periyar river. The most dominant substrate is mud and sand with little gravel. But from Pamba it is collected from rocky pools at Perumthenaruvi with clear waters.

***Ostobrama bakeri* (Day)**

It commonly inhabits lowland areas with sand, mud, and detritus as major substrates. Sometimes they appears in midland areas, especially in Pooyamkutty tributary of Periyar river with varied substrates like sand and gravel, cobbles, boulders and bedrock, or in deep bedrock pools with slow flowing waters. They prefer subsurface water and occationally seen in shoals along the banks of streams. Almost all collection sites were settlement areas with mixed agricultural lands.

According to Day (1878), its habitat was Cottayam in Travancore.

***Osteobrama cotio peninsularis* Silas**

Lowland areas of Periyar river with sand, mud, and detritus as major substrates. The other habitat conditions are almost same as those of *Osteobrama bakeri*. They can tolerate slight salinity variation also. This observation is based on their capture in summer months from slight saline water of Chelamattom area of Periyar river

***Osteochilus longidorsalis* Pethiyagoda and Kottelat**

Midland and highland areas of Chalakudy river. All the collection sites were in Parambikulam wildlife sanctuary with shrubs, trees as riparian vegetation. They prefer shady places with bedrock, boulders, and cobbles as major substrates. Generally inhabit deep pools with low water temperature (21 to 26^{0}C). Water was clear and slightly acidic.

***Osteochilus nashii* (Day)**

Urulanthanni area of Periyar river. This midland stream has a width less than 10 meters and an average stream depth 15 cm. Water temperature ranged between 22

to 26°C with dissolved oxygen value greater than 6 ppm. The water was slightly alkaline, clear with a flow rate 30 cm/sec. The dominant substrate was bedrock with some boulders and sand. The land use form was rubber and teak plantation, reserve forest, and some settlements.

Day (1878) observed its habitat as hill-streams of Coorg, south Canera and the Wynad.

Osteochilus thomassi (Day)

Lowland and Midland areas of Periyar river. Preferred habitat was hilly areas with bedrock, boulders, cobbles with little sand as major substrates. Rarely seen in lowland areas with sand and mud bottom. The habitat conditions was almost same as those of *Osteochilus nashii*.

According to Day (1878) its habitat was streams in south Canera.

Barbodes carnaticus (Jerdon)

Midland and highland areas of major river systems of southern Kerala. Most common in highland areas with bedrock, boulders and cobbles as dominant substrates. They found abundantly in shady bedrock pools with low temperatures. Majority of collection sites were in reserve forest including different types of plantation. Bottom vegetative matter form an advantage for their survival. This species was abundant in Parambikulam, Idukki, and Neyyar wildlife sanctuaries of southern Kerala. A good collection was also obtained from Chinnar wildlife sanctuary area of Pambar river.

Its growth in lentic waters is reported to be very good, but does not breed in ponds. Spawning occurs in flooded rivers during monsoon months (Talwar and Jhingran, 1991).

Puntius arulius (Jerdon)

Highland and midlands of Kallada river and high ranges of Pambar river. From Pambar it was collected from a moderately flowing, shallow stream with bedrock, boulders, and cobbles as major substrates. Trace quantity of gravel, sand

and mud was also found there. A good collection of vegetative matter was observed in the streams. They are common in bedrock and muddy pools with good shade. Water temperature ranged between 22 to 26^{0}C and dissolved oxygen was greater than 6 ppm. Most of the collection sites are in reserve forest of Chinnar wildlife sanctuary with grasses, shrubs, and trees as riparian vegetation.

They are collected from deep stream sections with bedrock, cobbles, and mud as dominant substrates in Kallada river. Here the bottom of stream was not visible and water temperature was slightly greater than that of Pambar river (25 to 29^{0}C). This area is not a good shading area. Teak plantation together with mixed agricultural lands from the land use.

It inhabits in streams of hilly area and rivers in their bases (Day, 1878)

***Puntius conchonius* (Ham.)**

Midlands of Bharathapuzha and Manimala rivers. Both the areas are in settlements with coconut plantation and other agricultural crops. The most dominant substrate was sand, followed by gravel and mud in Bharathapuzha river. Streams are shallow and slow moving. The bottom was bedrock with boulders and cobbles in Mundakkayam area of Manimala river. Here the species was collected from fast flowing waters and also from deep pools of rocky bottom. Water was slightly alkaline in both the rivers and temperature ranged between 27 to 30^{0}C.

It is one of the hardiest of the barbs and more abundant in the hills than the plains (Talwar and Jhingran, 1991).

***Puntius denisonii* (Day)**

Lowland and midland areas. Abundantly seen in midlands of Chalakudy, Bharathapuzha and Pamba rivers. In Pamba, it is seen in moderately gradient streams with bedrock, boulders and cobbles as the major substrates. Land use pattern was reserve forest and teak plantation with shrubs and trees as riparian vegetation. Water was clear and slightly acidic in nature. Almost the same habitat condition were observed in Chalakudy river, except the streams are low gradient. The other location are in plain lands with settlements and agricultural fields. The major substrates were

sand, followed by gravel and mud. Streams were deep and bottom not visible. The riparian vegetation was grasses and shrubs. Sometimes they appeared as groups in low lands of Chelamattam area of Periyar river.

Puntius dorsalis (Jerdon)

High range area of Chalakudy and Periyar rivers; and midlands of Bharathapuzha and Muvattupuzha rivers. In Chalakudy river it was recorded from upstreams of Karappara river with bedrock, cobbles, and gravel as major substrates. They were also obtained from nearby shallow pools. Land use were reserve forest and coffee plantation with shrubs and trees as riparian vegetation. Water temperature ranged between 25-29^{0}C and bottom of stream was visible fully. Leafy vegetative matter also found to be important for their survival. Bedrock was the dominant substrate in Kuttar area of Periyar river, with little amounts of sand and mud. Land use was coconut and arecanut plantation with grasses and shrubs as riparian vegetation. Water was slightly alkaline in both the areas.

Low gradient riffles in Mullaringad area of Muvattupuzha river and Aliyar area of Bharathapuzha river were also forms the habitat for the species. In this Aliyar was the reserve forest area, while the Mullaringad was a settlement area with rubber and teak plantation. Water was clear and slightly acidic in both areas.

It inhabits rivers, streams, ponds and lakes (Talwar and Jhingran, 1991).

Puntius melanampyx (Day)

Found throughout southern Kerala in varying altitudes, but rare in very low areas. Most common in running waters with bottom detritus, mud, sand, and gravel. They preferred small streams and bankside of large rivers. Recorded from high altitude areas of Vagamon in Meenachil river, where temperature may down upto 14^{0}C. Streams are small having a width less than 4 meters and average depth was 12 cm. They do not prefer temperatures greater than 30^{0}C.

It occurs in hilly areas of peninsular India and streams along the base of hills (Day, 1878; Talwar and Jhingran, 1991).

***Puntius melanostigma* (Day)**

Highlands of Bharathapuzha and Achankovil rivers. All the collection sites are in reserve forests with grasses, shrubs, and trees as riparian vegetation. Water temperature ranged between 24 to 26^{0}C and dissolved oxygen value was greater than 6.5 ppm. The dominant substrates was bedrock, boulders and cobble in pallivasal area of Achankovil river, while sand and gravel was the major substrates in Pudupati areas of Bharathapuzha river. They were common in muddy with sandy bottom pools with good shade.

***Puntius ophicephalus* (Raj)**

Vandiperiyar area of Periyar river. Streams are in highrange areas with moderate gradients. Bedrock, cobble and gravel forms the major substrates. These streams are fast flowing with high dissolved oxygen content. Land use was cardomon plantation with grasses and shrubs as riparian vegetation. More specimens were collected from deep pools with some overflowing water and good shade. Wetted width of stream was five meters and average depth was 14 cm. Water was clear and slightly acidic in nature.

***Tor khudree* (Sykes)**

Highranges, highland, and midlands of major river systems of southern Kerala. They are abundant in Parambikulam and Neyyar wildlife sanctuaries. Almost all collection sites were in reserve forest areas with shrubs and trees as riparian vegetation. Bedrock, boulders and cobbles are the major substrates, and fast flowing waters with high amount of dissolved oxygen was suitable habitat for this mahseer. They were also found in sandy pools and running waters with moderate gradient. The morphological features vary in different habitats, especially depends on flow pattern.

According to Talwar and Jhingran (1991) this mahseer is fairly common in the headwaters of the Godavari river and also in the rivers of the Deccan.

***Chela fasciata* Silas**

Midland and highlands of Bharathapuzha and Chalakudy rivers. The streams are low gradient riffles with bedrock, cobbles and gravel as the dominant substrates.

The land use were reserve forests and rubber plantation in Bharathapuzha and reserve forests with teak plantation in Chalakudy river. The shrubs and trees were the riparian vegetation. Temperature was less than 27^0C in all the collection localities. Bottom was visible and dissolved oxygen content was greater than 6.5 ppm. They were abundant in pools below the small falls (bedrock pools with sand and gravel).

***Salmostoma acinaces* (Val.)**

Highranges of Pambar river in Chinnar wildlife sanctuary. All the localities are reserve forests with shrubs and trees as riparian vegetation. Temperature ranged between 20 to 23^0 C and dissolved oxygen content was greater than 7 ppm. Water was clear and slightly alkaline in nature. Streams are low gradient riffles with cobbles and gravel as major substrates and some pools with sandy and gravel bottom. Number of specimens obtained in every castings was high throughout all the collection localities.

***Salmostoma clupeiodes* (Bloch)**

Lowlands of Kalady and Chelamattom areas of Periyar river. Moderately flowing waters with mud and sand as main substrates. The site is a settlement area, with coconut plantation and mixed agricultural lands. Temperature was ranged between 28 to 30^0 C with dissolved oxygen 5.8 ppm. Preferred habitat is stream banks with less flow. The water was slightly alkaline, sometimes saline.

***Barilius bakeri* Day, *Barilius bendelisis* (Ham.),**
***Barilius canarensis* (Jerdon) and *Barilius gatensis* (Val.)**

Mostly inhabits highlands and highranges, followed by midlands, Rarely observed in lowlands of Chalakudy and Periyar rivers. Temperature of collection sites ranged between 14 to 27^0 C. Most of the collection sites were in reserve forests with some settlement area. Streams were low gradient to moderately gradient with bedrock, boulders, cobbles and gravel as the dominant substrate. Abundantly seen in rocky pools of Parambikulam and Neyyar wildlife sanctuaries. Water was slightly acidic and bottom was visible. Dissolved oxygen content ranged between 5.2 to 7.8 ppm. All the barilians, except the *Barilius bendelisis* prefer the above habitat conditions. Regarding the substratum, *Barilius bendelisis* prefer sandy and gravel

bottom, with the same other environmental conditions as those for rest of the barilians mentioned above.

Barilians are mainly inhabitants of hilly areas and streams base of hills (Day, 1878, and Talwar and Jhingran, 1991). According to Badola and Singh (1982) *B. bendelisis* always prefer small rivers and streams having clear and high dissolved oxygen water

Esomus danricus (Ham.)

Mainly occurs in midland and highland areas. Occationally seen in high range of Cahalakudy river and low lands of Bharathapuzha and Periyar rivers. Streams are moderately flowing with sand, gravel, and mud as the major substrates. More abundant in pools with muddy bottom.

According to Talwar and Jhingran (1991), they inhabits ponds and weedy ditches.

Esomus thermoicos (Val.)

Vandazhi and Thippallikkayam areas of Bharathapuzha river, lowland areas of Chalakudy and Periyar rivers, and a pond adjacent to Mangalampuzha. Mud, sand, and gravel were the major substrates in Vandazhi. Thippallikkayam was a moderately gradient stream with bedrock and boulders as dominant substrate. The pond was with a muddy bottom. The water temperature ranged between 28 to 30^0 C and dissolved oxygen ranged between 5.2 to 6.7 ppm.

It was originally described from the hot springs at Kanniya of Sri Lanka. Inhabits ponds, tanks, ditches, and can tolerate very muddy water during droughts (Talwar and Jhingran, 1991).

Garra mcclellandi (Jerdon)

It mainly inhabits fast flowing waters with a rocky substratum. All the collection streams were located in the high altitude areas and the fish was collected from pools, which retains water, in post-monsoon periods. Detritus, gravel, cobbles, boulders, and bedrock are the major substrates; shrubs and trees being the main

riparian vegetation. It is adapted for life in the swift running hill streams, where they maintain their balance with the help of the small sucking disc on the ventral side of the body. They were dependent on the algae and other organisms attached to the substratum

Garra menoni Rema Devi and Indra, *Garra hughi* Silas and *Garra gotyla stenorhygnchus* (Jerdon)

Highrange and highland areas of Pambar river. Moderately gradient riffles, with cobbles, boulders, and bedrock as major substrates. Water was slightly acidic and clear with temperature ranged between 19 to 24^{0}C. Reserve forest areas with shrubs and trees as dominant riparian vegetation. They were abundant in rocky pools with leafy vegetative matter and good canopy value. Besides these, *Garra hughi* was also found in high elevated streams of Eravikulam national park; with sand, gravel, cobbles and bedrock as principal substrate. Water temperature was found to be a limiting factor for their survival.

Garra surendranathanii Shaji *et al.*

Orukombankutty of Chalakudy, Pooyamkutty area of Periyar, and Perumthenaruvi area of Pamba rivers. All the study locations are situated in hilly area. They were more abundant in Parambikulam wildlife sanctuary area of Chalakudy river. The land use pattern at the collection sites was reserve forest and teak plantation with shrubs, bamboo and trees as dominant vegetation. All the streams were low gradient riffles with bedrock, boulders, cobbles and gravel as major substrates. Like other species of the genus, it also possesses a small sucking disc on the ventral side.

Horalabiosa joshuai Silas

Streams of Chinnar wildlife sanctuary and Eravikulam national park. Prefers high altitude streams. Other habitat conditions area almost similar to those for the genus *Garra*. The collection site was characterized by bedrock as the major substratum. The land use pattern in Chinnar was reserve forest with large trees and shrubs as the riparian vegetation, while grasses were the major riparian vegetation in Eravikulam national park.

***Bhavania australis* (Jerdon)**

Hilly areas of major river systems of southern Kerala, rarely found in midland areas. The bedrock were the major substratum in almost all the collection sites, followed by boulders and cobbles. Always prefers shallow running waters, with good oxygen concentration and low temperatures. Most of the sites are in reserve forests, some in rubber and teak plantation. Always found moving upwards in small stream sections or from pools to moving bodies. Homalopterid fishes constitute a remarkable family of torrent – inhabiting loaches characterised by a subterminal and inferior mouth, a flattish lower surface and horizontal paired fins with the anterior rays 'simple' (Hora, 1931).

***Balitora mysorensis* Hora**

Thippallikkayam area of Bharathapuzha, streams of hilly area with steep slopes, . The specimen was collected from a pool, with little flow bedrock and boulders form the major substrate with some sand. The land use pattern at the collection site was rubber plantation on one side and settlement with agricultural area on the other. grasses, shrubs and trees are the major riparian vegetation.

According to Talwar and Jhingran (1991) it inhabits torrential streams.

***Travancoria elongata* Pethiyagoda and Kottelat**

Athirapilly and Parambikulam area of Chalakudy river. These areas are in reserve forests with shrubs and trees as major riparian begetation. Most preferred habitat is shallow streams with pools, and bedrock as major substate. Water was clear and well oxygenated.

***Travancoria jonesi* Hora**

Parambikulam wildlife sanctuary area of Chalakudy river. It is an inhabitant of high altitude streams with cobble, boulder and bedrock as major substrates. Land use pattern at the collection site was teak plantation with grasses, bamboos, shrubs and trees as riparian vegetation. The specimen was collected from rocky area with slowly moving water, dried up partially during the summer season.

It inhabits mountain streams (Talwar and Jhingran, 1991).

Nemacheilus denisoni Day, *Nemacheilus guentheri* Day, and *Nemacheilus triangularis* Day

Most preferred habitat is moderately gradient streams with sand and gravel as major substrates, followed by cobbles and bedrock. Common in streams of hilly region. *Nemacheilus triangularis* can be abundantly seen in Thenmala region of Kallada and Kallar area of Vamanapuram rivers. Water was clear with high dissolved oxygen and low temperatures. Land use forms reserve forests and various types of plantations, and settlements with agricultural field.

Nemacheilus evezardi Day, *Nemacheilus monilis* Hora, *Nemacheilus pambarensis* Rema Devi and Indra, *Nemacheilus pulchellus* Day and *Nemacheilus semiarmatus* Day

Streams of Chinnar wildlife sanctuary area of Pambar river. The water had low temperature and high dissolved oxygen value. *N. pulchellus* is also occurred in Idukki wildlife sanctuary.

Nemacheilus keralensis Rita *et al.*

Eravikulam national park and Karintiri area of Periyar, Kaitapara area of Muvattupuzha and Vagamon area of Meenachil rivers. It was collected only from high altitude streams with low temperatures (850 to 2200 m above msl.). Almost all the streams are with bedrock bottom, followed by cobble, gravel, sand and mud. Land use pattern at the collection site was reserve forest, with grasslands and tea plantation in Periyar river, reserve forest with cardamon plantation in Muvattupuzha river and tea plantation in Meenachil river. All the streams are narrow with average stream depth less than 20 cm.

Pangio goaensis (Tilak)

Lowland areas of Manimala river. Prefers shallow slow flowing waters with detritus, mud, sand, and gravel as the dominant substrates, of which sand constituted above 65% of the total. More abundant in river banks among the interstitial spaces of sand or mud. The land use at the collection sites was mainly rubber plantation and human settlements. They mainly seen in groups of more than 100 numbers in both the localities

Lepidocephalus thermalis (Val.)

They inhabits a variety of habitats, but common in lowland areas with sand and mud as the major substrates. Ability to tolerate less oxygenated; and saline waters. Rarely seen in high altitude streams.

According to Day (1878) its habitat was the Malabar coast and the Wynaad of Southern India and Ceylon.

Horabagrus brachysoma (Gunther)

It prefers lowland areas with mud and sand as dominant substrates. Rarely seen in midland areas of Chalakudy and Periyar rivers. They are benthic form and seen in abundance at the beginning of the south west monsoon. Land use pattern in the habitat was coconut plantation and paddy fields with human settlements at most of the sites.

According to Day (1878), it prefers the deepest pools and also backwaters. A very common catfish in the Kerala backwaters (Talwar and Jhingran, 1991). Jayaram and Singh (1982) collected it from the Cochin backwaters.

Horabagrus nigricollaris Pethiyagoda and Kottelat

Lowland and midland areas of Chalakudy river. More abundant in moderately gradient streams with bedrock pools with cobbles and boulders as the principal substratum. They can tolerate slightly saline water also. Land use pattern was reserve forests with shrubs and trees as dominant riparian vegetation, and coconut plantation and paddy fields with settlements. Dissolved oxygen concentration ranged between 5.2 to 6.4 ppm and temperature ranged between 24 to 31^{0} C.

Batasio travancoria Hora and Law

Prefers moderately gradient riffles with cobble, bedrock and gravel as the principal substratum. Sometimes seen in gravel and sandy bottom. It is mostly seen in crevices and on the underside of stones and rocks. Water was well oxygenated, cold and slightly acidic. Not recorded from high altitude areas. Land use was reserve forests, rubber, and teak plantation.

***Mystus bleekeri* (Day)**

Midlands at Ottasekharamangalam of Neyyar river. The site being of mixed substrates such as detritus, mud, sand, gravel, cobbles, and boulders. Mud was the prominent substrate. The land use pattern at the collection site was mainly settlements with mixed agricultural lands; grasses, shrubs and bamboo constituted the major riparian vegetation.

According to Day (1865), it inhabits upper waters and descends rivers. It also inhabits lakes, tanks and rivers (Talwar and Jhingran, 1991).

***Mystus malabaricus* (Jerdon)**

Midland and highland areas with sand, gravel and mud as the principal substrates. From Muvattupuzha river it was collected from a moderately gradient riffle at Edad with boulder and bedrock as the dominant substrates. Commonly seen in muddy or sandy pools with little flow. Temperature ranged between 24 to 29^{0}C and dissolved oxygen was between 5.2 to 6.8 ppm.

According to Talwar and Jhingran (1991), it inhabits freshwaters and estuaries.

***Mystus montanus* (Jerdon)**

Mostly in midland areas, collected from highland at Kottavasal of Achankovil river. Sand, gravel and mud were the dominant substrates in midlands and bedrock, boulders and cobble were in highlands. Land use pattern was reserve forest, rubber or teak plantation and settlements with mixed agricultural lands. Collected from slightly saline waters at Chelamattom of Periyar river during summer.

It inhabits freshwaters and estuaries (Talwar and Jhingran, 1991).

***Mystus punctatus* (Jerdon)**

Lowland area at Karikadavu of Karuvannur river. The site was a small stream with less than 10 m width and 15 cm. average depth. Moderately flowing water (15 cm/sec.) with sand and mud as principal substrate. The land use was human

settlements with agricultural lands. Grasses and shrubs are the major riparian vegetation

According to Day (1878), it prefers streams at base of hills.

***Mystus vittatus* (Bloch)**

Lowland and midland areas of Periyar river. The stream bottom was mixed with mud, sand, gravel, cobbles, and boulders as the major substrates in Ayyappankovil area; and bedrock and boulders in Thundam area. Shrubs and trees constituted the major riparian vegetation in both the areas. Prefers muddy and sandy pools with moderate flow.

According to Talwar and Jhingran (1991), it inhabits mostly standing and flowing waters, also occurring within the tidal influence.

***Clarias dussumieri* Val.**

It prefers lowland areas with mud and sand as the principal substrate. The land use pattern was settlements with paddy fields or mixed agricultural lands. Grasses and shrubs form the major riparian vegetation. Rarely seen in highland and highrange areas of moderately or highly gradient streams with bedrock, boulders and cobbles as substrate. The land use was reserve forest with shrubs and trees as riparian vegetation.

It inhabits tanks and ditches (Talwar and Jhingran, 1991).

***Heteropnenstes fossilis* (Bloch)**

Hilly areas with cobble and gravel as principal substrate. Most common in rocky pools with mud and sand in Karuvannur and Periyar rivers in the lowland areas. They can tolerate temperature ranged between 22 to 31°C and also in less oxygenated water

It inhabits freshwaters, rarely in brackish water (Talwar and Jhingran, 1991).

***Ompok malabaricus* (Val.)**

Lowland areas of Karuvannur and Chalakudy rivers. Mud and sand are the major substrates at both the collection sites. It was collected from a muddy pool at Anappantham of Karuvannur in reserve forest area; rocky pool with mud and sand at Kannamkuzhi area of Chalakudy river. They prefers slow moving water bodies and can tolerate less oxygenated water.

According to Day (1878) and Talwar and Jhingran (1991), it inhabits lowlands of coastal area.

***Pseudeutropius mitchelli* (Gunther)**

Midland areas of Periyar river with detritus, mud, sand, cobbles and boulders as the major substrates. The land use was reserve forest and teak plantation with shrubs as the riparian vegetation. Prefers slow flowing waters.

It inhabits freshwaters in coastal areas (Day, 1878; and Talwar and Jhingran, 1991).

***Glyptothorax annandalei* Hora**

Inhabits upstreams of Muvattupuzha river with detritus sand, cobbles and bedrock as principal substrates in Mullaringad area. Here the habitat was low gradient riffle with settlement area mixed with agricultural lands. From Moolamattom, it was collected from a rapid type stream with cobbles, boulders and bedrock as the major substrate. It is a benthic form inhabiting the underside of stones and rocks, but is also adapted to swift running hillstreams due to the presence of a thoracic sucking disc.

***Glyptothorax housei* Herre**

Midland and high land areas of streams with gravel, cobble and sand on the major substrate. Most common in midland areas of Muvattupuzha at Moolamattam and Mullaringad. They always seen hiding under stone with clear well oxygenated flowing waters and gravel substratum.

Glyptothorax lonah (Sykes)

High ranges of Chalakudy river. It prefers foothill rivers and mountainous swift running streams. The specimens were collected from pools, as the stream was dry (since the collections were done in summer). The main substrates at the collection site were bedrock, cobbles, boulders, and detritus. The land use was reserve forest with eucalyptus plantation on one bank and thick evergreen forest on the other

According to Day (1878), it occurs in headwaters.

Glyptothorax madraspatnum (Day)

Midland to highrange areas, and prefers riffle type of habitat with gravel, cobble and sand as the principle substrate. Most common in Bharathapuzha and Muvattupuzha rivers.

According to Day (1878) it inhabits the foot of hills. The genus *Glyptothorax* live in fast flowing hill streams and have developed an adhesive apparatus on their ventral surface for holding themselves to rocks and boulders (Jayaram, 1978).

Pristolepis marginata Jerdon

Inhabits hilly areas more common in midland areas of Bharathapuzha and Periyar rivers with mud, sand and bedrock as the principal substrates. The bottom was not visible in almost all the collection sites in these rivers. The other areas are in moderately gradient riffles with bedrock, cobbles and boulders as the dominant substrate.

It inhabits clear and rapid streams (Talwar and Jhingran, 1991).

Sicyopterus griseus (Day)

Lowland and midland areas of Chalakudy and Periyar rivers. Prefers low gradient shallow waters with bedrock and cobbles as major substrates. From Periyar it was collected from very low areas of Chelamattam and Kalady with mud and sand as dominant substrate.

According to Talwar and Jhingran (1991), it inhabits estuaries and backwaters.

Channa marulius (Ham.) and *Channa orientalis* Bloch and Schneider

Generally inhabited in clear freshwaters with boulders, cobbles and bedrock as principal substrates. Rarely seen in very low areas with muddy or sandy bottom. *Channa marulius* is more common in lowland reservoirs of Vazhani and Buthattankettu of Keechery and Periyar rivers respectively.

According to Talwar and Jhingran (1991), *Channa marulius* inhabits large lakes and rivers; prefers deep, clear stretches of water with sandy or rocky bottom. While, the *Channa orientalis* in mountain streams and lowland waters.

Channa punctatus (Bloch) and *Channa striatus* (Bloch)

Prefers deep pools of lowland areas with mud and sand as bottom material. *Channa striatus* is common in streams connected to paddy fields of Thrissur district *Channa punctatus* was recorded only from the lowland areas of Keechery, Karuvannur and Periyar rivers, and also from Chimmony wildlife sanctuary area of Karuvannur river. The sanctuary area was a moderately gradient stream with sand, gravel, cobble and bedrock as major substrates. The land use was teak plantation with shrubs as dominant riparian vegetation.

Channa punctatus inhabits large freshwater ponds and tanks, generally in the plains, while *Channa striatus* prefers stagnant muddy waters and grassy tanks (Talwar and Jhingran, 1991). All the species of Channa are monogamous and build nests for depositing their eggs (Raj, 1916).

Tetraodon travancoricus Hora and Nair

Mostly restricted to lowland areas except for Periyar and Pamba rivers, where it was also recorded in the middle reaches. Commonly seen as shoals of hundreds along the banks of streams. More abundant in Pamba and Muvattupuzha rivers. Detritus, mud, sand and gravel are the major substrates in almost all the collection sites. The land use was mostly settlements with paddy and coconut plantation.

Inasu (1993) found it in the brickyards of Thrissur district, and according to Talwar and Jhingran (1991), it inhabits fresh and brackish waters.

5.3.2 Plant species collected from the streams of the study area

The analysis of vegetation is used as a means of revealing useful information about the other components of the ecosystem (Goldsmith *et al.*, 1986). Streams and rivers provide habitats which are very different from those in spring, for they are subject to changes along their length associated with depth, rate of flow, geology of the land surface and of the stream bed, salt concentration, turbidity etc. Like animals, plant species also exhibits adaptations to survive in streams. Muenscher (1944) considered aquatic plants as "those species which normally stand in water and must grow for at least a part of their life cycle in water, either completely submerged or emerged"

The algae of running waters have received much less attention than those of other habitats since the measurement of variables such as rate of flow, temperature, nutrient status, etc. is more complicated in a habitat which changes rapidly in both time and space. According to Round (1977), the only macroscopic algae which is widely reported from spring is *Batrachospermum*, which often grows anchored in the fine sand around underwater spring and may itself be coated with diatoms.

The water dispersal has a certain role in structuring the riparian flora, and provide a basis for explaining species distribution patterns from dispersal characteristics (Mats *et al.*, 1996). The plant indicators are of greater value in finding out the potentiality and capability of lands and also function as a monitor which cautions the continuance of the various biological processes (Devaraj, 1999). The importance of riparian wetlands in assessing the biodiversity characteristics was also discussed by Toner and Keddy (1997) and Pollock *et al.* (1998). Sebastine and Ramamurthy (1996) studied the flora of Parambikulam and Aliyar submergible areas of south India and recorded 159 and 292 species respectively. Cook (1996) listed 352 aquatic and wetland plants from Kerala, of which 15 are endemic to Kerala.

During the present study the species were identified by following Cook, 1996; Subramanyam, 1974, Fassett, 2000; Round, 1977; and Manilal and Sivarajan, 1975.

A total of 15 species belonging to 10 families were recorded from the study area. All species except *Batrachospermum* are commonly distributed in various river systems. The *Batrachopermum* is mainly inhabited in hilly areas attached with sand and rocky substratum. The systematic list of species collected are summarized below (Table 5.2).

Table 5.2 Aquatic plants collected from southern Kerala.

No.	Name of species
	I. Family: Nymphaeaceae
1.	*Cabomba caroliniana* Gray
2.	*Nymphaea nouchali* Burm
	II. Family: Podostemaceae
3	*Dicraea munnarense* Nagendran et Arekal
4.	*Indotristicha ramosissima* (Wt.)
	III. Family: Hydrocharitaceae
5.	*Hydrilla verticillata* Royle
6.	*Vallisneria natans* (Loureiro)
	IV. Family: Araceae
7	*Legendandra toxicaria* Dalzell
8.	*Pistia stratiotes* L.
	V. Family: Cyperaceae
9	*Cyperus tenuispica* Steudel
10	*Eleocharis retroflexa* (Poiret)
	VI. Family: Scrophulariaceae
11	*Limnophila* sp.
	VII. Family: Polygonaceae
12.	*Polygonum galbrum* Wild.
	VIII. Family: Amaranthaceae
13	*Alternanthera tenella* Colla
	IX. Family: Boraginaceae
14	*Rotula aquatica* Loureiro
	X. Family: Rhodophyceae
15.	*Batrachospermum* sp.

5.4 Discussion

Fish assemblages in rivers and streams world wide show longitudinal zonation (Fisher, 1983), and the relationship between assemblage composition and physiochemical variability continues to be actively studied (Meffe and Sheldon, 1988). The longitudinal succession was evident in most of the rivers, with the number of species increasing downstream.

The temperature of running waters usually varies seasonally and daily, and among locations due to climate, elevation, extent of streamside vegetation and the relative importance of groundwater inputs. Stream temperatures can be quite constant under certain circumstances. The temperature of groundwater usually is within 1^0C of mean annual air temperature. Seasonal changes in water temperature in rivers show that mean weekly water temperature could be predicted very accurately from air temperatures

A multiple correlation analysis based on different habitat variables showed temperature with negative correlation (altitude and oxygen- r = p> 0.01) or with positive correlation (depth, width and species diversity – r = p> 0.01). In high range (>750 m msl) areas water temperature ranged between 14 to 25^0 C with a minimum 14^0 C in Konalar stream of Bharathapuzha river (1930 m msl) . Only one species , the rainbow trout *Salmo gairdneri irredius* is recorded from the stream. While in lowland areas (<75 m msl) the temperature ranged between 25.4 (Punnamattam area of Muvattupuzha river) to 33.7^0 C (Pulani area of Chalakudy river). The following spicies is found to prefer high oxygenated cold waters in high altitude streams : *Hypselobarbus kolus, H. periyarensis , Osteochilus longidorsalis , Puntius ophicephalus, Garra mclellandi, G. hughi, G. menoni, G. gotyla stenorhynchus, Horalabiosa joshuai, Bhavania australis, Balitora mysorensis, Travancoria elongata, T. jonesi, Nemacheilus pambarensis, N. evezardi, N. pulchellus, N. keralensis, N. monilis, N. semiarmatus, Glyptithorax annandalei, G. housei, G. lonah, and Salmo gairdneri irredius.*

The concentration of dissolved oxygen is always related to current , temperature or substrate conditions. Oxygen is transported across the gills and other

respiratory structures of aquatic organisms by diffusion. The current is continually renewing the water in contact with respiratory structure. The biota of running waters is in several ways highly dependant upon the ready availability of oxygen (Hynes, 1970). Oxygen is usually not limiting to the biota of running waters. Under certain condition it can be important and depend on interaction involving other physical and biological factors.

During the present study dissolved oxygen showed as a significant negative correlation with depth, species diversity, temperature (Fig. 5.1) and width ($r = p > 0.01$). The increase in oxygen value with low temperature is universally accepted. Decrease in oxygen with increased depth may be due to less mixing of water and also due to the microbial decomposition (usually deep areas are in lowlands with muddy or sandy bottom). The wider streams are generally in lowland areas with high temperature and low flow rate. This may be a reason for decreased oxygen in increased depths. The dissolved oxygen value is positively correlated with attitude and flow. This may be attributed to the decreased temperature in high altitudes (temperature and oxygen has high negative correlation) and well mixing of water in flowing systems. The data showed a decrease in species diversity with increased oxygen content (high altitude streams are usually less diversified and high oxygenated) (Fig. 5.2). The reason for low diversity can be due to the scarcity of food items and decreased volume of water. The altitude and width are negatively correlated.

Current is the defining feature of running waters that unites all rivers and streams. Water velocity and the associated physical forces collectively represent most important environmental factor affecting fish in running waters. The speed of the current influences the size of particles of the substrate. Current affects food resources via delivery and removal of nutrients and food items. The complexities of flow around obstructions and near the stream bed are important elements in the distribution of fishes. They usually prefer such a running water system. The common species seen in fast flowing waters with specific morphological adaptations come under the genus *Bhavania*, *Travancoria*, *Balitora*, *Glyptothorax* and *Nemacheilus*.

In the present study a positive correlation is obtained with flow and dissolved oxygen. The flow indirectly affects the organisms of stagnant water(s) also by supplying nutrients and other conditions necessary for survival. According to Angermeir and Karr (1983), fish biomass distributions among habitats within a stream appear to be more closely related dangers of predation by birds and mammals than to the distribution of food resources. However, distributions of small fish are closely correlated with food abundance. Generally small fishes and young ones inhabit close to the substrate with little current. Edds (1993) correlates with one species in fast flowing headwaters and 33 species in slow moving lowland sites.

The dissolved oxygen is not a limiting factor in all the collection sites, except at Tallakad of Muvattupuzha river (4 mg/l), Kumarakam of Meenachil river (4.8 mg/l), and Naduvilkoratti of Manimala river (4.2 mg/l). All these three areas are in lowlands with human settlements. The reason for the low values of oxygen may be the presence of large quantities of domestic wastes from nearby places. In most of the areas oxygen ranged between 5.4 to 7.8 mg/l.

The influence of pH on the distribution of freshwater fish species was not significant. The pH of stream water is dependant on local factors also. The less influence of pH observed during the present study is supportive to the statement of Whitton (1975) as 'under most natural conditions variation in pH has little effect on fishes, which can tolerate the normal daily pH range as well as the temperature range'.

Substrate is a complex aspect of physical environment and is determined by the current, together with available parent material. Substrate is relatively uniform in sandy bottom of low-gradient rivers or usually very heterogenous. Slower currents, finer substrate particle size and lower oxygen are correlated (data indicates that the lowland stream sections with sandy or muddy bottom are slow moving with less dissolved oxygen content compared to hillstreams). Substrate depends on the parent material available but there is a general tendency for particle size to decrease as one proceeds down streams i.e. larger stones and boulders are noticed in hilly areas and sandy bottom in lowland rivers. This is true with the streams in the study area.

Fish habitat assessment generally involves the study of morphology of the streams (physical features) which depends on stream flow duration, substrate distribution or bed features, land use pattern, riparian vegetation, gradient, entrenchment, nature of water, flow rate of water, width and depth of the streams, origin and order of the streams, bank stability and disturbance along the river basin. Winston (1995) studied the co-occurrence of morphologically similar species in Red River basin of Texas and concluded that the morphologically most similar pairs of stream-fish species co-occurred significantly less frequently than morphologically less similar pairs. The identification of limiting factors, or factors correlated with those that are limiting, may improve species management and habitat enhancement on streams (Layher and Maughan, 1988). The mechanisms maintaining community organization in stream fishes probably varies along the physical gradient from headwater to downstream or riffle to pool (Schlosser, 1982). According to Rahel (1984) the type of fish assemblage present in small, northern Wisconsin seepage lake was largely determined by a lakes position along three major environmental gradients- habitat size and heterogenecity, lake productivity and pH, and winter oxygen levels.

Woody debris is an important component of forested streams and its role in physical, chemical and biological process in streams is complex. It played a multidimensional role in the structure and functioning of stream eco-system. Woody debris not only influenced fish habitat characteristics, but also provided substrate for many aquatic invertebrates, the major food resource of most fish species (Angermeier and Karr, 1984; and Berry and Braaten, 1997).

Streams of rivers can be classified as 1st, 2nd, 3rd and 4th orders. Stream order is a rank of the relative size of streams within a watershed. The most commonly used method of ordering is to designate the smallest unbranched, or headwater tributaries as the first order streams. (Biju et al., 2000) A second order stream is formed when any two first order streams meet; third order by the junction of any two second order streams, and so on

Many of the first order streams were found to be intermittent, while some of them were ephemeral Second order streams seemed to be intermittent and also

perennial, while fourth order streams were perennial. The bed material were also showed variations in different orders. The particle size showed a decreasing trend when descending downwards. Fourth order streams generally have sand as the major substratum. The substrate distribution also varied with altitude. In the lower reaches, sand and mud were the main substrate; in the middle areas mud, sand, gravel, and pebbles; in highland areas, gravel, cobble and boulders; and cobble boulder and bedrock were the main substrates in high ranges.

Out of the 243 sites the diversity index showed greater values in Puzhakkal area of Puzhakkal river (H' =2.98), Manjamkuzhy area of Karuvannur river (H' = 3.14) and Elantikara area of Chalakudy river (H'= 3.25). These all areas are in low lands. The reason for greater diversity values may be due to the presence of species having adaptations to withstand wide range of temperature and salinity tolerance. An ecotone is a zone of transition between adjacent ecological systems and these low land areas sometimes act as ecotones. The ecotones are generally with high diversity of species. In contrast, the small index values are reported in streams of high altitudes. These fishes have generally narrow range of temperature tolerance. During the present study it is concluded that the species with narrow range of temperature tolerance are *Nemacheilus keralensis*, *Horalabiosa joshuai*, and an exotic fish *Salmo gairdneri irredius*. Mackay and Ragg (1945) collected Brown Trout from Eravikulam, where the temperature in very low, also indicates their narrow range.

In the present study it is noticed that the species diversity is positively correlated with water temperature and width of the stream ($r = p > 0.01$). It indicates that wide lowland steams have high water temperature and high diversity index. Contrastingly species diversity is negatively correlated with altitude and dissolved oxygen (r $p > 0.05$). This can be explained on the basis that well oxygenated waters in high altitude streams harbor less number of fish species.

The multiple correlation analysis shows that the most correlated parameters are altitude and temperature ($r = 0.667$), and oxygen and temperature ($r = 0.531$).

Periyar and Chalakudy rivers in southern Kerala presents the maximum diversification regarding fish fauna. Both the rivers harbor some of the endemic species in Kerala, and also endangered ones. Genus *Travancoria* is restricted only to these rivers. One of the two *Travancoria* species, *T. elongata* is restricted to Chalakudy river only. The other two species endemic to Chalakudy river are *Horabagrus nigricollaris* and *Osteochilus longidorsalis*. *Lepidopygopsis typus*, *Garra periyarensis*, *Nemacheilus menoni*, *Crossocheilus periyarensis* and *Hypselobarbus micropogon periyaransis* are the species endemic to Periyar river. The other endemic species recorded from these rivers are *Garra surendranathanii*, *Batasio travancoria*, and *Puntius denisonii*. The Periyar river also harbors *Nemacheilus keralensis*, which is also an endemic species to Kerala and is known only from Periyar, Muvattupuzha and Meenachil rivers

The remarkable diversity of fish fauna of these rivers may be correlated to the heterogeneity of substrates in stream habitat types. The variety of combinations of substrates existed in these rivers. Different altitudinal range are also indicative of large species number in these rivers. The land use pattern seen at most collection sites is of reserve forests, followed by teak plantation and settlements with agricultural area. In some collection sites were also seen coffee, coconut, cardomom plantations and grass land ecosystems. The riparian vegetation ranged from trees, followed by shrubs and grasses. In reserve forest areas, large trees formed the major riparian vegetation, and the stream bank stability was also very high. The lowland and midland areas had a mixture of habitat types, a number of protected area (wildlife sanctuaries and national park) are established in these rivers. Most of the above mentioned endemic species are restricted to these protected areas. This is a convincing indication of the role of protected areas in the conservation of nature and natural resources. Considering the diversity and endemicity of fish species, the Parambikulam wild life sanctuary can aptly be called as 'fish sanctuary of Kerala'.

The other rivers with high diversity of fish fauna are Bharathapuzha, Pamba, Kallada and Neyyar. The Pambar river, a tributary of Cauvery is famous for its diversity of Nemacheiline fishes. Except *Nemacheilus keralensis*, all other species of *Nemacheilus* are distributed in this river. Likewise Bharathapuzha is important for

its Barilians, all the four species of *Barilius* are found in Bharathapuzha. It also harbour endemic species, *Chela fasciata*, which is found only in Chalakudy and Bharathapuzha rivers. These results indicate that substrate distribution plays an important role in the diversity of fishes, providing different types of stream habitats.

The stream sections with less or no canopy had high water temperature due to exposure to sunlight, whereas shading reduced the water temperature in sections with high percentage of canopy. Rivers like Keechery, Puzhakkal, Karuvannur, Meenachil, Achankovil, Pallikkal, Ayiroor and Mamom rivers dried up during summer, sometimes even in lowlands. Hence the typical hillstream fishes are rare in these rivers. The fish diversity was also high in stream sections with natural forest as land use. Root system of trees in forest areas provide shelter for stream fishes in that area.

Based on the present observations it is noticed that the following are the species mainly inhabited in hill streams: *Hypselobarbus kolus, H. micropogon periyarensis, Osteochilus longidorsalis, O. nashii, Barbodes carnaticus, Puntius ophicephalus, Tor khudree, Chela fasciata, Barilius bakeri, B. bendelisis, B. canarensis, B. gatensis, Garra mcclellandi, G. menoni, G. hughi, G. gotyla stenorhynchus, G. surendranathanii, Horalabiosa joshuai, Bhavania australis, Balitora mysorensis, Travancoria elongata, T. jonesi, Nemacheilus denisoni, N. evezardi, N. guentheri, N. monilis, N. keralensis, N. pambarensis, N. pulchellus, N. semiarmatus, Batasio travancoria, Mystus vittatus, Glyptothorax housei, G. annandalei, G. madraspatanum, G. lonah, Salmo gairdneriii irredius* and *Pristolepis marginata*.

Periyar and Chalakudy rivers in southern Kerala presents the maximum diversification regarding fish fauna. In the present study it is noticed that the protected areas play an important role in conservation of fish species. Stream sections with forest areas and heterogeneity in substrates shows maximum diversity.