1.1 Global Freshwater Bio-diversity

Freshwaters make up only around 0.01% of the world’s water, approximately 0.8% of the earth’s surface (Gleick, 1996) and it yet supports 100,000 species (Hawksworth & Kalin-Arroyo, 1995). A global stand for the conservation of freshwater species has been largely constrained by a general lack of broad scale information (Darwall et al. 2011). The catalogue of fishes established by Eschmeyer (2005) provided an approximate of 27,300 valid fish species, with a forecast of about 31,500 species when all inventories are completed. While in 2005, Fish Base already
listed 28,900 species (http://www.fishbase.org). According to Leveque et al. (2008), the number of fish species able to use freshwaters about 13,000-15,000 species, which is 40-45% of the global fish diversity. Nelson (2006) recorded that about 11,952 fish species, or 43% of all fish species belonging to 33 orders live completely in freshwater lakes and rivers. Globally an estimated 126,000 described species depends on freshwater habitats, including fishes, molluscs, reptiles, insects, plants, and mammals, and of which freshwater fishes comprise almost 45% of total fish species (IUCN, 2007). IUCN (2013) reported an estimated 15,000 fish (including brackish water species) depends on freshwater habitats.

Figure 1.1. Global IUCN Red List of threatened Species (Data source: IUCN-2013.1).
Freshwater ecosystems may well be the most endangered ecosystems in the world (Duncan & Lockwood, 2001), with a projected extinction rate of five times that of terrestrial fauna and three times that of marine mammals (Cooke et al. 2005) and the decline in freshwater biodiversity is far greater than in most affected terrestrial ecosystems (Sala et al. 2000). Chapin et al. (2000) revealed that current extinction rates of species are estimated to be 100 to 1,000 times greater than pre-human rates. Globally about 10,000 to 20,000 freshwater species are already extinct or imperiled due to human activities (Fig. 1.1) (IUCN, 2007).

1.2 Freshwater Fish Diversity of India

A very small number of countries mostly located in the tropical belt contain a high percentage of biodiversity and endemism, are considered as “mega diversity” countries (Mc Neely et al. 1990). To qualify as a hotspot region, a region must meet the area needs to contain at least 1500 species of endemic vascular plant and to have lost at least 70% of its original habitat (Molur et al. 2011). India is one of the mega biodiversity countries in the world and occupies the 9th position in terms of freshwater biodiversity (Mittermeier et al. 2003). According to Leveque et al. (2008), knowledge of the fish fauna of tropical Asia is still in its exploratory phase particularly in India. Day (1889) described 1,418 fish species under 342 genera from British India. Later, Jayaram (1981) estimated 742 freshwater species of fishes coming under 233 genera, 64 families and 16 orders from the Indian region. Talwar & Jhingran (1991) estimated 930 species from India and adjacent countries, while Jayaram (1999) estimated 852 species of fishes belonging to 71 families and 16 orders from the Indian region, while Menon (1999) listed 68% by the Cyprinoids, 18% by Siluroids and 14% by other groups.

Rema Devi & Indra (2010) updated the checklist as 667 freshwater fish species, which includes 12 orders, 35 families and 149 genera and it includes 62%
Cyprinoids, 26% Siluroids, 12% other groups and several new species. Recently Sarkar et al. (2013) documented 2,799 species of fin fishes from India, of which 877 are freshwater, 113 are brakishwater, 1,518 are from marine environment and including 291 exotic species. Among the Indian freshwater fishes, family Cyprinidae is the largest and the most dominant with the maximum number of endemic species (97 species), followed by the family Balitoridae (46 species) and Sisoridae (21 species). The indigenous fishes are distributed across all parts of the country but few regions are considered to be hotspot. It is estimated that about 33% of freshwater fishes are exploited from the North-Eastern region, 24% from Southern region, 23% from Eastern region, 6% from Western region, 3% from Northern region, 2% from Central region and 10% throughout India (Swain, 2008).

1.3 Freshwater Fish Diversity in the Western Ghats

The Western Ghats of India is a part of Western Ghats-Sri Lanka Biodiversity Hotspot in peninsular region of freshwater biodiversity (Dahanukar et al. 2011). Of the 34 biodiversity hotspots in the world, India is endowed with a rich biodiversity of fresh water fishes in the Western Ghats and the North Eastern Hills (Kurup, 2002). The Western Ghats consists of range of hills running along India’s west coast (08°19’-21°16’N to 72°56’-78°19’E) is one of the richest regions in terms of its biological diversity (Fig. 1.2.). The Western Ghats bio-geographic region in India runs along the west coast extending north to south distance of 1,490 km with a minimum width of 48 km and maximum width of 210 km (Molur et al. 2011) and are drained by 38 east flowing and 27 west flowing major rivers with running water habitat and lacustrine habitats (Abell et al. 2008).
Figure. 1.2. Geographical position of Western Ghats biodiversity hotspot, India (Adapted from Molur et al. 2011).

The Western Ghats region of India is one of the freshwater fish biodiversity hotspots in the world (Myers et al. 2000). The Kerala region of Western Ghats has a higher percentage of threatened species when compared to other global eco-regions such as Eastern Himalayas (13.5%) and Eastern Africa (28%) (Menon & Bawa, 1997; Gopalakrishnan & Ponniah, 2000; Dahanukar et al. 2004; Raghavan et al. 2007; Molur et al. 2011). Western Ghats region of India is a gold mine for ornamental fishes (Mercy, 2009) and these areas harbors over 30% of the total life forms known from India (Myers, 1988; CAMP, 1998). A number of authors have described the richness of fish diversity and endemcity of fish fauna in the Western Ghats system (Subhash Chandran, 1997; Myers et al. 2000; Gopalakrishnan & Ponnaiah, 2000; Gopi, 2000; Ramadevi & Indra, 2000; Chandrashekharraiah et al. 2000; Arunachalam et al. 2000; Daniels, 2001; Shaji et al. 2001; Ghosh & Ponniah, 2001; Bhat, 2003; Dahanukar et al. 2004; Dahanukar et al. 2011 and Raghavan & Dahanukar, 2013). Out of the 617 freshwater fish species identified from India (Gopalakrishnan & Ponniah, 2000); 287 species are reported from the Western
Ghats (Shaji et al. 2000) of which 207 species are exclusively from the Kerala region (Gopi, 2000), which makes this region a hotspot of fish diversity.

Daniels (2001) has listed 218 species from the Western Ghats of which 114 (52%) are endemic to Western Ghats. The subsequent checklist (Shaji et al. 2001) listed 287 fishes with names of species, and Dahanukar et al. (2004) listed 288 species (Critically endangered-24, Endangered-54, Vulnerable-41, Low risk-58, Data Deficient-105, Introduced-6) belonging to 12 orders, 41 families and 109 genera, of which 118 species are endemic and 51 are unique. Dahanukar et al., in 2011 listed 290 freshwater fishes of which 189 endemic species (65% of the total) belonging to 7 orders, 23 families and 69 genera. The most recent information’s is available by Ragahvan & Dahanukar (2013), listed 320 species of freshwater fishes including some secondary freshwater species, which can also live in brackish water and marine habitats, belonging to 11 orders, 35 families and 112 genera. However, baseline information on taxonomy and distribution of the region’s fish fauna needs to be well-documented and is now fragmented or inconsistent (Raghavan et al. 2007).

1.4. Threatened status of Freshwater Fishes in the Western Ghats

The freshwater fish biodiversity in the Western Ghats is alarmingly declining due to man-made pressures (Kurup, 2000). The threat status of fishes in the Western Ghats suggests that nearly 41% of the fish fauna are in threatened, Vulnerable, Endangered or Critically endangered state (Dahanukar et al. 2004). The IUCN Red List categories and criteria are proposed to be better system for classifying species at high risk of extinction (Molur et al. 2011). Species assessed under the categories of Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) is considered as “Threatened” and they face high risk of extinction in the future. According to the IUCN Red List, 734 species of fishes are classified as threatened, of which 84% are freshwater species (IUCN, 1996). In the Western Ghats of India, around 33% of the total species are under Threatened or Near Threatened categories, while 17% are
under Data Deficient or Not Evaluated categories (Molur et al. 2011). Out of the 212 endemic species, 47% are under threatened or Near Threatened categories and 23% are under Data Deficient or Not Evaluated categories (CAMP, 1997; Lakra et al. 2010; Dahanukar & Raghavan, 2013). A continuous update and follow up of the IUCN Red List assessments is essential for the conservation of freshwater fishes in the Western Ghats of India (Dahanukar & Raghavan, 2013).

The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on plants and animals (Fig. 1.3) (Molur et al. 2011). Species are generally categorized in one of the following group of extinction risk, extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC) and data deficient (DD).

**Extinct (EX)** - A taxon is Extinct when there is no reasonable doubt that the last individual has died.
Extinct in the Wild (EW)- A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.

Critically Endangered (CR)- A taxon is critically endangered when it is facing an extremely high risk of extinction in the wild in the immediate future as defined by the criteria.

Endangered (EN)- A taxon is Endangered when it is not critically endangered but is facing a very high risk of extinction in the wild in the near future as defined by the criteria.

Vulnerable (VU)- A taxon is Vulnerable when it is not critically endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future as defined by the criteria.

Near Threatened (NT)- A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Least Concern (LC)- A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Data Deficient (DD)- A taxon is Data Deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

Not Evaluated (NE)- A taxon is not evaluated when it has not yet been assessed against the criteria.
Table 1.1. Red List status of freshwater fishes in the Western Ghats of India (Data Source: Published literatures).

<table>
<thead>
<tr>
<th></th>
<th>EX</th>
<th>EW</th>
<th>CR</th>
<th>EN</th>
<th>VU</th>
<th>NT</th>
<th>LC</th>
<th>DD</th>
<th>NE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dahanukar (et al. 2011)</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>54</td>
<td>31</td>
<td>6</td>
<td>161</td>
<td>26</td>
<td>0</td>
<td>290</td>
</tr>
<tr>
<td>2. Ragahvan &amp; Dahanukar (2013)</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>53</td>
<td>32</td>
<td>53</td>
<td>164</td>
<td>39</td>
<td>0</td>
<td>320</td>
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<tr>
<td>3. Updated</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>53</td>
<td>32</td>
<td>32</td>
<td>164</td>
<td>39</td>
<td>0</td>
<td>331</td>
</tr>
</tbody>
</table>

Raghavan & Dahanukar (2013) updated the freshwater fishes from the Western Ghats of India as 320 species without including introduced species and while this species list is hereby updated into 331 species (Table 1.1) with the addition of *Pethia lutea* (Katwate et al. 2014a); *Pethia longicauda* (Katwate et al. 2014b); *Bhavania australis* Jerdon, 1849 (Abraham et al. 2011); *Clarias batrachus* Linnaeus, 1758 and *Macrognathus pannatus* Hamilton, 1822 (Dahanukar et al. 2004); *Mystus bleekerii* Day, 1877 (Abraham et al. 2011; Dahanukar et al. 2012); *Mastacembalus malabaricus* Jerdon 1849 (Plamoottil & Abraham, 2013); *Puntius viridius* (Plamoottil & Abraham, 2013); *Macrignathus albus* (Plamoottil & Abraham, 2014); *Macrognathus fasciatus* (Plamoottil & Abraham, 2014); *Pristolepis pentacantha* (Plamoottil, 2014) and *Mystus keralai* (Plamoottil & Abraham, 2014). Twenty four alien fish species (Table 1.2) were reported from Western Ghats includes non-native (*Oreochromis mossambicus*, *Oreochromis niloticus*, *Gambusia affinis*, *Poecilia reticulata*, *Cyprinus carpio*, *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, *Hypophthalmichthys nobilis*, *Puntius orphoides*, *Tor putitora*, *Tor tor*, *Salmo trutta trutta*, *Onchorhynchus mykiss*, *Clarias gariepinus*, *Piaractus brachypomus*, *Rhinomugil corsula*, *Pterygoplichthys multiradiatus*, *Osphronemus goramy*, *Trichogaster trichopterus*, *Xiphophorus hellerii* and *Xiphophorus maculates* and transplanted from gangetic plains are *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*).
Table 1.2. Checklist of fishes in Western Ghats Region

<table>
<thead>
<tr>
<th>Category</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fish species from Western Ghats</td>
<td>331</td>
</tr>
<tr>
<td>2. Alien/transplanted fish species in Western Ghats</td>
<td>24</td>
</tr>
<tr>
<td>3. Updated number of fish species in Western Ghats</td>
<td>355</td>
</tr>
</tbody>
</table>

Recently, Katwate et al. (2014c) successfully proved that the original description of *Pethia muvattupuzhaensis* by Beevi & Ramachandran (2005) to be a junior synonym of *Pethia punctata*, not a new species, so here excluded this species. Similarly Ali et al. (2014) successfully proved that the original description of *H. melanosoma* by Plamoottil & Abraham (2013) to be a junior synonym of *H. brachysoma*, not a new species. There is an uncertainty still existing in freshwater fish taxonomy, hence a continuous update and follow up of the IUCN Red List assessments is essential for the conservation of freshwater fishes in the Western Ghats of India.

1.5. Freshwater Indigenous Ornamental Fish diversity of India

Globally aquarium fish trade is a multibillion dollar business with an annual turnover more than 8 billion US$ and India with a contribution of nearly 1% (Froese & Pauly, 2012). Indian ornamental fish export accounted for about US$ 0.24 million in 1991 and increased into export value was nearly US$ 3.8 million in 2007 and marked the highest export value in the two decades (1991-2009) (Liya & Ramachandran, 2013). A total of 187 species are traded from India (Raghavan et al. 2013) and around two hundred species of freshwater fishes from the Eastern Himalaya (Allen et al. 2010) and more than hundred from Western Ghats (Raghavan, 2010) are exploited for aquarium fish trade. The existing aquarium export business is not in sustainable, because the present trade is completely dependent on wild collection (Dhahanukar et al. 2004; Rani et al. 2013). Currently, aquarium fish trade is entirely open access, and unregulated in India (Raghavan, 2010). Liya & Ramachandran (2013) reported five species are mainly contributed
for capture based fish trade from Western Ghats of Kerala region namely, *Tetraodon travancoricus*, *Dario dario*, *Sahyadria denisonii*, *Botia striata*, and *Carinotetraodon imitator*. While, Raghavan *et al.* (2013) reported around two dozen species are regularly exported from Western Ghats of Kerala.

Monitoring and record keeping is one of the prime requisite for responsible aquarium fisheries and trade (Moreau & Coomes, 2007; Rhyne *et al.* 2012), but these are continues to be neglected worldwide (Raghavan *et al.* 2013). Silas *et al.* (2011) stated, sustainable harvest of wild fish populations is possible, if the managers and government officials have sufficient knowledge and foresight of the future disasters. There is an immediate need of a shift from capture based sector to culture sector and implementation of scientific breeding technology is the core area for development of ornamental fish trade (Mercy *et al.* 2007). It is needed to encourage breeding of new species which in turn can reduce the pressure on wild ecosystem, and thus ensuring trade and sustainability of freshwater fishes.

### 1.6. Threats to Western Ghats Fish Bio-diversity

Globally, freshwater ecosystems are the most severely affected due to human development and economic activities (Richter *et al.* 1997; Vorosmarty *et al.* 2006; Collen *et al.* 2009). With increasing human interventions, habitat loss and degradation, freshwater fish biodiversity has been reported to be exposed to increasing pressures (Mc Allister, 1999; Brautigam, 1999). Compared to other hotspots, Western Ghats has the highest density of human population (> 300/km$^2$) making it challenging to conserve Western Ghats (Molur, 2009). Forty one percentages of fish species in Western Ghats are threatened, being listed in vulnerable, endangered, or critically endangered group. Western Ghats region is undergoing rapid transformation by human intervention like other parts of the tropics (Chandran, 1997). The important threats noticed in the freshwater fish biodiversity are listed below,
1.6.1. Habitat Fragmentation and Deforestation: Habitat fragmentation is one of the greatest threats to global and regional biodiversity. This may be mainly through the construction of dams across the rivers, conversion of wetlands into other forms of land uses, destruction of riparian vegetation (Molur et al. 2011). It has been estimated that about 25.6% of the forest cover in Western Ghats is lost over a span of two decades (Panigrahy et al. 2010). This rapid transformation of habitats in the form of silt deposition may result in the total changes in the species composition of the particular habitat (Myers et al. 2000). Moreover Harrison & Stiassny (1999) reported habitat alteration contributed to 54%, over fishing to 29%, and pollution to 26% of extinctions.

1.6.2. Flow Regulation: Flow modifications are mainly from human need for flood protection or water storage, mainly due to the construction of dams across the rivers (Castro & Arcifa, 1987). Ghosh & Ponniah (2001) reported construction of Stanley and Bhavani sagar reservoirs in Kaveri River system are the reason for the disappearance of *Tor khudree* and *Acrossocheilus hexagonolepis*. Dams have been built across the major river systems of Western Ghats which makes lotic habitats into lentic habitats (Nilsson et al. 2005) and obstruct the free movement of freshwater fishes across the dam (Harikumar & Rajendran, 2007). These structures obstruct the upstream spawning migration of fishes and displace populations from their normal spawning grounds (Das et al. 2007), and it may threaten the population of various catfishes and loaches, because they were adapted for fast flowing habitats (Dahanukar et al. 2011).

1.6.3. Sand Mining: Indiscriminate sand mining is now the leading threat to the ecosystem and biodiversity of the river basin in Western Ghats (Newcombe & Mac Donald, 1991; Biju kumar et al. 2013). Sand mining may reduce the suitability of the habitat for breeding with egg production being more strongly affected than
nesting density (Cote et al. 1999). Dahanukar et al. (2011) reported, Glyptothorax poonaensis in Indrayani River became now endangered due to sand mining.

1.6.4. **Over Harvesting**: Due to the booming state of aquarium trade from Western Ghats, half a dozen indigenous fishes are traded both domestically as well as internationally during the last one decade. For this species are exploited beyond their sustainable levels and it leading to their endangerment (Liya & Ramachandran, 2011; Raghavan et al. 2013). Recent studies have established that species like Tor khudree (Raghavan et al. 2011); Horabagrus brachysoma (Prasad et al. 2008); Labeo fimbriatus, Schismatorhynchos nukta, Silonia chidreni (Kharat et al. 2003), and Tetraodon travancoricus, Sahyadria denisonii (Raghavan et al. 2013) are being over exploited from rivers of Western Ghats. Another threat is the illegal collection of endemic species from inside the protected areas of Western Ghats for the international aquarium trade (personal observation).

1.6.5. **Destructive Fishing**: Illegal usage of chemicals and herbal poisons damage the entire fish population of the aquatic body (Euphrasia, 2006). Dynamiting is another destructive method by which fishermen easily collect huge quantity of fishes for consumption, but they are not concerned about small fishes. The fishing practices may also a reason for fin rot, tail rot and body ulcerations in freshwater fishes. Insecticides and pesticides are invariably used as a fish catching method, the target fishes being either nocturnal or dwelling in small caves or crevice (Kurup et al. 2004).

1.6.6. **Introduction of Alien species**: A number of species get introduced into the waters, most of which are to the dams with a view to increase the fish yield (Raghavan et al. 2008). Raghubanshi et al. (2005) observed that threat to biodiversity due to alien species is second only to that of habitat destruction. Species like Labeo rohita, Catla catla, Cirrhinus mrigala have been introduced recently in to the reservoirs and importantly Cyprinus carpio has been widely introduced into
the reservoirs of Western Ghats (Santha, 2007; Nanda kumar, 2010). The exotic high yielding culture species like African cat fish (*Clarias gariepinus*) is another potential threat to the indigenous species in the open water bodies (Krishna Kumar *et al.* 2011; Dahanukar *et al.* 2011). Mc Neely (1999) reported genetically modified fish or transgenic fishes are capable of mating with indigenous fish, is a yet another potential threat to the diversity of wild population and gene pool. Most recently, invasion of Amazonian Pacu, *Piaractus brachypomus* into the River Chalakkudy (Sudhi, 2009) became new threat to indigenous stock. Exotic larvicidal fishes such as *Poecilia reticulata* and *Gambussia affinis* are threat to the native larvicidal species such as, *Aplocheilus lineatus* by sharing same habitat. Most of the invasive species occur in the Western Ghats area have been documented that it became threat to the local fauna (Knight, 2010). The predatory alien birds like little cormorant (*Phalacrocorax niger*), Indian pond herone (*Ardeolagrayii grayii*) and Little grebe (*Podiceps ruficolis*) are the latest threat to the native fishes (personal observation).

1.6.7. Pollution: Changes in water quality due to discharge of effluents from various industrial, domestic and agricultural sources have deteriorated the water quality of rivers (Galloway *et al.* 2004). Chemical pollution from factories located in the Nilgiris, Mysore and Kodagu regions of the Western Ghats are known to have destroyed hill stream fishes (Pandey & Das, 2002). Raghavan *et al.* (2008) reported that fin rot, tail rot and body ulcerations in freshwater fishes collected from streams flowing through tea plantations in Valparai in Western Ghats. The abandoning of organic pollution from rubber plantations or chemical industry into streams has been observed in Kalu in Mumbai (Mhatre *et al.* 1980), River Tapi (Shrivastava & Patil, 2002), River Mula-Mutha in Pune (Kharat *et al.* 2003), River Narmada (Jain *et al.* 2008), Ashambu Hills near south Kerala (Abraham *et al.* 2011), and River Periyar (Krishna Kumar *et al.* 2011).
1.7 Conservation Measures for Freshwater Fishes

1.7.1. In-Situ Conservation:

The important in-situ conservation measures are,

a. Habitat Restoration: Most of the damage done to the various fish habitats so far is irreversible, where the fish species or communities are severely threatened (Wang et al. 1997). Habitat protection and restoration are the principal long term means through which successful conservation will be attained (Surtida, 1998).

b. Implementation of Conservation Acts and Regulations: Regulations should be brought into place to stop the unmanaged collection of endemic and threatened aquarium fishes from many areas in the river basin (Menon, 1989; Dubey & Ahmad, 1995; Collen et al. 2013). The Indian Fisheries Act (1897) prohibits destructive fishing methods such as dynamiting, poisoning etc. to conserve living aquatic resources. Stronger enforcement is also required to prohibit the use of destructive fishing practices, especially dynamite fishing. Knight (2010) reported, at least 300 exotic aquarium species are imported and traded in India without any regulation. As an in situ-conservation measure for S. denisonii, Government of Kerala implemented the ‘closed season’ since 2011, based on the assumption that spawning takes place during these months but Solomon et al. (2011), Raghavan et al. (2013) and Mercy et al. (2013) demonstrated that its breeding occurs from October to March and collection should instead be prohibited between these months in order to adequately protect populations.

c. Control of Alien species: The Ministry of Agriculture, Government of India has issued “Guidelines for the Import of Ornamental Fishes into India” based on the recommendations of the National Committee on introduction of exotic aquatic
species into India, but it has failed to prevent the entry of exotic fishes into the natural ecosystems of the country (Biju Kumar et al. 2013). Local exotic eradication plans have a more balanced cost-success ratio and are particularly useful when they are applied in small areas of high conservation value (Aparicio et al. 2000; Maceda-Veiga et al. 2010). Recently as a control measure a project has been implemented by Zoo Outreach Organization (Coimbatore) and Conservation Research Group (Kerala) in the Periyar River for the local eradication of African cat fish (Clarias gariepinus) (Krishna kumar et al. 2011). Knight (2010) reported, at least 300 exotic aquarium species are imported and traded in India, without any regulation, so there is an urgent need to formulate and implement a national level policy on the introduction of exotic species.

d. Protected Areas/ Fish Sanctuaries: Freshwater Protected Areas (FPAs) have been proposed as a management solution for conserving fresh water biodiversity (Maitland, 1995; Keith, 2000; Saunders et al. 2002; Rivelli, 2002; Rivelli et al. 2002; Suski & Cooke, 2007; Abraham et al. 2011). The protection of key habitats in rivers, such as rapids and deep water pools during the dry season, is rarely implemented but can be effective (Baird, 2006). Recent study by Abraham et al. (2011) reported, Protected Areas in Western Ghats have high importance for the conservation of many endemic species of freshwater fishes, with the active enforcement from different government agency is important for the conservation of many endemic, threatened fish species.

e. Sustainable collection practices: Sustainable collection of freshwater aquarium fishes has been promoted recently in rapid biodiversity assessments of Western Ghats (Silas et al. 2011). According to Mercy et al. (2010a), freshwater ornamental fishery showed heavy post-harvest mortality at collection as well as at distributor’s
level. This is mainly due to lack of knowledge about eco-friendly method of collections, conditioning, packing and transportation (Images. 1.1-1.3). Most sustainability issues at the collection stage includes, fish collection during breeding time, use of destructive gears, poisoning water for catching food fish, lack of technical knowledge in transportation and handling (Image. 1.4), disease outbreaks, (Sajan et al. 2011). Increasing government’s capacity to monitor collections and trade has been long recommended as one of the critical needs for the industry (Moreau & Coomes, 2007), but continues to be neglected worldwide.

Image. 1.1. Encircling net operation for fish collection
Image 1.2. Cast net operation for fish collection

Image 1.3. Hand net operation from shallow water
1.7.2. Ex-situ Conservation:

a. **Cryopreservation:** Cryopreservation is considered to be cost effective method for the long term storage of the genetic material for future use (Bart, 2002). Establishment of Gene Bank with cryopreserved milt, eggs or embryos assures further availability of genetic materials of threatened categories and for extensive breeding programmes of economically important species (Chao & Liao, 2001).

b. **Captive Breeding/ Live gene bank:** Captive propagation is considered to be an integral part of the global strategy to conserve genetic diversity. Despite these captive propagation is viewed as conservation option doubtfully by numerous biologists and conservationists (Franklin, 1980). Now a day, science of captive breeding is growing rapidly and benefiting from numerous successes. Mercy *et al.* (2007) has been established captive breeding technology for thirteen freshwater fish species in Western Ghats of Kerala.
c. Reintroduction of captive bred fish into the natural environment: Restocking is carried out in water bodies or river where the species is either absent, but was formerly present or is still present but in low numbers due to poor recruitment success (Naryani & Tamot, 2002). Restocking operations characterize three main functions: (1) maintaining a wide reserve of fish and potential breeders for culture and artificial propagation; (2) preserving the ecological diversity of fish communities; and (3) securing fishing or angling activities. Ranching of hatchery reared young ones has been practised as a conservation of commercial fishery (Kulkarni & Ogale, 1979; Schegal, 1999; Kurup et al. 2001; Ogale, 2002; Padmakumar et al. 2002; Naryani & Tamot, 2002).

d. Awareness Program: Most of the fisher folks involved in the trade of indigenous ornamental fish from Western Ghats included local fishermen, tribes, and aquarists. They were not conscious about sustainability of the wild population. Prevention is the best way to avoid further introductions of alien species, practices of illegal fishing methods, or other types of anthropogenic activities. Education programmes, together with the banned exploitation of recognized invaders, are key steps towards achieving this goal (Helfman, 1997; Olden et al. 2010). Sustainability of freshwater fishes of the Western Ghats is possible, only through responsible management effort by collectors, exporters, researchers, managers and government officers and the foresight of future disasters (Raghavan et al. 2013). The State fish concept introduced by NBFGR created awareness to local people about conservation of fishes (Devi, 2010). Recently, involvements of local fishers have been integrated into research as participatory stock assessment of endangered species Tor tor in Kerala (Raghavan et al. 2011). It has therefore become necessary to have efficient management measures for the sustainability of freshwater fish resources in Western Ghats of India.
Globally, riverine fishes face many anthropogenic threats including riparian and flood plain habitat degradation, dam construction, over exploitation, climate change, and introduction of invasive species (Allan & Flecker, 1993; Dudgeon et al. 2006). Presently, freshwater ecosystems are the most threatened species in the world; the loss of their biodiversity appears to be more intense than that of any other habitat (Dudgeon et al. 2006; Mims et al. 2010; Maceda-Veiga, 2012). Globally, human population generate enormous consequent pressures over the freshwater fish biodiversity (Dudgeon et al. 2006). If human demands for water remain unaltered, then species losses may continue at current rates, the opportunity to conserve remaining freshwater biodiversity will disappear within decades (Sala et al. 2000). Implementation of suitable management strategies will be a challenging task and requires intensive efforts, collaborative research and management approach (Sarkar et al. 2013).

Freshwater biodiversity in general is rich (Poff et al. 2003), particularly with respect to invertebrates, amphibians and fish, but our knowledge of freshwater biodiversity is incomplete (Mc Neely et al. 1990; Allan & Flecker, 1993; Dudgeon et al. 2006). India inhabits just 2.5% of the global geographic area, but it supports over 7% of plants and 64% of animal population in the world (Padmakumar, 2005; Sunesh Thamby, 2009). Western Ghats have been identified as one of the few sites in the world exhibiting high degree of endemism and exceptional biodiversity (Mc Neely et al. 1990; Meyers, 1990). According to Molur et al. (2011), a total of 162 (15.8%) species were included under threatened category which comprised of 24 critically endangered (CR), 79 endangered (EN) and 59 vulnerable (VU). However, in Western Ghats of India encompassing around 192 endemic species of the total 290 species of fishes reported from this region (Molur et al. 2011).

Like other parts of the tropics, Western Ghats region is undergoing rapid transformation due to human intervention (Ramachandran, 2002; Kurup et al. 2004;
Raghavan et al. 2007; Mercy, 2009; Silas et al. 2011; Raghavan et al. 2013a). Any study on the conservation status of freshwater fish in India is to be expected to reach the inference that the existing protection given to most native fish species is insufficient both in terms of legislation and establishment of appropriate nature reserves. Studies of Shaji et al. (2000); Gopi (2000); Ajithkumar et al. (1999); Kurup (2000); Ramachandran (2002); Dahanukar et al. (2004); Kurup et al. (2004); Radhakrishnan (2006); Kurup & Radhakrishnan (2006); Raghavan et al. (2007); Mercy (2009); Silas et al. (2011) and Raghavan et al. (2013a) clearly shows that many of the freshwater fish species, especially those endemic to Kerala are still under threatened condition. According to Kurup & Radhakrishnan (2004), Sahyadria denisonii, Nemecheilus keralensis, Osteobrama bakeri, Chela dadiburjori, Gonoproktopterus micropogon periyarensis, Silurus wynaadensis, Neolissochilus wynaadensis, Puntius ophicephalus, Garra surendranathani and Garra menoni are showing high degree of endemism to Western Ghats of India.

Sahyadria denisonii was described from Kerala by Francis Day (1865), it was of no interest to fisheries until 1996. After it got selected as a 'new species' at Singapore's Aquarama exhibition in 2003, it exploded in popularity almost immediately (Mercy, 2009; Raghavan et al. 2013). Among Kerala’s native ornamental fish, no species has received as much global attention as S. denisonii (Raghavan et al. 2008), and this endemic barb has recently become India’s most exported ornamental fish (Raghavan et al. 2013). This popularity in the international trade has resulted in organized exploitation of this species (Raghavan et al. 2007). Because of declining populations (Dahanukar et al. 2004; Mercy et al. 2010; Raghavan et al. 2013a) and restricted distribution (Mercy et al. 2009; Raghavan et al. 2013), S. denisonii has been listed as Endangered (Ali et al. 2011). Despite being the most threatened native fish species, S. denisonii has not been well documented in literature (Dahanukar et al. 2004; Raghavan et al. 2008; Raghavan et al. 2010) and the absence of a reliable
scientific database concerning its population status, reproductive biology and captive breeding and larval rearing technology has significantly affected conservation efforts. This study is an attempt made to document, life history traits of *Sahyadria denisonii* (Day 1865) for its conservation management.

### 1.8. Objective of the Study

Knowledge on diversity, distribution ecology, biology, and conservation and utilization prospects of diverse species is most essential for sustainable management of endemic biodiversity (Sarkar *et al.* 2002). Over the last few decades wild population of *S. denisonii* has been declined due to indiscriminate exploitation and species was categorized as Endangered in red list. Hence the present study was carried out in Redline torpedo fish, *Sahyadria denisonii* (Day 1865) with following objectives. All the fish samples collected for this study were anaesthetized before fixing in formaldehyde. Main objectives are,

- To study the biometric characteristics such as, length-weight relation, length-length relation, condition factors, morphometric and meristic features
- To study the population parameters and stock dynamics of species
- To study the reproductive characteristics of *S. denisonii*
- To study the morphological and histological assessment of reproductive developments in male (Spermatogenesis) and female (Oogenesis) *S. denisonii*
- To study the efficiency of anaesthetics for handling during transportation and captive propagation
- To develop captive breeding technology, and study the embryonic and larval development of *S. denisonii*
- To study the different morphological abnormalities during early development in *S. denisonii*
1.9 General Organization of Thesis

This thesis organized into ten chapters.

First chapter covers the general introduction, objectives of the study, organization of the thesis, review of literature, systematic of candidate species, species distribution, and habitat of River Valapattanam.

Second chapter includes the biometric parameters such as length-weight relationship, length-length relationship, condition factor, relative condition factor, morphometric and meristic characters.

Third chapter consists of the population structure by assessing the growth parameters like asymptotic length ($L_\infty$), growth coefficient (K) and age at length zero ($t_0$) etc. and stock dynamics by assessing mortality rates and there by deriving catches and biomass of the resources.

Fourth chapter describes the reproductive characteristics such as fecundity, Gonado-somatic index, sex ratio, spawning season, spawning frequency and ova diameter studies. The morpho-histological developments of reproductive System of male is included in the Fifth chapter.

Sixth chapter covers the morpho-histological developments of reproductive System of female fish. Seventh chapter narrates the management practices to reduce stress during fish handling. The development and standardization of captive breeding technology and larval rearing techniques as an ex-situ conservation measures are explained in the Eighth chapter.

Ninth chapter includes the deformities observed in wild population and hatchery produced young ones. The study and recommendations for the management and conservation of $S.\ denisonii$ are given in the Tenth chapter.

In general, each chapter is subdivided into Introduction, Materials & Methods, Results, and Discussion. Tables, graphs, figures and images inserted at appropriate places.

The Research papers published or presented were documented at the end of thesis.
1.10. Systematic of the Species

1.10.1 Family Cyprinidae (Order- Cypriniformes)

The family Cyprinidae is the largest of all fish families with more than 2,000 species of the family have already been described (Fig. 1.4) and representing about 10% of world, or about 25% of freshwater fish species (Schofield et al. 2005). The Catalogue of Fishes established by Nelson (2006) provided an estimate of 3268 valid fish species in Cypriniformes, while in 2005 Fish Base listed 3451 species. South East Asia is generally considered to have become the centre of cyprinid evolution because the cyprinids are extra ordinarily numerous and diverse there as well as on the Indian subcontinent (Moyle & Cech, 2000). Globally, most number of endemic freshwater fish species occurs in India, contributing 27.8 % of the native fish fauna followed by China, Indonesia and Myanmar (Ponniah & Gopalakrishnan, 2000; Vishwanath et al. 2007). In the Western Ghats of India, the order containing largest number of species in Cypriniformes followed by Siluriformes.

Figure 1.4. Geographical distribution of family Cyprinidae (Adapted from Schofield et al. 2005).
1.10.2 Genus Puntius

The genus *Puntius* (Hamilton-Buchanan) of the family Cyprinidae is represented by a large number of small freshwater fishes of Asian tropics. The striking colouration of many species of *Puntius* has also led to their popularity as freshwater-aquarium fishes; many species are traded internationally as ornamentals (Collins *et al.* 2012). Roberts (1989) described the genus to have the following combination of characters; Barbels variable, rostral and maxillary, maxillary only, or absent; dorsal fin with last simple ray serrate or entire, branched rays usually eight; anal fin with last simple ray serrate or entire, branched rays usually five; lateral line complete or incomplete, lateral line scales 17-36; cephalic cutaneous papillae minute or absent; pharyngeal teeth in three rows, usually 2, 3, 5/5, 3, 2; colour pattern extremely variable; size ranging from less than 10 to 30cm (Shantakumar & Vishwanath, 2006). The status of *Puntius* is obscure; the delimitation and nomenclatural validity of the genus have remained unsettled (Hora & Mukerji, 1934; Smith, 1945; Myers, 1960).

Kottelat (1999) described *Puntius* as a genus in which a large number of unrelated small barbs have been placed however restricted to a very limited geographical area and without information on the limits of the genera. Rainboth (1991) classified this genus into three genera based on morphological characteristic which include *Systomus*, *Barbodes* and *Hypsylobarbus*. Pethiyagoda *et al.* (2012) classified Genus *Puntius* based on external morphology, osteology, and analysis of 16S ribosomal RNA and cytochrome *b* gene fragments. *Puntius chalakkudiensis* and *P. denisonii* differ from all other species of *Puntius* in terms of colour pattern and mouth shape; however Pethiyagoda *et al.* (2012) remained them in *Puntius* only because they lacked material for DNA and osteological analysis. Recently Raghavan *et al.* (2013), figured out two species from existing *Puntius* genus into new genus *Sahyadria*. 
Current valid genera of *Puntius* in Western Ghats of India are (Adapted from Pethiyagoda et al. 2012),

1. **Systomus**: “Possesse maxillary and rostral barbels; last unbranched dorsal-fin ray stiff, serrated; and lateral line complete, with 27-34 scales”. The species included in this genus are *Systomus sarana* (Hamilton, 1822) and *Systomus sarana subnasutus* (Valenciennes, 1842).

2. **Dawkinsia**: “Distinguished by lacking rostral barbels; having the last unbranched dorsal-fin ray smooth; lateral line complete, with 18-22 scales; and a juvenile colour pattern that includes three black bars on the body”. *Dawkinsia* is named after the evolutionary biologist Richard Dawkins in recognition of his contribution to the public understanding of science, particularly, of evolutionary science. The species included are *Dawkinsia arulius* (Jerdon, 1849), *Dawkinsia assimilis* (Jerdon, 1849), *Dawkinsia exclamatio* (Pethiyagoda & Kottelat, 2005), *Dawkinsia filamentosus* (Valenciennes, 1844), *Dawkinsia rohani* (Rema Devi et al. 2010), *Dawkinsia rubrotinctus* (Jerdon, 1849), *Dawkinsia tambraparniei* (Silas, 1954).

3. **Haludaria**: “Distinguished by having both rostral and maxillary barbels present; lateralline complete, with 18–26 pored scales; dorsal fin with 4 unbranched and 8 branched rays, last unbranched dorsal-fin ray smooth; infra-orbital 3 deep, partly over lapping the pre operculum; and free uro-neural and post-epiphysial fontanelle absent”. *Haludaria* is a genus of cyprinids native to India. Originally the genus was named *Dravidia* by Pethiyagoda et al. (2012), but this name is preoccupied by *Dravidia* Lehrer (2010) in Diptera (Pethiyagoda 2013). The species included are, *Haludaria afasciata* (Jayaram, 1990),
Haludaria fasciatus (Jerdon, 1849), Haludaria kannikattiensis (Arunachalam & Johnson, 2003), Haludaria melanampyx (Day, 1865).

4. Pethia: “Distinguished by having the last unbranched dorsal-fin ray stiff, serrated; infra-orbital 3 deep, partially overlapping pre-operculum; rostral barbels absent; maxillary barbels absent or minute; a black blotch on the caudal peduncle; and frequently, black blotches, spots or bars on the side of the body”. The species include, Pethia conchonius (Hamilton, 1822), Pethia gelius (Hamilton, 1822), Pethia narayani (Hora, 1937), Pethia nigripinnis (Knight, Rema Devi, Indra & Arunachalam, 2012), Pethia pookodensis (Mercy & Jacob, 2007), Pethia setnai (Chhapgar & Sane, 1992), Pethia ticto (Hamilton, 1822).

5. Puntius: “Has the rostral barbels absent; last unbranched dorsal-fin ray weak or strong, smooth; and lateral line complete, with 22-28 pored scales”. The species included are Puntius ambassis (Day, 1869), Puntius amphibius (Valenciennes, 1842), Puntius arenatus (Day, 1878), Puntius bimaculatus (Bleeker, 1863), Puntius cauveriensis (Hora, 1937), Puntius chola (Hamilton, 1822), Puntius crescentus (Yazdani & Singh, 1994), Puntius deccanensis (Yazdani & Rao, 1976), Puntius dorsalis (Jerdon, 1849), Puntius fraseri (Hora & Misra, 1938), Puntius madhusoodani (Kumar, Pereira & Radhakrishnan, 2012), Puntius mahecola (Valenciennes, 1844), Puntius melanostigma (Day, 1878), Puntius mudumalaiensis (Menon & Rema Devi, 1992), Puntius parrah (Day, 1865), Puntius sahyadriensis (Silas, 1953), Puntius sharmai (Menon & Rema Devi, 1993), Puntius sophore (Hamilton, 1822), and Puntius vittatus (Day, 1865).
6. **Sahyadria**: This genus is separated from the existing *Puntius* group by the combination of characters and character states by Raghavan *et al.* (2013). This genus name is derived from the word “Sahyadri”, a local name for the ‘Western Ghats’. Currently two species are included in this genus, *Sahyadria chalakkudiensis* (Menon, Rema Devi & Thobias, 1999) and *Sahyadria denisonii* (Day, 1865).

1.10.3. **General characteristics of *Sahyadria denisonii***: (Image. 1.5)

Body of *S. denisonii* (Image. 1.5) is deep and moderately compressed, with an elevated dorsal profile. Mouth is sub terminal. There are 2 pairs of barbels with the rostral equal to the length of orbit and a longer maxillary. The snout is rounded with no observable pores. Body scales are cycloid. The last ray of the dorsal is unbranched, strongly osseous and finely serrated along its posterior edge. The origin of the dorsal is slightly nearer to the tip of the snout than to the caudal base. The pectoral is nearly as long as the head excluding snout. The pelvic fin originates below the origin of dorsal.

**SYNONYMS:** Day (1865) described the species *Sahyadria denisonii* in his work “On the fishes of Cochin on the Malabar coast of India”, as *Labeo denisonii*, obtained in the hill ranges of Travancore. Later, in his works on the “Fishes of Malabar” and “The Fishes of India; being a Natural History of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon”, he described the species as *Puntius denisonii* and *Barbus denisonii*, respectively. Present valid generic name is *Sahyadria* by Raghavan *et al.* (2013b).

- *Barbus denisonii* (Day, 1865)
- *Crossocheilus denisonii* (Day, 1865)
• *Barbus denisonii* (Day, 1865)

• *Puntius denisonii* (Day, 1865)

• *Sahyadria denisonii* (Day, 1865)

Image. 1.5. Candidate species *Sahyadria denisonii*, a. sample from River Valapattanam, b. Reproduced from Day (1875).

**Common/ vernacular names:**

Common name- *Denison’s barb*, *Red line torpedo fish*, *Miss Kerala*, *Bleeding eye barb*, *Denisoni barb*, *Denison’s flying fox*, *Rose line shark*, ‘*Bleeding-eye barb*’, *Red flash barb*, *Indian flasher barb*; Vernacular (Malayalam)-*Ckenkanajon*, *Chorakaniyan*, *Chorakanni*

**Conservation status:**

Endangered (Dahanukar et al. 2004)
SYSTEMATIC POSITION OF *Sahyadria denisonii*

**Species** recognized by NCBI Taxonomy:

- Cellular organisms
  - Eukaryota
    - Opisthokonta
      - Metazoa
        - Eumetazoa
          - Bilateria
            - Coelomata
              - Deuterostomia
                - Chordata
                  - Craniata
                    - Vertebrata
                      - Gnathostomata
                        - Teleostomi
                          - Euteleostomi
                            - Actinopterygii
                              - Actinopteri
                                - Neopterygii
                                  - Teleosteii
                                    - Elopocephala
                                      - Clupeocephala
                                        - Otocephala
                                          - Ostariophysi
                                            - Otophysi
                                              - Cypriniphysi
                                                - Cypriniformes
                                                  - Cyprinoidea
                                                    - Cyprinidae
                                                      - Sahyadria
                                                        - *Sahyadria denisonii*
1.10.4. Distribution and Habitats of *Sahyadria denisonii*

The rivers of Kerala, part of the Western Ghats (8° 20’ N & 73° 77’ E), one of the 34 global biodiversity hotspots is considered to be an exceptional hotspot of freshwater fish diversity (Kottelat & Whitten, 1996). The state of Kerala, on the south western corner of the Indian peninsula is crisscrossed by 44 rivers, of which 41 are west flowing, and three east flowing having an immensely rich and diverse fish fauna (Raghavan *et al.* 2007). Among the native ornamental fishes of the region, no species has received global fame and hobbyist attention as much as the Redline Torpedo fish, *S. denisonii*, an endemic cyprinid. *Sahyadria denisonii* highly restricted distribution in the southern regions (Kerala and south Karnataka) of the Western Ghats hotspot of India and population appear to be extremely fragmented in fourteen rivers (Fig.1.5) such as Chalakudy (Shaji & Easa, 2001; Kurup *et al.* 2003), Periyar (Biju *et al.* 2000), Achenccoil (Shaji & Easa, 2001; Kurup *et al.* 2003), Pampa (Shaji & Easa, 2000), Valapattanam (Biju *et al.* 2000), Chaliyar (Shaji *et al.* 2000; Shaji & Easa, 2001), Kallarpuzha (Shaji *et al.* 2000), Chandragiri (Biju *et al.* 2000; Kurup & Radhakrishnan, 2006b), Bharathapuzha (Kurup & Radhakrishnan, 2006a). Mercy *et al.* (2013) reported *S. denisonii* from eleven rivers of Western Ghats. *Sahyadria denisonii* is known to be overexploited in at least three rivers of the Western Ghats region from where they are collected for the pet trade, of which River Valapattanam contribute major share of aquarium trade (Liya & Ramachandran 2013; Raghavan *et al.* 2013).
Figure 1.5. Geographical distribution of Sahyadria denisonii in Kerala
Valapattanam River is one of the west flowing river lies in the Western Ghats region of South India (Fig. 1.6). This is one of the largest river in Kerala State and main tributaries are Irikkurpuzha Srikandapurampuzha, Bavalipuzha, Venipuzha and Aralampuzha (Anon, 2014a). Valapattanam River originates from the Brahmagiri Reserve Forest in Karnataka at an altitude of 900-1350m above mean sea level and drains into the Arabian Sea at Azheekkal estuary (Anon, 2014b). The area of river Valapattanam experiences northeast monsoon from November to March (Thulavarsham) and the strong and steady southwest monsoon from June to September (Edavapathi), and a first inter-monsoon in April-May and also a second inter-monsoon in October-November. The steady and seasonal availability of the two monsoons is a critical factor for the water availability of Kerala (Amitha Bachan, 2003).

The freshwater fishes show a significant degree of habitat preference and habitat selectivity based on their ecological adaptability, and microhabitat conditions. Each riverine habitat produce characteristic surface flow patterns, and are often associated with different substrate types and the commonest riverine habitats includes riffles,
rapids, runs, pools and cascades (Morhardt, 1986; Gordon et al. 2004). Stream pattern morphology is directly influenced by eight major variables including channel width, depth, velocity, discharge, channel slope, roughness of the channel materials, sediment load and sediment size (Leopold et al. 1964). Different types of habitats observed in River Valapattanam are (Images. 1.6),

1. **Rapid**: Rapid is an area of shallow, moderate depth, swift flow and strong currents, surface broken with white water.

2. **Cascade**: When water flows over larger rocks and boulders, it becomes a cascade. Cascades are rough places to live, water often beats onto rocks so hard that it creates foam and spray. Cascade is similar to rapid but it has series of small waterfalls over boulders or bedrock.

3. **Riffles**: Riffles are the swift flowing section of the channel unit, where velocity is greater, depth is less, substratum heterogeneous, often big rocks are exposed over the surface.

4. **Runs**: Run has a character in between that of riffle and pool, it is slow-moderate in depth and water velocity, uniform-slightly variable current, surface unbroken, smooth-rippled, where substratum more or less homogenous either with sand bed, gravel bed or cobbles.

5. **Pools**: Pool is an area of deep, slow flowing water with a smooth surface, usually where the stream widens and/or deepens.

6. **Pool-riffle reach**: The reach characterized by the alternative riffles and pools and is very prevalent type of reach in alluvial valley of low to moderate gradient.

7. **Bed rock reach**: This reach exhibits little or no alluvial bed material and is generally limited by valley walls and lack flood plains.
Habitat selection of fish depends on availability of appropriate depth, velocity, substrate, and forest cover (Bovee, 1982). *Sahyadria denisonii* preferred an altitude between 100-200m MSL and a narrow range of microhabitats at the pool-riffle or rocky pool habitats with cobbles, gravels and even at sand as substratum (Radhakrishnan & Kurup, 2008) and they normally moved as groups in rocky pools with thick vegetation along its riverbanks (Raghavan *et al.* 2007). It was noticed that *S. denisonii* prefer relatively still or slow flowing water (Run and Pool) habitat in river Valapattanam, similar to other cyprinids *D. filamentosus*, *P. dorsalis*, *P. bimaculatus* and *Tor khudree* as reported by Jayaratne & Surasinghe (2010). The low abundance, gregarious and aggregating nature, easy location from habitats, global market demand and popularity makes *S. denisonii* highly vulnerable to over fishing and possible endangerment (Raghavan *et al.* 2008).

Stream cover is defined as the structured material (Boulders, logs or stump), channel features (ledges, vegetation) and water features (turbulence or depth) in the wetted channel or within one meter above the water surface that provides hiding, resting or feeding places for fish (Manoj Kumar, 2006). Majority of the upper watershed area of the river is covered with undisturbed riparian vegetation, submerged and emergent rooted plants in the river provide habitat for many aquatic fauna. During dry season 80% of the river bed is exposed, imposing a lot of restrictions to the surviving fishes to remain in the isolated rocky pools formed in the river bed.
General Introduction

CASCADE REACH

POOL RIFFLE REACH

RIFFLLE REACH

RUN REACH
Image 1.6. Different types of habitat noticed in River Valapattanam