

**REVIEW OF LITERATURE**

**2.1 River systems in India**

The Indian River Systems can be divided into four categories – the Himalayan Rivers, the rivers traversing the Deccan Plateau, the Coastal Rivers and those in the inland drainage basin. The Himalayan Rivers are perennial as they are fed by melting glaciers every summer. During the monsoon, these rivers assume alarming proportions. Swollen with rainwater, they often inundate villages and towns in their path. The Gangetic basin is the largest river system in India, draining almost a quarter of the country.

The rivers of the Indian peninsular plateau are mainly rained type. During summer, their flow is greatly reduced, and some of the tributaries even dry up, only to be revived in the monsoon. The Godavari basin in the peninsula is the largest in the country, spanning an area of almost one-tenth of the country. The rivers Narmada (India’s holiest river) and Tapti river flow almost parallel to each other but empty themselves in opposite directions. The two rivers make the valley rich in alluvial soil and teak forests cover much of the land. While coastal rivers gush down the peaks of the Western Ghats into the Arabian Sea in torrents during the rains, their flow slow down after the monsoon (Goldara and Banerjee, 2004).

**2.2 Godavari River System**

The river with second longest course within India, Godavari is often referred to as the Vriddh (Old) Ganga or the Dakshin (South) Ganga. The name may be apt in more ways than one, as the river follows the course of Ganga's tragedy. The river is about 1,450 kms (900 miles) long. It rises at Trimbakeshwar, near Nasik and Mumbai in Maharashtra around 380 km distance from the Arabian Sea, but flows southeast across south-central India through the states of Madhya Pradesh, Karnataka, Orissa and Andhra Pradesh, and empties into the Bay of Bengal. At Rajahmundry, 80 km from the coast, the river splits into two streams thus forming a very fertile delta. Some of its tributaries include Indravati River, Manjira, Bindusara and Sabari. Some important urban centers on its banks include Nasik, Nanded,
Bhadrachalam, Rajahmundry and Narsapur. The Asia's largest rail-cum-road bridge on the river Godavari linking Kovvur and Rajahmundry is considered to be an engineering feat (Bhandari, 2004).

The Godavari basin receives its maximum rainfall during the Southwest monsoon. The monsoon currents strike the West Coast of the peninsula from West and South-West; meet the Western Ghats or Sahyadri Range which present almost an uninterrupted barrier ranging from 600 m. to 2100 m. in height. Before surmounting this barrier the currents deposit most of their moisture on its windward side, and then sweep across the interior of the peninsula on the Easterly course. Rainfall is governed largely by the orography of the area, which leads to variation in the amount of precipitation. In crossing the Ghats, the monsoon wind loses a large part of their moisture. The monsoon currents follow the Eastward slope of the country from the crest of the Ghats, which form the watershed. Conditions in the interior are somewhat unfavorable for heavy precipitation except in association with the depression from the Bay of Bengal. The north-east part of the Godavari basin also receives some rain in association with monsoon depressions, which move west-north-west across the Orissa coast. (CWC, 2004 and 2005)

2.3 Freshwater fish resources

The country is endowed with vast and varied resources possessing river ecological heritage and rich biodiversity. Freshwater fishery sites are varied like 45,000 Km. of rivers, 126,334 Kms. of canals, ponds and tanks 2.36 million hectares and 2.05 million hectares of reservoirs (Ayappane et al., 2004). The assessment of fresh water fishes is done mainly on the basis of six drainage systems in the country. These are Indus river system, upland cold-water bodies, Gengetics river system, Brahmaputra river system, east flowing river system and west flowing river system. About 21,730 species of fishes have been recorded in the world; of which, about 11.7% are found in Indian waters. Out of the 2,546 species so far listed, 73 (3.32%) belong to the cold freshwater regime, 544 (24.73%) to the warm fresh water domain, 143 (6.50%) to the brackish waters and 1440 (65.45%) to the marine ecosystem (ICBD, 1994).
Freshwater ecosystems may be the most endangered ecosystems in the world. Declines in biodiversity are far greater in fresh waters than in the most affected terrestrial ecosystems (Sala et al., 2000). What makes freshwater habitats and the biodiversity that they support especially vulnerable to human activities and environmental change? The main reason is the disproportionate richness of inland waters as a habitat for plants and animals. Over 10,000 fish species live in fresh water (Lundberg et al., 2000); approximately 40% of global fish diversity and one quarter of global vertebrate diversity. When amphibians, aquatic reptiles (crocodiles, turtles) and mammals (others dolphins, and platypus) are added to this freshwater-fish total, it becomes clear that as much as one third of all vertebrate species are confined to fresh water. Yet surface freshwater habitats contain only around 0.01% of the world’s water and cover only about 0.8% of the Earth’s surface (Gleick, 1996). Another way of looking at this is to ask: how many of the species described by scientists live in fresh water? The answer is around 100,000 out of approximately 1.75 million (Hawksworth and Kalin-Arroyo, 1995): almost 6%, and an additional 50,000 to 100,000 species may live in ground water (Gibert and Deharveng, 2002).

Studies of freshwater fishes in the Indian subcontinent have been limited to scattered works on commercial fisheries and even these have been largely restricted to some of the major river systems like the Ganga and the Yamuna. Out of the 2,500 species of freshwater fishes that have been recognized in the Indian subcontinent, 930 are categorized as freshwater species (Jayaram, 1999). Much of the early study on the freshwater systems of the Indian subcontinent started with the works of British officers working for the East India Company, who took great interest in the natural history of the region. Some early contributions were those of Hamilton-Buchanan (1822) in ‘The Fishes of the Ganges’ and by others like McClelland (1839) and Jerdon (1849). Some of the most important contributions to such studies were made by Francis Day in his Fishes of India (1875–1878). Substantial literature is now available on the identification and systematic of freshwater fishes of India, starting with Hora’s contributions between the 1920 -1950s and the most recent texts by Talwar and Jhingran (1991), and Jayaram (1999).
The Indian fish fauna is divided into two classes, viz., Chondrichthyes (cartilaginous fishes) and Osteichthyes (bony fishes). The endemic fish families form 2.21 per cent of the total bony fish families of the Indian region. 223 endemic fish species are found in India, representing 8.75 per cent of the total fish species known from the Indian region. The Western Ghats is the richest region in India with respect to endemic freshwater fishes (Jayaram, 1999). Northeastern India, which has a very high diversity among freshwater fish, does not have many endemic species within India because of its jagged political boundary. There are about 450 families of freshwater fishes globally. Roughly 40 are represented in India (freshwater species). About 25 of these families contain commercially important species. Numbers of endemic species are about 544. Freshwater fishes are a poorly studied group since information regarding distribution, population dynamics and threats is incomplete, and most of the information available is from a few well-studied locations only (www.freshfish.html).

2.4 River Habitat Modifications

Freshwater habitats in rivers, streams, springs and headwaters are heterogeneous due to variations in altitude, flow rates, dissolved oxygen, physical substrate and the riparian zones that provide food, shade and cover (Armantrout, 1990). Lots of fresh water ecosystems are being changed very rapidly by manmade activities, viz., deforestation resulting in increasing in flood, deposition of fine sediment increasing in suspended matter, introduction of exotic species, exploitative fishing and pollution. Basic data on distribution and abundance of species in various river systems are of prime need for understanding fish diversity, before the species and ecosystem disappear due to human activities. Already much damage has been done to our indigenous fish fauna due to habitat loss.

Dams interrupt stream flow, and generate hydrological changes along the integrated continuum of river ecosystems (Vannote et al., 1980; Junk et al., 1989) dams on rivers result from formation of new lentic or semi-lentic environments upstream from the dam, and tail water environments downstream from the dam. Both
environments can be conducive to the establishment and maintenance of fish stocks appropriate for exploitation by fisheries.

The extent to which fisheries can be developed, sustained or protected along these modified riverine ecosystems reflects basin topography, geological features, watershed hydrology, and climate, as well as engineering features of the dam itself, and operational programmes for retention and release of water from the reservoir, through the dam and into the tail waters. Fundamental considerations must include establishment and maintenance of habitat for spawning, recruitment and maturation of the fish stocks, and provisions for passage by fishes that during certain phases of their life cycles depend on longitudinal movements along the stream continuum (FAO, 1998).

In this regard, Bernacsek (1984) provided an excellent summary of design and operational features for dams to address fisheries concerns. Although the emphasis of Bernacsek's paper focused on African reservoirs, the general orientation has applicability to many situations on a global scale. He suggested: (i) maximum possible crest elevation; (ii) discharge structure intakes positioned at highest possible elevation; (iii) discharge water into tail waters be sufficiently oxygenated to support aquatic fauna; (iv) annual water level fluctuation in the reservoir to be within the range of 2.5-4.0 m; (v) drawdown rate not to exceed 0.6 m/month; and (vi) downstream discharge to include an annual artificial flood event.

Along the stream continuum, dams and their associated upstream reservoirs have downstream effects on riverine environments and, subsequently, diverse influences on downstream fisheries, even beyond the lotic ecosystem. Cumulative effects of dams in catchment basins and tributary streams can significantly block nutrient flow throughout the ecosystem, affecting fisheries production in downstream reservoirs (Welcomme, 1985), river channels (Hess et al., 1982) and estuary and marine environments (Ryder, 1978).

Dams also block the flow of nutrients from ocean environments upstream into riverine environments. This is particularly true of anadromous fishes (*Oncorhynchus* spp.) that die in the rivers after spawning one time. Cederholm et al.,
(1999) give an account of the essential contributions of nutrients and energy of Pacific salmon carcasses to the ecosystem. Post spawning mortality of these adult fish introduces nutrients back into the stream in proportion to the number of carcasses deposited. Blockage of this allochthonous organic material from the sea can severely restrict subsequent recruitment of young salmonids in these rivers, directly by limiting their consumption of flesh from dead adults, and indirectly by reducing primary production of plankton and secondary production of benthic macro invertebrates (Piorkowski, 1995).

Fisheries benefits from most tail water fisheries typically encompass relatively short sections of streams below their respective dams. Fish migration is a primary concern throughout this region. Kvernevik (1997) concluded that fishes in Malaysian rivers utilized migration as an important adaptive tactic, and that migratory species were more common in the Kelantan River system, which has no large hydroelectric dams acting as barriers, than in the Perak River where there are four large hydroelectric dams acting as mainstream barriers. Roberts (1995) discussed impacts from 12 hydropower projects on the mainstream of the Mekong River and stressed that the combined impact on fisheries from these dams is greater than the sum of the individual impacts. Each of the Mekong River dams addressed by Roberts (1995) will block fish migrations. Dams, however, are not the only concerns with respect to riverine fisheries in the region. For example, Roberts (1993a) attributed the 80-90% declines in fisheries below the great waterfalls of the Mekong River (southern Laos) primarily to overfishing and to fishing with explosives. Roberts (1993b) emphasized that tropical river in regions subject to deforestation and dams become increasingly simplified ecologically and unable to withstand additional impacts. Following construction of the Pak Mun Dam (Thailand) Roberts (1993b) also emphasized the need to consider industrial development associated with the dam, and its impacts to river fisheries. He also expressed concern that 200 fish species occurring naturally in the river would be replaced with only 25 species stocked from hatcheries into the reservoir above the dam.
Dams alter river ecosystems and subsequently require development of new relationships between humankind and natural resources associated with these ecosystems. We build dams because we perceive that benefits will accrue to us from them in the form of energy, water supply, transportation, flood control, fishing, recreation, aesthetics, and so on. We must, however, be on guard against developing arrogance with respect to ecosystems and the resources they afford (Catton and Dunlap, 1980).

Some researcher has experienced centuries of sustained human impact and are among the most degraded, densely settled and human-modified river basins on the Earth. Their waters are grossly polluted, and dams and impoundments influence their natural discharge to such an extent that the lower Ganges and the Indus virtually cease to flow during the dry season (Postel and Richter, 2003). Pressure from large impoverished human populations has forced most Asian governments to focus on economic growth rather than environmental protection; the government response has been to implement massive development projects. There is an urgent need to halt ongoing habitat degradation and to restore or rehabilitate damaged Asian rivers or to manage them in a way that will sustain biodiversity.

Flow modifications are ubiquitous in running waters (Dynesius and Nilsson, 1994; Vorosmarty et al., 2000; Nilsson et al., 2005a). They vary in severity and type, but tend to be most aggressive in regions with highly variable flow regimes. This is because humans in these places have the greatest need for flood protection or water storage. That existing dams retain approximately 10 000 km$^3$ of water, the equivalent of five times the volume of the entire world’s rivers (Nilsson and Berggren, 2000) illustrates the global extent of human alteration of river flow. Water impoundment by dams in the Northern Hemisphere is now so great that it has caused measurable geodynamic changes in the Earth’s rotation and gravitational field (Chao, 1995). Even some of the world’s largest rivers now run dry for part of the year or are likely to do so as a result of large-scale water abstraction (Postel and Richter, 2003). Flow modifications are likely to be exacerbated by global climate change because greater frequency of floods and droughts, and consequent increased water-engineering responses, can be anticipated (Vorosmarty et al., 2000). Although this matter will not
be explored herein, impacts on river biota (fishes, for example) are likely to be severe (Dudgeon, 2000a; Xenopoulos et al., 2005).

Asia is the most densely populated region on Earth, with more than 50% of the human population in ~15% of the land area, and many people live in poverty. Five Asian countries account for about half of the global annual growth in population, and, although populations are becoming increasingly concentrated in cities, many people still live in rural areas, e.g., more than 70% in India. As a result, much of the landscape can be described as “human-dominated” (Hannah et al., 1994). Deforestation and logging rates are the highest on the Earth, and forest fires are frequent (Laurance, 1999, Taylor et al., 1999, Achard et al., 2002).

Soil erosion impact in Godavari River studied by Hori et al., (2001) such a rapid delta degradation is probably the result of increased soil erosion in the catchment due to deforestation, which led to increased sediment delivery at the deltas in historical times (Hori et al., 2001; Pranzini, 2001). The Deccan Plateau region (which includes the catchment of the Godavari River) witnessed deforestation and increased agricultural activity over the past two millennia (Allchin and Allchin, 1997). This might have led to increased sediment loads through the Godavari River catchment and the resulting rapid delta growth during the Late Holocene. At present, the Godavari has two active distributaries lobes –the Gautami and Vasishta. The discharge data for a 16-year period from 1988 to 2003 recorded at the Dowlaissaram barrage (about 10 km downstream of the delta apex) shows that out of the total average discharge of 96.5 km (67%) was through Gautami distributors, (33%) flowed through Vasishta branch.

Deforestation of drainage basins causes sedimentation, degrades rivers, and can have unexpected consequences for freshwater biodiversity (Brewer et al., 2001). In addition, the conversion of floodplains and riparian zones to agriculture has detrimental effects on plants and animals in riverine wetlands (Dudgeon, 2000c). Translocation of native species and exotic introductions are an additional threat to indigenous biota, and their influence as drivers of freshwater biodiversity loss is projected to increase substantially (Sala et al., 2000), in part because exotic species
are more successful in habitats that have already been modified or degraded by humans (Bunn and Arthington, 2002 and Koehn, 2004).

Flow regulation, which includes dam-building for hydroelectricity and impoundment of rivers to control floods and provide irrigation water, has a history of more than 4000 years in Asia, and its many effects range from the alteration of natural flow regimes to the obstruction of fish breeding migrations (Dudgeon 1995, & 2000a). The ecological consequences of human-induced changes in flow variability are well established elsewhere (Poff et al., 1997, Nilsson and Berggren, 2000) aggressive attempts to regulate flow are continuing over much of Asia. The monsoon climate causes highly variable natural flow regimes, and the dense human settlement of river floodplains has spurred the development of water engineering schemes for flood protection during high-flow periods and for water storage during low-flow periods and dry seasons. Habitat degradation is brought about by an array of interacting factors. It may involve direct effects on the aquatic environment (such as excavation of river sand) or indirect impacts that result from changes within the drainage basin. For example, forest clearance is usually associated with changes in surface runoff and increased river sediment loads that can lead to habitat alterations such as shoreline erosion, smothering of littoral habitats, clogging of river bottoms or floodplain aggradations.

The erosion of soil also impact on fish diversity, this erosion impact studied by Gadgil et al., 2001. In India, the freshwaters have been viewed from a single perspective: that of economic production. They are to be sources of irrigation or urban-industrial water supply or of hydel power; they are to receive sewage and industrial waste; they may produce edible fish. In this strictly utilitarian framework, there is no space to conserve the rich heritage of freshwater fish diversity of the country. All over India, freshwater fish diversity is on a decline. Many of them have been lost forever; few studies have been carried out so far regarding this aspect. They mainly identified three major forces driving extinction which are; over –harvesting, competition by newly introduced exotic fishes and pollution. According to a workshop estimate hosted out by National Bureau Fish Genetic Resources a total of 227 Indian freshwater fishes are threatened based on the IUCN Red list Categories of
1994. The species that suffered much are Indian long fin eel (*Anguilla bengalensis*), the red finned Mahseer, the catfish (*Rita pervimentata*), Chitala (*Notoptrus chitala*), smaller fishes like Indian Hatchet fish (*Chela laubuca*), Scarletbanded Barb (*Puntis amphibious*), Indian Tiger Barb (*Puntis filamentous*) to name a few. Some other factors are also contributing towards this biodiversity erosion. In the irrigation canal when water is stopped in the canals, they are trapped near the gate and fished out. The nets used for the fishing often has very small mesh and so everything is caught. The shallow streams and pools, such as those at the base of waterfalls, fall victim to the easy availability of dynamite ever since quarrying and road construction began on a grand scale in the country. The shock waves of the blast destroy all fish in the vicinity. Sewage, industrial effluents, chemical fertilizers and pesticides are polluting India’s freshwaters. Several carps and barbs as well as fresh water prawns are being susceptible to pollution. The drastic modification of freshwater habitats by damming streams and rivers siltation leading to reduction in their depth has also profoundly affected many fish species like the Indian shad (*Hilsa ilisha*), the carps (*Labeo calbasu*), the catfish (*Bagarius bagarius*) etc. Due to changed habitat, the life cycles of these species have been seriously disrupted. Moreover exotic species like Tilapia, the silver carps, the grass carps, The African catfishes proved catastrophic for native species. Its prolific breeding nature simply crowd out its native competitors. The overall deterioration of habitat has rendered many fishes susceptible to diseases. Rates of species loss from fresh waters in non-temperate latitudes are not known with any degree of certainty. They are likely to be high because species richness of many freshwater taxa (e.g. fishes, macrophytes, decapod crustaceans) increases toward the tropics. The drainage basins of many large tropical and subtropical rivers (e.g. the Ganges and Yangtze) are densely populated – with large dams, altered flow patterns and gross pollution from a variety of sources being the inevitable outcomes (Dudgeon, 2000a, & 2002). For larger species in these rivers, the situation is parlous: the Yangtze dolphin (*Lipotes vexillifer Miller*) is probably the most endangered mammal on Earth (now numbering fewer than 100 individuals; Dudgeon, 2005), and the Ganges dolphin (*Platanista gangetica (Roxburgh)*) is ‘Endangered’ (IUCN, 2003). The crocodilian fauna of the Ganges and Yangtze likewise consists entirely of
threatened or highly endangered species. Many other species of water associated reptiles – a primarily tropical group – are gravely threatened (Gibbons et al., 2000; Van Dijk, 2000), most particularly turtles, as are large freshwater fishes in most rivers (Baird et al., 2001; Carolsfeld et al., 2004; Hogan et al., 2004), and many freshwater fish stocks are over-fished to the point of population collapse (FAO, 2000; Dudgeon, 2002).

The particular vulnerability of freshwater biodiversity also reflects the fact that fresh water is a resource for humans that may be extracted, diverted, contained or contaminated in ways that compromise its value as a habitat for organisms. In some instances, impacts have been sustained over centuries and, in the case of many of the major rivers of China, they have persisted for more than 4000 years (Dudgeon, 2000a). Indeed, some authors now believe it unlikely that there remain a substantial number of water bodies that have not been irreversibly altered from their original state by human activities (Leveque and Balian, 2005b).

2.5 Fish diversity studies

Knowledge of the total diversity of fresh waters is woefully incomplete – particularly among invertebrates and microbes, and especially in tropical latitudes that support most of the world’s species. Even vertebrates are incompletely known, including well-studied taxa such as fishes (Stiassny, 2002). Between 1976 and 1994, an average of 309 new fish species, approximately 1% of known fishes, were formally described or resurrected from synonymy each year (Stiassny, 1999) and this trend has continued (Lundberg et al., 2000). Among amphibians, almost 35% of the global total of 5778 species has been described during the last decade (AmphibiaWeb, 2005). Regional discovery rates of new freshwater species vary: for example, Rainboth (1996) estimates that the Mekong drainage may support as many as 1000 fish species, more than twice the total given by earlier researchers, placing it third in the global ranking of rivers according to fish species richness. A more recent figure puts Mekong fish richness in the order of 1700 species (Sverdrup-Jensen, 2002). Clearly, the Mekong is one of a number of global ‘hotspots’ for river fish
biodiversity (others include the Congo and Amazon) but, in general, freshwater hotspots receive less attention than their terrestrial counterparts (Myers et al., 2000).

Day (1875-1878) was the first to give an account of fresh water fishes of Western Ghats, form his exhaustive work on the fishes of Asia, he opined that the Indian fresh water fish fauna resembles more closely with that of Eastern countries like Burma, China and Malayan archipelago (Day, 1889). It is suggested that Western Ghats harbor, approximately, 231 species of freshwater fish species and 102 species are presently listed from Western Ghats water bodies between 750 and 2000 meters of altitude. Boote (1979) studied the freshwaters of Western Ghats and concluded that the streams lack large sized fishes. Kharat et al., (2003) studied the changes in the freshwater fish fauna of Mula-Mutha river system of Western Ghats of Maharashtra and observed that besides species richness the characteristic of fish fauna have also undergone change in terms of feeding habits. Recent studied have shown that increase in small and medium sized fish species, while proportion of very small, large and very large fish species has not changed significantly.


In Maharashtra some places were studied for fish diversity; this explores the deplorable condition of fish fauna of Pune urban area that once revealed 25 species new to science out of total 26, described by Sykes in 1841 during his study on the fish fauna of Deccan (Tilak and Tiwari, 1976). After a silent century, there was a sudden spurt of publications. The huge collection of fishes made by Fraser (1942) from Pune area was investigated by Hora and Misra (1942) recording 54 fish species. Suter (1944) added 17 species to Pune list. Tonapi and Mulherkar (1963) recorded 60 fish species from Pune, 25 being new local records. Yazdani and Mahabal (1978) recorded 34 fish species from Indrayani River.
A comparative account of fish fauna covering 12 river basins representing the state of Karnataka, Kerala and Tamil Nadu part of Western Ghats revealed that, there were about 85 species of fishes belonging to 8 orders and 16 families (Arunachalam, 2000). Unnithan (2000) reported the decline in the endemic fish species in the reservoirs of Western Ghats. Raghunathan and Rema Devi (1999) have reported an inventory of biodiversity of freshwater fishes.

A detailed account on Cauvery river systems and pattern of fish distribution has been studied by Jayaram (1982). The same author worked on bio-resource of Krishna River along with tributaries and provided excellent information on physico-chemical parameters and fish fauna. A total of 142 species under 27 families have been reported. Mirza (1975) has listed 156 species of freshwater fishes, belonging to 58 genera from Pakistan. Almost all of the species of fish form Pakistan have been reported in India too (Talwar and Jirgann, 1991). Ramachandran (1973) made attempt to prove an illustrative list of local and scientific names of fishes of Karnataka region of Western Ghats.

Hamilton-Buchanan (1822) described numerous freshwater fishes from Gengetic systems and synthesis of this work and subsequent studies in the Icthyofauna of Ganga is detailed by Jhingran and Talwar (1991). Sykes (1838) described 46 species from fresh waters of south India. Comprehensive accounts of south Indian freshwater fishes were compiled by Jerdon (1849). He listed 11 fishes from Canara district of Karnataka both in rivers and tanks (Hora and Law, 1941).

The Western Ghats biogeographic region of India is home to a highly diverse fish fauna, consisting of 288 known species belonging to 12 orders, 41 families and 109 genera (Dahanukar et al., 2004), of which 116 (53%) species are endemic to this region (Daniels, 2001). The species richness of river fauna may be dependent on the accessibility of streams (Horwitz, 1978). The high species richness streams of Thalayanai and Achankoil are located in well protected areas and less accessible to people. In addition to the stream accessibility, diversity and distribution patterns of freshwater fishes are associated with different sets of environmental gradients that
have been well studied in streams of the Western Ghats (Johnson 1999; Arunachalam 2000; Bhat 2003 & 2004).

Hossain, et al., (2005), studied the fish diversity from Padma River; in order to explore the existing fish fauna of the Padma River near Rajshahi (Godavari to Charghat) and found 135 species of fishes under 77 genera, 33 families, 14 orders and two classes. It was also found that more than 50 species have become rare, which were found abundantly in the research-covered areas during last two decades.

Ogale (1997) studied Western Ghats fish diversity and found 102 species of fish situated between 750 and 2000 m altitude. The Western Ghats ranges in western India run for about 1600 km and have an average altitude of 1200 m (max. 2339 m). These important mountain ranges attract precipitation, which is then drained east and west. The three major rivers draining towards west are Godavari, Krishna and Cauvery, the last river being famous for its sport and recreational fishing for Mahseer (*Tor khudree*).

Bhat (2004) studied Western Ghats and recorded 288 species belonging to 12 orders, 41 families and 109 genera, of which 118 species are endemic and 51, are unique to this region. An analysis of the distribution pattern of fishes in the Western Ghats suggests that the southern region is more diverse than the northern and central regions. The southern region shows high endemism and high uniqueness while the northern region shows high endemism but less uniqueness. The similarity index between the zones indicates that as the distance between the zones increases similarity decreases. The status of 105 of 288 species was not known due to data deficiency but among the remaining 183 species, 58 species were categorized as least rare, 41 as Vulnerable, 54 as Endangered, 24 as Critically endangered while the remaining six species were introduced. The threat status of fishes found in Western Ghats suggests that at least 41% of fish fauna is threatened by either being vulnerable, endangered or critically endangered. Implication of potent conservation measures is necessary to conserve the fish fauna of Western Ghats.

On similar agro-climatic zone to adjoining countries like Bangladesh and Pakistan fish diversity studies shows variation in species diversity and same threats
like India. Ahmed (1953) who included 107 freshwater species from the East Pakistan. Bhuiyan (1964) recorded 71 species from fresh water area of Dhaka district in Bangladesh. Qureshi (1965) in his monograph of common freshwater fishes of Pakistan included 133 species, most of which occurred in Bangladesh. Doha (1973) published a list of 106 species from waters of Mymensingh and Tangail districts. Rahman (1989) first made a complete list of 257 species inhabiting the fresh water areas in Bangladesh, many of them are also found in marine and estuarine areas. Ahmed and Hasan (1981) published a list of 69 species inhabiting in the Karnaphuli Reservoir.

In fish diversity exotic fish also impact in various rivers. Several cases of fish species decline from various water bodies in India including reservoirs and rivers due to proliferation of tilapia have been documented (Jhingran, 1984). The presence of a well established population of tilapia in the Chalakudy River will invariably cause negative effects on the native fish fauna of the region. An important native ornamental fish of River Chalakudy, *E. maculatus* shares more or less the same resources as that of *O. mossambicus* and so the proliferation of the former will invariably harm the native stocks of *E. maculatus*. (Raghavan et al., 2008)

### 2.6 Fish diversity Conservation

In-situ conservation of endemic, endangered fish species is necessary to protect fish diversity. It has been suggested by the authors that every taluka should have a fish seed producing centre and fish rehabilitation centre nearer to the lakes. Here cultivable fingerlings can be produced and the threatened fish species could be pooled out and grown to suitable size for the propagation so that they may be restored to their optimum population level. As a rehabilitation measure, young ones of the endangered fish species should be collected from the lakes and reared in these centers and thus can be propagated.

The health of the environment decides the diversity and productivity of the systems. Therefore, for sustaining the diversity of fish, and for sustainable management of the fish culture, it is important to know the factors controlling the quality of the lake systems. Certain changes in physico-chemical parameters,
drainage of pesticides and fertilizers from the surrounding crop fields, heavy siltation during heavy rainfall, high density of fingerling stocking of selected culture fishes, poor management of fish culture and fish diseases were found to exert undesirable impacts on fish diversity and productivity.

Rational management methods by creating public awareness has to be followed for sustaining fish diversity and for sustainable fish production in these lakes for preventing any further rural economic loss. A periodic survey and monitoring of these water bodies is essential to check the water quality and prevent any disturbances to these wetland ecosystems. The documentation of fish species distribution in various habitats will assist in resource allocation between different user communities who depend on fishing as a livelihood strategy. This baseline information allows for informed decision-making by both resource managers and users and will cater to more equitable and sustainable use of fish resources. This approach captures the key tenets of the ecosystem approach, defined by IUCN as ‘a strategy for management of land, water and living resources that promotes conservation and sustainable use in an equitable way’ (Smith and Maltby, 2003). Awareness programmes among the locals regarding the importance of preserving the water resources and judicious exploitation of fish resources will immensely help in sustaining these valuable aquatic resources.

Guegan et al., (1998) found that latitude also important diversity study. In general the lower the latitude of the river, the richer in species it is. This is a clear manifestation of the most well known global diversity gradient, namely that species diversity increases with decreasing latitude. Analysis by Guégan et al., (1998) appears to indicate that latitude may be a surrogate measure for productivity within the basin. Longitudinal migrations may occur within the river or from river to sea or lake and back or from sea or lake to river and back. Such movements put animals at risk from stresses in various parts of their habitat at different times; long-lived species with low reproductive rates are likely to be the most vulnerable (Carolsfeld et al., 2004). Dams in tropical regions are generally constructed without appropriate fish ways or fish passes, or based upon designs that are suitable only for salmonids, and thus they obstruct fish migrations (Roberts, 2001). A dam on the lower course of
a river prevents migratory fishes with an obligate marine phase in their life cycle from moving to and from the sea, creating the potential for activities in downstream reaches to impact upstream portions of the river by way of, for example, the nutrient transmission that occurs during spawning migrations of salmon (Naiman et al., 2002; Pringle, 2001). Lateral migrations, between inundated floodplains or swamp forest and the main river channel, represent another axis of connectivity important for feeding and breeding in many fishes and other animals (Welcomme, 1979; Ward et al., 2002; Carolsfeld et al., 2004; Arthington et al., 2005) that is dramatically altered by human activities.

2.7 Rare, Threatened, Endangered and Critically Endangered taxa

The threats to global freshwater biodiversity can be grouped under five interacting categories overexploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species (Allan and Flecker, 1993, Naiman et al., 1995; Naiman and Turner, 2000; Jackson et al., 2001; Malmqvist and Rundle, 2002; Rahel, 2002; Postel and Richter, 2003; Revenga et al., 2005).

For instance, river dolphins receive much less attention than their marine counterparts, despite the fact that three of the five taxa of “true” river dolphins, i.e., those that never enter the sea, are endangered or critically endangered (IUCN 2004). Crocodiles, river turtles, specialist river birds, and large freshwater fishes in the region are also increasingly rare and globally threatened by overharvesting and habitat degradation (Wei et al., 1997, Dudgeon 2000a and Baird et al., 2001).

2.8 Exotic and introduced species

Widespread invasion and deliberate introduction of exotic species adds to the physical and chemical impacts of humans on fresh waters, in part because exotics are most likely to successfully invade fresh waters already modified or degraded by humans (Bunn and Arthington, 2002; Koehn, 2004). There are many examples of largescale and dramatic effects of exotics on indigenous species (Nile perch, Lates niloticus, in Lake Victoria, the crayfish plague in Europe, salmonids in Southern Hemisphere lakes and streams) (Rahel, 2002), and impacts are projected to increase
further (Sala et al., 2000). Indirect impacts can arise from exotic terrestrial plants such as *Tamarix spp.* (Tamaricaceae), which alter the water regime of riparian soils and affect stream flows in Australia and North America (Tickner et al., 2001).

The advisability or otherwise of introducing exotic fish species for food raises problems that call for much careful research, for once introduced, exotic fishes are generally impossible to eradicate, and in many cases such introductions have led to extinction of indigenous species. However, the Brazilian fish fauna is still poorly known and only a preliminary list of endangered fish species is available (Rosa and Menezes, 1996). No case of native fish species extinction caused by introduction of species is reported in Brazil.

### 2.9 Biodiversity Conservation

Globally, awareness of the need to conserve freshwater biodiversity seems limited. Between 1997 and 2001, only 7% of papers in the leading journal in the field, Conservation Biology, were concerned with freshwater species or habitats (Abell, 2002). Most reported studies from northern temperate latitudes. This negligence is particularly acute in regions where biodiversity is both rich and highly threatened. A mere 0.6% of papers in the conservation biology literature between 1992 and 2001 dealt with freshwater biodiversity in Asia (Dudgeon, 2003b).

There is growing awareness that maintenance of natural variability in flows and water levels is essential to underpin conservation strategies for freshwater or water-associated biodiversity and their habitats (Poff et al., 1997; Richter et al., 1997 & 2003; Pollard and Huxham, 1998; Arthington and Pusey, 2003). Over the last century, riverine ecosystems have suffered from intense human intervention resulting in habitat loss and degradation and as a consequence, many fish species have become highly endangered, particular in rivers where heavy demand is placed on freshwaters. The main causes are habitat destruction and defragmentation, water abstraction, industries and private use (Szollosi-Nagy 2004; Ricciardi and Rasmussen, 1999; Gibbs. 2000) exotic species introduction (Copp et al., 2005), pollution (Lima-Junior et al., 2006) and global climate change impacts (Leveque et al. 2005a; Mas-Marti et al., 2010). Freshwater fish are one of the most threatened taxonomic groups (Darwall
and Vie, 2005) because of their high sensitivity to the quantitative and qualitative alteration of aquatic habits (Laffaille et al., 2005; Kang et al., 2009; Sarkar et al., 2008). As a consequence, they are often used as bioindicator for the assessment of water quality, river network connectivity or flow regime (Chovance et al., 2003). Today the fish diversity and associated habitats management is a great challenge (Dudgeon et al., 2006). Conservation measures to mitigate the impact of the pressures have largely been slow and inadequate and as a result many of the species are declining rapidly.

2.10 Methodology for assessing conservation status

Globally, many systems of categorization and criteria’s have been developed like World conservation Union (IUCN), American Fisheries Society (AFS) and Australian Society for Fishery Biology (ASFB). According to the World Conservation Union (IUCN, 2001), any of the five criteria’s within the categories has to be satisfied for a taxon to be included as “threatened” these are; (i) Population reduction, (ii) Restricted distribution, (iii) Population estimates, (iv) Restricted population and (v) Probability of extinction. In ASFB (Pollard et al., 2001) more importance has been given to population size, habitat and distribution range. The AFS system (Williams and Miller, 1990; Miller et al., 1989) is the simplest system without any supporting conditions by which the categories can be assessed. Other systems like categorizing based on the probability of extinction within a set time period (Mace and Lande, 1991) and occurrence ranking (Master, 1991). Though IUCN categories did well globally but guidelines for regional or national assessments have not yet developed fully. In IUCN categorization, emphasis has been on causative factors. But for many species causative factor cannot be directly responsible to population decline. Based on the population biology, three categories Critical endangered, Endangered and Vulnerable were proposed by Mace and Lande (1991) with decreasing probability of extinction over increased time scale. For assessing this, data on effective population size (Ne) and number of sub population, with migration rates and percentage population decline are required. The model proposed by Mace and Lande (1991) are more exact and less subjective than that of
IUCN, ASFB. But such quantitative data is not available at present and it may not be available in near future also. The conservation status report (NBFGGR, 2010) is based on the compilation of scientific documentation and report developed from the research programmes in the area of conservation of freshwater fish resources of India (Dehadrai et al., 1994; Ponniah et al., 1998; Das et al., 2004; WII, 2007; Anonymous, 1992-93; CAMP, 1998, Lakra and Sarkar, 2007)

2.11 Quantifying Biodiversity

Species richness is the simplest way to describe community and regional diversity (Magurran 1988), and this variable (±) number of species forms the basis of many ecological models of community structure (MacArthur and Wilson, 1967; Connell, 1978 and Stevens, 1989). Quantifying species richness is important, not only for basic comparisons among sites, but also for addressing the saturation of local communities colonized from regional source pools (Cornell, 1999). Maximizing species richness is often an explicit or implicit goal of conservation studies (May, 1988), and current and background rates of species extinction are calibrated against patterns of species richness (Simberloff, 1986). Therefore, it is important to examine how ecologists have quantified this fundamental measure of biodiversity and to highlight some recurrent pitfalls. Even the most recent reviews of biodiversity assessment (Lawton et al., 1998; Gaston, 2000; Purvis and Hector, 2000) have not discussed the sampling issues in relation to the measurement and comparison of species richness. In contrast, the uses and abuses of species diversity indices, which, by design, combine richness with relative abundance, enjoy a substantial and venerable literature (Washington, 1984). Although species richness is a natural measure of biodiversity, it is an elusive quantity to measure properly (May, 1988). The problem is that, for diverse taxa, as more individuals are sampled, more species will be recorded (Bunge and Fitzpatrick, 1993). The same, of course, is true for higher taxa, such as genera or families. This sampling curve rises relatively rapidly at first, then much more slowly in later samples as increasingly rare taxa are added. In principle, for a survey of some well-defined spatial scope, an asymptote will eventually be reached and no further taxa will be added.
Four kinds of taxon sampling curves, based on two dichotomies are found. Although it will present these curves in terms of species richness, they apply just as well to richness of higher taxa.

The first dichotomy concerns the sampling protocol used to assess species richness. Suppose one wish to compare the number of tree species in two contrasting 10 ha forest plots. One approach is to examine some number of individual trees at random within each plot, recording sequentially the species identity of one tree after another is referred to be an assessment protocol as individual-based. Alternatively, one could establish a series of quadrates in each plot, record the number and identity of all the trees within each, and accumulate the total number of species as additional quadrats are censused (Cannon et al., 1998; Chazdon et al., 1998; Hubbell et al., 1999; Vandermeer et al., 2000). This is an example of a sample-based assessment protocol. The relative merit of these approaches for estimating species richness of trees is not the point here. Rather, the species richness censuses can be validly based on datasets consisting either of individuals or of replicated, multi-individual samples. The key distinction is the unit of replication: the individual vs. a sample of individual’s a distinction that turns out to be far from trivial. Examples of individual-based protocols include birders' "life lists" (Howard and Moore, 1984), Christmas bird counts (Robbins et al., 1989), time-based "collector's curves" (Clench, 1979; Lamas et al., 1991), and taxon richness counts (often families or genera) from palaeontological sites (Raup, 1979). In addition, when an unreplicated mass sample Sanders (1968) treated as if it were set of randomly captured individuals from the source habitat, an individual-based taxon-sampling curve can be produced for the sample. Examples of sample-based protocols using sampling units other than quadrats include replicated mistnet samples for birds (Melhop and Lynch, 1986) and replicated trap data for arthropods (Stork, 1991; Longino and Colwell, 1997; Gotelli and Arnett 2000). Individual-based rarefaction for individual-based rarefaction curves, a precise mathematical expression based on combinatoric theory can be computed for expected richness, given n individuals, instead of actually re-sampling to randomize. Sanders (1968) provided what was intended as an individual-based rarefaction formula for calculating the expected number of species in a random
subsample of individuals from a single, large collection. Although the principle of rarefaction was sound, Sanders derived the rarefaction formula incorrectly (Hurlbert, 1971). The correct derivation is based on a hypergeometric sampling distribution, in which individuals are sampled randomly and without replacement (Heck et al., 1975). From this model, both the expected number of species and its variance can be derived. A mathematically distinct but computationally much faster way to produce individual based rarefaction curves is to compute the corresponding "random placement" curve of Coleman (Coleman et al., 1982), which has been shown to very closely approximate the hypergeometric rarefaction curve (Brewer and Williamson, 1994; Colwell and Coddington, 1994). Some theoretical progress has been made in modifying the rarefaction curve for cases of known spatial distributions, such as the negative binomial (Kobayashi, 1982 & 1983; Smith et al., 1985). However, these analyses still assume that individuals have been sampled randomly. In reality, ecologists rarely sample individuals randomly. Instead, quadrates or sampling devices are implemented randomly (or in stratified random design), and all of the individuals in a small collection are sorted, yielding datasets appropriate for Sample-based rarefaction.

2.12 Estimating shared species

Estimating the number of species in a community is a classical problem in ecology, biogeography, conservation biology, and parallel problems arise in many other disciplines. This topic has been extensively discussed in the literature, Bunge and Fitzpatrick (1993), Seber (1982, 1986, 1992.) for a review of the historical and theoretical development. In a subsequent paper, Bunge and Fitzpatrick (1993) also compared three principal frequents procedures using simulation results. Ecologists and other biologists have long recognized that there are undiscovered species in almost every survey or species inventory.

Very often comparison of two communities is required in ecological applications and environmental policy decisions. The two communities could be candidate sites for conservation or restoration, or areas at different latitudes or elevation above sea level (Colwell, 1973; Colwell and Coddington, 1994; Feinsinger,
1976; Karr et al., 1990), or could represent the same area at two different times, e.g., before and after pollution (Grassle and Smith, 1976).

2.13 Similarity and dissimilarity

A common approach to comparing two communities is to measure the extent of “similarity” (using an overlap index) or “dissimilarity”. For example, Gower (1985) listed 15 different overlap measures based on various justifications, Pielou (1975 & 1977) and Ludwig and Reynolds (1988). Grassle and Smith (1976) proposed a new measure of similarity based on the expected number of species shared between sub-samples of larger collections for two sites. Colwell and Coddington (1994) suggested the use of a dissimilarity measure called “complementarity”. All these measures are functions of the number of species shared by two samples. Hence an estimator of the shared species plays an important role in comparing two communities. Surprisingly, ecologists have generally used the observed number of shared species as the real number of shared species. Regarding the estimation of unobserved shared species, it seems worthwhile to explore estimation procedures for this topic. Ecologists who conduct field surveys of species richness have long recognized that it is virtually impossible to detect all species and their relative abundances with a limited number or intensity of samples. Sampling limitations create challenges for making accurate estimates of alpha diversity, the number of species within local, approximately homogeneous assemblages, particularly for assemblages with high species richness and a large fraction of rare species (Colwell and Coddington, 1994; Chazdon et al., 1998; Colwell et al., 2004; Magurran, 2004). To meet this challenge, several methods have been developed for estimating species richness from sample data, either through extrapolation of species accumulation curves, or through application of nonparametric methods (Bunge and Fitzpatrick, 1993; Colwell and Coddington, 1994; Magurran, 2004). The latter approach involves the estimation of unseen species (species that are likely to be present in a larger Homogeneous sample of the assemblage, but that are missing from actual sample data). Because estimates of unseen species are based on the numbers of rare species observed within samples (Colwell and Coddington, 1994;
Chazdon et al., 1998), either abundance data or replicated incidence samples are required for richness estimation. In the simplest richness estimators (Chao1, Chao2, or jackknife estimators), rare species are classified as species with a total abundance of 1 (singletons) or 2 (doubletons) in an abundance-based sample or that occur in only one sampling unit (unique) or in exactly two sampling units (duplicates) in replicated incidence data. The abundance-based coverage estimator (ACE) uses additional information based on those species with 10 or fewer individuals in the sample (Chao et al., 1993) and the corresponding incidence-based coverage estimator (ICE) is based on species found in 10 or fewer sampling units (Lee and Chao 1994; Chazdon et al., 1998; Magurran 2004).