2.1. INTRODUCTION

History of the study of the freshwater fishes way back to Hamilton (1822) on the fishes found in the river Ganges and its branches. The naturalists documented the fishes in different parts of India and the listing was mainly done by Jerdon (1848) and Sykes (1838). A comprehensive and authoritative account on the freshwater fishes has been provided by Day in 1865 and 1871-78. It was Hora (1922; 1939; 1940a; 1940b; 1941; 1943; 1951a; 1951b; 1953) who enunciated the Satpura hypothesis initiated the further investigation on the freshwater fishes of India especially the Western Ghats. This lead to the new descriptions, enlisting and elaborate discussions on the endemism and other zoogeographical relevance. Several new taxa have been added from Kerala during this period (Hora and Law, 1941; Hora and Nair, 1941; Raj, 1945).

There are several gaps in our current knowledge on the evolutionary history of the mahseer (Singh and Menon, 1994). Hora (1930) has described the possible evolution of the torrential sisorid fishes as induced by the rate of flow and dissolved oxygen content of water, the two main factors in the environment. Hill stream fishes including mahseer inhabiting the torrential waters of the Himalayan region might have evolved from fish inhabiting the low land streams. The evolution of hill stream fish has been possible through speciation and adaptive diversification (Singh and Kumar, 1993). It is generally considered that the cypriniform fish, which have evolved in South West China must have descended from a toothless Protocyprinoid charcoid stock. The Cypriniformes have flourished and prospered in Eurasia into
the largest familiar group of Ostariophyseans. It is believed that the cyprinoids evolved in China and spread westwards along the Himalayas during the Pliocene and South to Malay Archipelago and South-Westwards to the Indian Peninsula and Sri Lanka in the Pleistocene. There are about 200 genera of Cyprinoid fishes and there are many whose relationships are still poorly known. To understand the phylogeny of mahseers the knowledge on barbin groups is a must. The heterogeneric group of Barbus of Day and earlier workers has been spit up into several genera - Punitus, Chagunius, Tor, Neolissochilus, Propuntius, Hypselbarbus, Orichthys, Barbodes, Eechathalakenda, etc. There are other closely related genera like Discherodontus, Hampala, Sowbwa and Spratellicypris in South East Asia. Tor and Neolissochilus seem to be only distantly related to any of the various genera of barbels of eastern and south-eastern Asia. Each group has its own modifications, mechanisms and other adaptations for their existence, and so too the mahseers.

2.2. TAXONOMY

A taxonomic uncertainty still remains in the classification of mahseers. Thomas (1897) pointed out that ‘if due attention is given to mahseers as it has been given to family Salmonidae in the West, it would be found that the mahseers of India would also grow in numbers’. His view was surprisingly accurate as more and more species are being added to this group even today!

Many authors have critically analyzed and explained the systematic position of the various species fall under the Genus Tor and allied genera. After analyzing the observations of all the previous workers, Nautiyal (1994) extensively reviewed the taxonomy of Indian mahseers. They were earlier assigned the genus Cyprinus (Hamilton), Tor (Gray), Labeobarbus (Ruppell) and Barbus (Sykes, 1838; McClelland, 1939; Jerdon, 1848; Day, 1868; 1878). Hora (1939) used the generic name, Barbus and erroneously recognized Tor Gray as its subdivision. Later workers once again assigned the genus, Tor for the group (Misra, 1959; Menon, 1974). Sen and Jayaram (1982) reviewed the literature on mahseers in India and described 6 species (T. putitora, T. tor, T. mosal, T. mussullah, T. khudree, T. progeneius) and 3 sub species (T. khudree longispinis, T. khudree malabaricus, T. mosal mahanadicus). They also described certain species of mahseer (Barbus hexastichus, B. dukai, B. neilli, B.
chilinoides) as ambiguous. Further, Menon (1992) described five species under the genus Tor Gray; T. putitora (Hamilton), T. tor (Hamilton), T. khudree (Sykes), T. progeneius (McClelland) and T. kulkarnii (Menon), as he considered T. mussullah same as T. khudree. He synonymised T. mosal (Hamilton) with T. putitora (Ham.), Tor mosal (Hora) with T. tor (Ham.), and considered the deep bodied mahseer from the peninsula so far confused with Tor mussullah (Sykes) as an abnormal T. khudree (Sykes). The new species described by him, T. kulkarnii was collected from Darna river (Godavari drainage). From Hora to Menon and Rainboth there is an agreement on at least four species; T. putitora (Hamilton), T. tor (Hamilton), T. khudree (Sykes) and T. progeneius (McClelland).

Many species/sub species got included in the list and some got trimmed out too; no wonder, contradictory observations have also been came out on the taxonomical issues (David, 1953; Menon, 1992; Mirza and Bhatti, 1996; Jayaram, 1997; 1999; CAMP, 1998; Gopalakrishnan and Basheer, 2000). To make it simple to the amenity of a biologist, not to a true taxonomist, Desai (2003) stated that the carp with big scales, fleshy lips continuous at the angles of the mouth with uninterrupted fold or groove across the lower jaw, two pairs of big barbels, lateral line scales ranging from 22 to 28, and length of head equal to or greater than the depth of the body are considered as ‘true mahseers’ and are included in the genus Tor. CAMP (1998) workshop on Freshwater fishes of India organized with the objective of assessing the freshwater fishes of the country has listed eight species of mahseer, T. khudree (Sykes), T. khudree malabaricus (Jerdon), T. kulkarni (Menon), T. mosal (Hamilton), T. mussullah (Sykes), T. progenius (McClelland), T. putitora (Hamilton) and T. tor (Hamilton).

Talwar and Jhingran (1991) described eight species of mahseer commonly found in India of which 7 belong to the genus Tor, T. putitora (Hamilton), T. tor (Hamilton), T. mosal (Sykes), T. khudree (Sykes), T. mussullah (Sykes), T. neilli (Day) and T. progeneius (McClelland) and Neolissocheilus hexagonolepis. In Kerala, N. wayanadensis has been reported from Tholpetty, Wayanad.

A tentative list of species comes under the genus Tor with their identification characters and geographic distribution is presented in the Table 2.1. (based on Sehgal et al.(2007) with other inclusions)
Table 2.1. List of mahseers

<table>
<thead>
<tr>
<th>No.</th>
<th>Valid Species</th>
<th>Characteristics</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>T. putitora</em> (Hamilton)-Golden/ Putitor/ Yellow fin mahseer</td>
<td>Head-pointed; Head Length &gt; Body Depth; LL: 23-28</td>
<td>All along the Himalayas</td>
</tr>
<tr>
<td>2</td>
<td><em>T. tor</em> (Hamilton)-Deep bodied/ Red fin/ Turia mahseer</td>
<td>Head Length &lt; Body Depth LL: 23-28</td>
<td>All along the Himalayas and Narmada</td>
</tr>
<tr>
<td>3</td>
<td><em>T. khudree</em> (Sykes)-Deccan mahseer</td>
<td>Head Length = Body Depth; fins bluish grey; LL: 25-27</td>
<td>Orissa and Peninsular India south of Tapti</td>
</tr>
<tr>
<td>4</td>
<td><em>T. mussullah</em> (Sykes)-Hump-backed mahseer</td>
<td>Head Length &lt; Body Depth; LL:24-27</td>
<td>Peninsular India - Krishna and Godavari river systems.</td>
</tr>
<tr>
<td>5</td>
<td><em>T. progenieus</em> (McClelland)-Jungha mahseer</td>
<td>Head Length = Body Depth; LL:27-31</td>
<td>Eastern Himalaya</td>
</tr>
<tr>
<td>6</td>
<td><em>T. remadevi</em> (Kurup and Radhakrishnan, 2007)</td>
<td>Elongated body; possession of a strong and osseous dorsal spine equal to body depth, straight head; LL:27-29</td>
<td>Western Ghats</td>
</tr>
</tbody>
</table>

The species/ sub species like *T. mosal*, *T. neilli*, *T. cheylinoides*, *T. moyarensis* and *T. kulkarnii* are not included as their taxonomic status is yet to be assessed/ confirmed.

The vernacular name is also as important as the scientific name and the Table 2.2. provides a list of common names available for the mahseers in India.

Table 2.2. Vernacular names of mahseers

<table>
<thead>
<tr>
<th>Language/Region</th>
<th>Vernacular Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hindustani</td>
<td>Mahasir</td>
</tr>
<tr>
<td>Hindi</td>
<td>Naharm</td>
</tr>
<tr>
<td>Punjabi</td>
<td>Kakhiah</td>
</tr>
<tr>
<td>Marathi</td>
<td>Kadchi, Masta</td>
</tr>
<tr>
<td>Sindhi</td>
<td>Jungah, Petiah, Karriah</td>
</tr>
<tr>
<td>Assamese</td>
<td>Barapetiah, Barapatra, Jhangah</td>
</tr>
<tr>
<td>Tamil</td>
<td>Bommin, Pumin, Kendai</td>
</tr>
<tr>
<td>Karnataka</td>
<td>Peruval, Harale-minue, Devara menu</td>
</tr>
<tr>
<td>Mysore</td>
<td>Hallamin</td>
</tr>
<tr>
<td>Malayalam</td>
<td>Katti, Kuyil, Choora</td>
</tr>
<tr>
<td>Tulu</td>
<td>Heragulu, Peruval</td>
</tr>
<tr>
<td>Jhelum</td>
<td>Kakur and Sakhral</td>
</tr>
<tr>
<td>Central India</td>
<td>Chandni Matchli</td>
</tr>
</tbody>
</table>
2.3. MORPHOLOGY

The original description of *T. tor* (=*Barbus tor*) by Gray (1834) is as follows. Body elongate anteriorly, trunk and peduncle smoothly tapering. Abdomen rounded. Head moderately large, snout obtusely rounded and prominent, sometimes with tubercles. Mouth inferior to sub-inferior, no horny covering on lower jaw. The lips are more or less thick, fleshy and continuous upper lip protrusible, lower with or without a median lobe, the labial fold is uninterrupted. Nostrils close together, nearer to eye than snout tip. Eyes large, far forward, not visible from ventral side. Interorbital space wide, slightly convex. Gill openings wide. Dorsal fin with scaly sheath at base, origin. Pectorals pointed, not reaching pelvic. Pelvic with an axillary appendage, short, not reaching anal (5 branched rays). The dorsal fin is provided with 8-9 branched rays and commences either before or opposite to the origin of the pelvic fins; its last undivided ray is large, osseous and smooth spine. Caudal deeply forked. Scales large. Lateral line complete (21-30 scales), simple, running through the middle of the caudal peduncle. There are two pairs of small, but well defined barbels, one pair rostral and one pair at the angles of the mouth. The pharyngeal teeth are present.

The head length/body length ratio is a taxonomic character of high value for distinguishing the species of *Tor* (Beavan, 1877). Johal et al. (1994) and Bhatt et al. (1998b) have carried out detailed studies on the morphometry of *T. putitora* in the Ganga river system and compared the values with the stocks of the Gobindsagar reservoir. The head length accounted for approximately 22% of total length which was statistically similar in both the stocks. The body depth ranged from 16.3% to 19.48%. It was postulated that the variation observed might be due to the change in TL of the fish groups used for the analysis. Analyzing the Narmada river population of *T. tor*, Dubey and Dubey (1987) found that growth of head length in relation to total length of fish was fastest, that of caudal peduncle was the slowest. The relationship between total length and body measurements in this species was given by Desai (1982). Jayaram (1997) noted the HL/SL percentage as 25.6 to 29.4 in *T. mussullah* collected from Chaliyar river, North Kerala.
In mahseer, the head length/body length ratio is a measure of the efficiency of the fish to withstand the fast flowing current as the fish becoming more streamlined. Cylindrical body, powerful muscular tail and hypertrophied lips are some of the important characters that enable mahseer to live in fast flowing streams (Menon et al., 2000). According to the requirements, fins of mahseer are more osseous and strongly built compared to other carps (Pisolkar, 2000). Mac Donald (1948) noted that its fin area is greater than the total superficial area of the rest of the body. The upper lip is protrusible, so as to form a cup on the bottom of the stream, and cover any small body. The molluscs thus get covered and detached and are readily drawn up into the mouth by suction. The mouth may also be used for adhesive purposes against the swift currents. Mahseer does not possess teeth in the jaws as in the case of carnivorous fishes. But the fifth branchial arch bears the pharyngeal teeth for tearing and masticating the food materials. These teeth are arranged in three rows, on either side two in the upper, three in the middle and five in the lower and are expressed in a dental formula 2/3/5-5/3/2. The teeth are curved near their extremity; hooked and pointed. They appear as the continuations of the pharyngeal bones having a coating of enamel down to their base. Hora (1940) reported that anglers in India often preserve the pharyngeal teeth of the mahseer as trophies since they provide a reliable evidence of the size of the fish caught. Another aspect of interest is the presence of hypertrophied lips in the group. Thomas (1897) believed that this is a taxonomic character which can be used for differentiating a species which was proved incorrect by later workers (Hora, 1940). Though it is believed to be formed as an adaptation to live in the fast flowing waters, why it has been noted only in a limited number of population is yet to be ascertained.

It is a fact that mahseers have bigger scales than any other freshwater Indian cyprinids and can easily be used to identify this group. A fully grown mahseer may have scales as big as the palm of one’s hand. The scales are reported to be used as playing cards in some parts of India (Hora, 1953).

2.4. SIZE

Regarding the maximum size attained by mahseer various reports are available. The Golden mahseer has been known to reach 2.75m in length and 154 kg in weight (Talwar and Jhingran, 1991). A length of 274cm was reported in 1822.
by Hamilton. Around 185 years have elapsed since then and this kind of size has not been reported for the Himalayan mahseer. A female measuring 148.0 cm from the Sarju River, Kumaon Himalaya, India is the only report available over the last two decades (Nautiyal, pers.com.). Size less than that (137.5 cm) were reported in early eighties (Nautiyal and Lal, 1981). Maximum weight reported for Tor mussullah and Tor khudree are 90 kg and 22.5 kg respectively (Gupta and Gupta, 2006). It is reported that most specimens fished in Sri Lanka are of small size (20-50cm; and 1-5 kg) since small sized gill nets are widely used all over the country (Pethiyagoda, 1991). The largest recorded specimen in Sri Lanka was with a weight of 27.4kg caught very long back (Deraniyagala, 1930).

2.5. SPORTING QUALITY

Undeniably, mahseer is one of the fiercest fighting freshwater game fish present in India with unparalleled strength and endurance, pound for pound (Dhillon, 2004). For serious anglers in India, there is only one fish worth fighting about-and fighting against, which is mahseer (Thapa, 1994). It was the Oriental Sporting Magazine which mentioned mahseer for the first time as an angling fish in 1833. Lacy and Cretin (1905) referred to it as ‘playing a mahseer’. The book named ‘With Gun and Rod in India’ published by the Government of India, New Delhi in 1958 (Anon., 1958), described the mahseer as an ever fascinating lure to the hunter. ‘Circumventing the Mahseer and other sporting fish in India and Burma’ by Mac Donald (1948) could be considered as the best treatise of Indian mahseer in every respect. The books, ‘Rod in India’ by Thomas (1897), ‘The angler’s hand book for India’ by Lacy and Cretin (1905), ‘The anglers in India or the mighty mahseer’ by Dhu (1923), ‘Game fishes of India and angling’ by Tilak and Sharma (1982), ‘Mahseer-the game fish’ by Nautiyal (1994), ‘Kings of the rivers’ by Kiat (2004) and ‘Mahseer fish-bionomics and population’ by Malik and Negi (2007) provided valuable information on the sporting quality, required fishing rods, ideal hooks and baits and fish behaviour.

2.6. SEXUAL DIMORPHISM

Pathani (1978) reported the significant sexual dimorphic characters of T. tor collected from Bhimtal and Naukuchiatal (Uttar Pradesh) during the breeding
season. Males were narrower and pectoral fins were longer and rough and reached up to the sixth scale of the lateral line. In females, pectoral fins reached just below the fifth scale of the lateral line and are smooth. Tubercles were present on the dorsal side in the head of males and were absent in the females. Other reports on the topic include that of Kulkarni (1970), Chaturvedi (1974), Desai (1982; 2003) and Nautiyal (1985).

2.7. FOOD AND FEEDING

Several authors including the anglers of the nineteenth century have given a detailed account on the food and feeding habits of mahseer. Mac Donald (1948) noted that mahseer is an intermittent feeder. Green filamentous algae and other water plants, slimy matter encrusted the rocks, insect larvae, etc. have been recorded from the stomach contents of the Putitor mahseer. Thomas (1897) observed that ‘aquatic weeds of all sorts, some taken intentionally, some when grabbing at the insects that live on them; seed of Vateria indica or Dhup of the west coast; bamboo seeds; rice thrown in by the man; and un husked rice, or paddy; crabs, small fish, earth worms, water beetles, grasshoppers, small flies of all sorts, water or stone crickets, shrimps, molluscs or freshwater snails were also noticed in the stomach’. Karamchandani et al. (1967) and Desai (1982) reported that mahseer is omnivorous and the menu ranges from small prawns, crustaceans, molluscs, insects, insect larvae, eggs to paddy grains and various seeds. However, they have preference to vegetative matter that too depending on the availability. Pisolkar and Karamchandani (1981) also indicated that although macro vegetation constitutes the main diet of the fish, the fish matter, insects and molluscs taken in insignificant quantities form the subsidiary food. It has also been reported that the fish derives nutrition mainly from the macro vegetation as the bulk of this food had direct correlation with condition factor of the fish.

The diet of T. putitora is reported to be diverse in different river systems. In the Ganga river system, the diet of the species comprised of insect nymph (Ephemeroptera, Plecoptera, Odonata), insect larvae (Trichoptera, Diptera, Coleoptera, Lepidoptera), miscellaneous insects, fish, organic debris, zooplankton, macrophytes, diatoms, other algae, and sand. Nautiyal and Lal (1984) made
observations on the feeding habits of the Himalayan mahseer migrants in the Alaknanda and juveniles from the nurseries (Nayar) and categorized it as marginal-cum-column feeder. The adults which are more powerful swimmers definitely feed in the column with insectivorous feeding habit as no other group of animal was found in their guts (barring 1.6 % fish that too in the migrant adults only) which makes them to be rightly called as ‘monophagic’. Kishore et al. (1998) studied the dietary habits of the Gangetic Putitor stock and confirmed their carnivorous habit. Variation in the dietary habits was observed in the early larval stages, 1-7mm was omnivorous and 7-10mm was carni-omnivorous. There were no differences among the sex. A definite shift from omnivorous/herbi-omnivorous to carnivorous is reported to occur in fish attaining 7cm size, which proves it is the size and not the age which matters. However, fish of 1+, 2+ and 5+ age are reported to become carnivorous, carni-omnivorous and omnivorous respectively. During migration, fish of all age remain carni-omnivorous. Observations on the intraspecific competition in *T. putitora* stock revealed positive preference/selection for all insect groups, while negative for diatoms. Insects were categorized as ‘most preferred’ food item of *T. putitora* owing to high values of Strauss Linear Index. The food spectrum is found to be varied according to the age, river systems and habitat. The rate of feeding in Golden mahseer varied according to the season as evident from the studies by Mohan (2000) in Kumaon region of Uttarakhand. The rate was higher during winter and slowed down towards the monsoon. The estimation of Gastro Somatic Index also supported this observation. The fish was found to be fed mainly on the micro benthic biota available over the river substratum. Diatoms formed the most preferred food component supported by green algae, blue green algae and micro and macro-benthic animals. Various species present in the gut included *Navicula, Amphora, Cymbella, Synedra, Fragillaria, Oscillatoria, Zygnesia, Spirogyra, Tribonema, Arcella, Keratella* and *Chironomus*.

2.8. **REPRODUCTIVE BIOLOGY**

Information is available on the behaviour, season and sex organs of mahseer since the nineteenth century itself contributed by the anglers and naturalists. Beavan (1877) puts ‘When the rains begin these fishes commence moving up the streams for spawning purposes’ and reported the breeding period as May to August. Thomas (1897)
noted that mahseer does not spawn like the Salmon all at one time, but just as a fowl lays an egg a day for many days, lays a batch of eggs at a time, and repeats the process several times in a season. As far as the factors responsible for triggering spawning in hill-stream fishes are concerned, it is a specific combination of temperature, pH, velocity, turbidity and rains, which collectively induce the fish to spawn (Dobriyal et al., 2000). Khan (1939) opined that mahseer spawns more than once during the year.

The pioneering observation on the spawning of mahseer dates back to Cordington (1946). The gonads of mahseer occur as a pair of elongated, light coloured, strap shaped bodies lying one on each side of the intestine, and lodged in the groove between the air bladder and the abdominal wall (Mac Donald, 1948). The mahseer prefers clean water for breeding and its migratory habits are well studied. The brood fish migrate upward from deeper waters to the tributaries for spawning but do not stay there after spawning (Badola and Singh, 1984; Nautiyal et al., 2007). David (1953) reported that the commencement of breeding is related to the change in water temperature. Chaturvedi (1976) agreed with this observation and concluded that the flood of clear water accompanied by drop in temperature is the prerequisite for spawning of mahseer.

Pathani (1983) recorded four groups of eggs in ripe females from Lake Bhimtal, and Chaturvedi (1976) experimented on the monthly changes in the gonads of *T. tor* from Lake Udaipur in Rajasthan. They accomplished that the fish breeds there only once in an year from July to September with peak in August.

Hora and Mukherjee (1936) and Hora (1940) observed that *T. putitora, T. tor* and *T. mosal* breed during August- September in the Himalayan rivers. Hora and Misra (1938) opined that *T. khudree* breeds in August - September in Deccan hills. David (1953) while dealing with Mahanadi mahseer, *T. mosal mahanadicus* believed that breeding takes place only during the post monsoon period between October and November. He further reported that in *T. khudree* and *T. mussullah* spawning takes place in November in the Cauvery system. Qasim and Qayyum (1961) argued that *T. putitora* from Aligarh may breed several times over a greater part of the year. Karamchandani et al. (1967) observed that breeding of *T. tor* from Narmada river commences in July- August and continues up to December-January.
Kulkarni (1971) observed a fortnight or two between late July and early August for the peak breeding season of *T. khudree* in Maharashtra. Pathani (1983) observed that the spawning season of *T. tor* and *T. putitora* from Bhimtal lake extends from August to September and May to September respectively. Nautiyal (1984) observed that in Garhwal the fish breeds at least twice in a breeding season which extends from July to September. Sehgal (1987) reported two breeding seasons, first during May-June and second during August-September, on the basis of the collection of fertilized eggs and hatchlings from the rivers of Himachal Pradesh. He observed that in the snow-melt rivers of the State, *T. putitora* spawns twice in an year, when the tributaries receive spate with rapid snowmelt water inducing the local stocks to spawn. Studies by Mohan (2000) revealed that *T. putitora* spawns in batches and number of batches may depend on the environmental conditions. He concluded that the species has only one spawning season during July-August. In this species, females outnumbered males and average annual sex ratio was estimated as 1: 1.29. The total fecundity ranged from 3987 to 7320 in the spawners within the size range of 190 to 250mm total length. Nautiyal and Lal (1985 a) reported that the fecundity was quite low (7076-18528) in lacustrine mahseer when compared with riverine fish (26,998-98,583) in similar climatic regime. The fecundity per kg body weight obtained was 3375- 8944 (mean 6,000) in the length range of 78.0 -137.7cm and weight range of 3.5 to 23kg.

Based on the collection of partially spent wild brooders and one-week-old fry from the Harangi river (a tributary of the Cauvery), the spawning season of *T. khudree* has been found to be September-October (Basavaraja *et al.*, 2002). On the basis of the residual eggs in the wild brooders and oocytes at different stages of development in the ovary, they also indicated that *T. khudree* is a batch spawner, unlike Indian major carps.

Observation on the size at first sexual maturity is found to vary with locations. The females of Himalayan mahseer commence to mature at 40cm of length in the river Ganga and 30.9cm in the lakes of Kumaon. The smallest mature male measured 36.5 cm (370gm) and 20.7cm in the respective environments. In the mountain stretch of the Ganga in Garhwal, the male matures at 30-50cm and the female at 50-70cm (Nautiyal, 1984). The calculated weight at the onset of sexual
maturity was found to be 1119.21gm- the observed average weight being 875.5 gm- and the age 3+ (Nautiyal, 1990). However, the attainment of maturity is linked to size of the fish.

It was observed by Nautiyal and Lal (1985b) that maturity in the species is directly linked to the growth rate of the gonads, which depends on the quality and quantity of food available. Significantly the testes of *T. putitora* were found to possess higher growth rate implying early maturity in the males. The greater size of the ova was explained as an adaptive significance from the view point of food supply- reproduction relationship attributed mainly to scarcity of larval food during monsoon, when the fish spawns. Studies by Chaturvedi (1976) on the gonads of both the sexes of *T. tor* showed that the gonads undergo certain progressive change as the fish attain sexual maturity. Chaturvedi (1976) also found that the number of ova per gram weight of ovary varied from 259 to 361 and the number of ova per gram weight of fish from 24.61 to 36.35.

Kulkarni and Ogale (1991) reported that *T. khudree* attains sexual maturity at a minimum size of 900g. Basavaraja et al. (2002) reported that pond-raised *T. khudree* males attained maturity after one and a half years (weight: 25-40g) at Mangalore where temperature ranged between 25 and 31°C. Kulkarni (1971) has clearly followed the structure of eggs and their further development in *T. khudree* and stated that the eggs are bright lemon yellow in colour merging on golden brown resembling the eggs of *Gonoproktopterus kolus*. The perivitelline space is small and they absorb only a small quantity of water for increasing the size from 2.5mm (freshly laid) to 3.2mm (after water hardening).

Desai (1973) after extensive studies on *T. tor* reported that the ova diameter increased progressively from April to September and thereafter decreased gradually till March. The Gonado-Somatic Index (GSI) of females increased from March (2.85) to August (30.10) and declined in September (25.44) indicating the commencement of breeding in July-August. The GSI gradually decreased from October (6.56) to February (4.17) giving indication of continuity of breeding until February-March. The GSI of male fish also showed peak values in July-August.
The length weight relationship coefficient $b$ was more for $T. tor$ (3.02) compared with $T. putitora$ (2.88), which implies that the former takes less time to attain the size desired for maturity compared with $T. putitora$, owing to slower increase in length and weight. It was assumed that $T. putitora$ when living sympatrically with $T. tor$ has slower growth rate. Though $T. putitora$ does not mature prior to $T. tor$, its maturity is advanced somehow in the lake environment compared with that in the river. May be it might get better nutrition with efficient foraging in lakes where food can be obtained with minimal movement compared with the rivers where fish spends lot of energy to maintain its balance (Nautiyal, pers.com.).

2.9. AGE COMPOSITION AND POPULATION STATUS

The size and age composition reflects the state of population, as is also reflected by the maximum size observed from time to time (Nautiyal, 1990). Bhatt et al. (2000) reported that the samples comprised of 1-9+ age classes individuals in foothill Ganga. Of these, 2+ and 4+ together constituted 66.01%, while 1+ was merely 8.07% of the total stock. These results pertained to two segments of the population and not the whole population. Study of population indicated prevalence of fish below 30 cm TL, which can at the best be extended to 50cm TL. Considering the size reported earlier (137cm) and that observed recently (110cm), the numbers should be more but fragmentation of the habitat has resulted in the reduction of its area of occurrence, thus inhibiting the population growth. With respect to age composition, Nautiyal (2006) found that in the Ganga river system stock, the age group 0+ was dominant (43.2%) and 0-1+ comprised 69% and 70% in male and female, respectively. The age group 0+ to 4+ (pre-reproductive) constituted 90% of the total population.

A stable population represented by bell-shaped pyramid should have a moderate proportion of young to old, which was not the case of the Himalayan mahseer because the share of middle and older age classes (9+ onwards) was extremely low as 0+ to 4+ age group formed a sizeable component of mahseer fishery. Since higher age classes are removed from natural environment and very few remain to be recruited to higher age classes and contribute to recruitment. The
broad based pyramid due to high predominance of 0+ age group indicates truly increasing/recovering population showing no much competition for resources. It seems that *T. putitora* population in Garhwal region might have been biologically over fished and would remain as a rapidly growing population till it becomes extinct or just manages to survive. The projected K (0.035- 0.041 year\(^{-1}\)) and the total (instantaneous) mortality rates of 0.366 - 0.589 (Bhatt and Nautiyal, 1999) for *T. putitora* from the Ganga river system indicate slow rate of increase. The exploitation rate so essential to determine the MSY has also increased from 0.376 to 0.7 while exploitation ratio from 0.85 to 0.89 over the last two decades. E>0.5 is considered to be over fishing (Nautiyal *et al.*, 2007).

According to Johal and Kingra (1989) the estimate of harvestable size for the reservoir mahseer from Gobindsagar was much low (38.62, 2-3+ age) compared with 65.6cm observed for the Gangetic mahseer. The latter estimate seems to be true as it approaches the size at maturity (Nautiyal, 1984). However, the Gangetic mahseer is being harvested at much lower size (19-46cm- Ganga; 10-28cm-Saung; 1-19cm-Nayar; 10-46cm-Alaknanda). On the basis of the average growth constants, three phases of growth were evident in the Himalayan mahseer; the first immature phase extending up to 5+, the second, mature extending up to 12+ and the third old age from 12+ onwards (Nautiyal, 2006).

### 2.10. MOLECULAR STUDIES

Molecular techniques have been used extensively to study the taxonomy. National Bureau of Fish Genetic Resources (NBFRG) developed a number of genetic markers and determined genetic variations not only among different species but also within the population (biological stocks) of the same species of mahseer. The chromosomal banding techniques or NOR (Nucleolar Organizer Region-cytogenetic method) and C-banding have been developed for different endangered and commercial species including *T. putitora*. Mohindra *et al.* (2004) identified micro satellite loci in *T. putitora* and the loci were found to be suitable for genetic diversity analysis. Genetic population structure analysis of natural population of *T. putitora* has been carried out using the identified polymorphic micro satellite and allozyme markers from rivers of Indus, Ganges and Mahanadi system (Ranjana,
The study revealed moderate level of population sub structuring in *T. putitora*. Genetic relatedness between five mahseer species (*T. putitora*, *T. tor*, *T. khudree*, *T. mosal mahnadicus* and *N. hexagonolepis*) was described using RAPD markers (Mohindra *et al.*, 2004). The results demonstrated that the *T. mosal mahnadicus* of the river Mahanadi is closer to *T. putitora* than to the other *Tor* species. The authors are of the opinion that reassessment of its taxonomic position is required. Lakra (1996) reported karyotypes of three species of mahseers, *T. putitora*, *T. tor* and *T. khudree*. Interestingly, apparent differences in karyotypes and NOR band have been observed even in the closely related species like *T. khudree* and *T. mussullah* (Anon., 2001a & b). Differential growth rates, maturity stages and sex ratio of *T. putitora* in the riverine as well as lacustrine populations were studied by National Research Centre for Coldwater Fisheries (NRCCF) for determining the stocks with potential performance for sustainable reproductive management of the species. Further efforts were also made to scrutinize the sex-linked biochemical parameters in different stocks for using them as markers in sex identification (Anon., 2003).

Attempts were made by NRCCF to investigate the sex linked enzyme activity. The five muscle enzymes viz. Glutamo oxaloacetate transaminase, Glutamo pyruvate transaminase, Lactate dehydrogenase, Alkaline phosphatase and Acid phosphatase were estimated spectrometrically as per standard methods. The enzyme values observed did not elicit any significant difference in relation to sex. Singh and Kapila (2005) tried the sex manipulation in *T. putitora* by incorporating $17 \alpha$ Oestradiol @ 150 µg/g feed, which induced feminization up to 69.5%. This technique may help to rectify the difference in the sex ratio of the wild populations and for better reproductive management.

Comparative cytogenetic studies were carried out in two mahseer, *T. tor* and *T. putitora* to identify species-specific cytogenetic markers. Chromosome number in both species was observed as $2n = 100$. Restriction Enonucleases (RE) digestion was studied in *T. khudree* and *T. mussullah* to get the RE banding of these fishes. Characteristic serial bands were observed on all chromosomes, which are useful for the identification of homologous chromosomes and ascertain the identity of the species. Kushwaha *et al.* (2001) studied the chromosome number of these two
species. The chromosome formula derived were 18m + 16sm + 44st + 22st and 22m + 24sm + 24st + 30t for the two species respectively, with common diploid (2n) chromosome number 100.

2.11. AQUACULTURE

There was an apprehension that these fishes could be reared only in cold waters which was contradicted by Karamchandani (1972). He concluded that though *Tor khudree* is an inhabitant of hill streams, it thrives well in waters with high temperature ranges also. Badapanda and Mishra (1992) reported the transplantation of *T. khudree* to Sonepur, Orissa during 1987 for a culture trial. One consignment of 5000 fry with an average size of 10mm was transported from Lonavala to Sonepur Fish Farm by rail and road. The result was encouraging that even after a long transit of 57 hours; the fry were quite healthy indicating that they can withstand long transportation. During the 254 days of rearing, the fish were fed with Ground nut oil cake and rice polish at 1:1 ratio. As the physico chemical parameters like pH, dissolved oxygen, total alkalinity, and free carbon dioxide were in the acceptable limits, the only parameter that could be attributed for the poor growth was the high temperature of the region.

Kulkarni (1971) proved that mahseer is an apt species for aquaculture and attempted the commercial seed production of the group. N.B.F.G.R. has identified *T. khudree* as a potential cultivable species. The constraints identified were lack of standardized seed production technique, dearth of information on the biology especially on the reproduction as well as scarcity of spawners and seed. Breeding and larval rearing technologies are available for many species of mahseer now and it has been prioritized as a group not only for aquaculture but also for ranching. The copper mahseer is reported to be suitable for culture in ponds and is used for stocking in Tamil Nadu (Pisolkar, 2000).

Since *T. khudree* generally shows a slow growth in the ponds and reservoirs, its culture trials were carried out in floating cages in open waters (Kohli et al., 2002). The experiment was conducted in Walwan lake, Lonavala with a water spread area of 6.216 km$^2$ in cages made up of HDPE knotless webbing of 15 mm mesh size. Each cage was stocked with 450 nos. of *T. khudree* fingerlings with an
average length of 161.38±25.63mm and average weight of 35.2±22.38g. The fishes were fed with formulated feed twice a day @ 2-10% of body weight. After the culture period of 371 days, total increment in weight (g) in the three cages were 173.60, 217.74 and 358.55 with percentage survival of 46.67, 56.67 and 35.35 respectively. Sunder et al. (1993) stocked golden mahseer in flow through tanks (2m²) and fed with a diet containing 30-45% protein @ 10-15% of body weight. After a rearing period of 3-4 months, the fishes attained a size of 50-65mm (0.095-0.250g) with a survival of 68.8-80.3%. Kohli et al. (2005) stocked T. putitora having initial length and weight of 100-140 mm and 5-25 g in cages. The stocking density was 25 nos/m³. After the culture period of 356 days, the final harvested length and weight of the fish were 180-290 mm and 180-250 g respectively with a survival percentage of 68.89.

Raina et al. (1999) grew T. putitora in manured ponds, for an year, with artificial feed and obtained a survival rate of 55%. Islam and Tanaka (2004) after conducting pond culture trials concluded that T. putitora is a highly promising species for commercial aquaculture and the fish performs well if proper dietary conditions are met. Conducting culture trials in properly managed earthen ponds, National Research Centre for Coldwater Fisheries could realize a size of 210 mm and 175 g for T. putitora within one year.

Ogale (2002b) reported that in village ponds near Lonavala, Maharashtra T. khudree has grown between 600-900g in one year and in Bhatnagar reservoir near Pune the fish is reported to be growing even faster. Experiments conducted in Lonavala (Ogale, 2002 b) proved that T. khudree fingerlings could be grown to 110-120 g in monoculture at a stocking density of 11,000/ ha in 8 months with the conventional feed of rice bran and ground nut oil cake (1:1). Monoculture of T. putitora was also carried out at Lonavala with pelletized feed prepared with rice bran, ground nut oil cake and fish meal (30:30:40) and mineral mix. The average growth obtained was 110 g and 90 g at stocking densities of 10,000 and 20,000/ha respectively. Badapanda and Mishra (1992) observed discouraging growth rate in T. khudree reared in ponds and concluded that the fish grows well only at lower temperatures. There are other reports too, depicting that T. putitora and T. khudree are relatively slow growing and cold loving (Pathak, 1991, Bazaz and Keshavanath,
1993; Sharma, 2001; Keshavanath et al., 2002). Therefore, lower growth rates are likely to be obtainable in confined environments with relatively high temperatures.

2.11.1. Nutritional studies

Aquaculturists have been trying to find out nutritionally balanced diet by incorporating different ingredients in varied proportions. Effect of feeding different levels of sardine oil on growth, muscle composition and digestive enzymes of *T. khudree* was studied by Bazaz and Keshavanath (1993). Sardine oil was incorporated in the feed at varying percentages (3-12%) into the 40% protein diet and fed to *T. khudree* fingerlings for 126 days at 5% of body weight daily. At the end of the experimental period, all the treated groups differed significantly. Higher feed efficiency was recorded with 6% oil incorporated diet. Fish survival ranged from 80.33 to 90%. Viscerosomatic index, VSI (expressed as viscera weight/total fish weight×100) was higher for the treated fish. The results clearly indicated a positive correlation of sardine oil on weight gain of the fish. Incorporation of silkworm pupae as a protein source in the diet of Deccan mahseer was tried by Shyama (1990) and found that it has no adverse influence on flesh quality, the optimum level of inclusion being 60%. Spirulina was used as an effective protein source for the species by Keshavanath *et al.* (1986). Several experiments and trials have been conducted at NRCCF to formulate diets for various life stages of Golden mahseer by using local ingredients like soyameal, silkworm pupae, rice/wheat starch etc. On the basis of these investigations, it was observed that the early rearing stages of mahseer up to advance fry/ fingerlings (45 - 55 mm) require about 45% of protein (Mohan, 2002).

Islam (2002) after conducting studies in indoor and outdoor systems on *T. putitora* in monoculture concluded that the indoor culture of mahseer is discouraging and unprofitable. So he suggested for polyculture for better yields. Three feeds with 20%, 25% and 30% protein were given to *T. putitora* in two phases. In the outdoor phase, the net increase in length and weight were 8.1, 8.3, and 8.6 cm and 68.3, 69.6, and 76.7g respectively, whereas in indoor phase, it was 4.3, 4.2, and 4.8 cm and 18.6, 22.9, and 22.8 g. Production was 471.4, 541.9 and 497.3 kg/ha in the out door phase and 83.7, 170.5 and 161.5 kg/ha in the indoor phase respectively. Bazaz and Keshavanath (1993) reported weight gains of 19.37-
25.65 g in an experiment with four different types of feeds (37.12-39.8% protein) on *T. khudree* for 126 days. Butt and Khan (1988) reported that lower growth rate is associated with lower appetite and insufficient food utilization due to carnivorous behaviour of the fish. Nautiyal and Lal (1985c) and Sharma (1987) observed that animal food comprises a higher proportion of the natural food of mahseer. Bazaz and Keshavanath (1993) conforming to the observation made by Srinivasamurthy and Keshavanath (1986) reported that protein requirement of *T. khudree* is 40%. Sunder *et al.* (1998) reported better growth, survival and feed conversion with 45.4% crude protein in *T. putitora* after conducting a growth trial with six formulated diets containing 21.4-50.2% crude protein. In an early study, Joshi *et al.* (1989) reported 35% crude protein as the best for growth and feed efficiency in *T. putitora*.

A feeding trial conducted on *T. khudree* by Srikanth (1986) incorporating cheaper, unconventional protein sources (de-oiled silk worm pupae, prawn waste and leaf powder of *Leucaena leucocephala*) revealed that the feed incorporated with de-oiled silk worm pupae has resulted maximum growth over a period of 126 days. According to him, the ideal diet may contain 40.39% crude protein, 6.56% crude fat, 25.99% carbohydrate, 7.06% crude fiber, 10.67% ash and 9.33% moisture with a calorie content of 3.65 kcal/g. The weight gained by the individual fish grown on the best diet ranged from 60.4g to 70.32g (Av. 64.42g). The average daily increment was 0.51g and net gain in weight was 54.68g. Keshavanath *et al.* (1986) reported that incorporation of 17 α methyl testosterone @ 2.5 ppm to the diet has improved the growth and survival in *T. khudree*. Hormone feeding enhanced muscle protein and fat contents in the fish meat and the organoleptic characteristics remained unaltered (Keshavanath, 2000).

2.11.2. Artificial propagation

Artificial fecundation of eggs of true mahseer (*T. khudree*) was successfully carried out on a large scale for the first time in 1970 (Kulkarni, 1971). Natural breeding of mahseer has been reported in reservoirs, lakes and ponds during the monsoon and in other seasons (Kulkarni and Ogale, 1978; 1991; 1995). They attempted breeding of four species of mahseer using hypophysation and stocked them in ponds. Successful spawning of pond raised mahseer, *T. khudree* using
inducing agents like pituitary extract and Ovaprim was reported by Nandeesha et al. (1993). In order to overcome the problem of non-availability of ready to spawn fishes from the wild, they tried to raise the mahseer brood stock in culture ponds at the Harangi fish farm in Kodagu District of Karnataka. Normally mahseer does not attain sexual maturity in captivity with normal food, which was overcome by providing a good quality feed. Even though the protein content of the feed was a little lower (31.49%) than the earlier reported protein requirement for the species ie. 40% by Srinivasamurthy (1985), the deficiency might have been nullified by the natural food available in the pond. The fat level was also kept low (4.63%) to avoid excess accumulation of fat, which they assumed may hinder proper maturation. The addition of vitamin mixture must have contributed to the maturation as the vitamin E is known to play an important role in maturation of gonads. The mature fishes could be spawned with injection of either pituitary extract or Ovaprim as described by Jhingran (1991), followed by stripping. In similar trials conducted at Mangalore, a coastal place, away from the original habitat of the mahseer, Keshavanath et al. (2006) observed that cryopreserved spermatozoa of the species performed comparably (P>0.05) with that of normal spermatozoa in terms of fertilization rate and quality of hatchlings. As expected the duration of egg hatching and yolk absorption were found to be temperature dependent. Fertilized eggs incubated in Mangalore at 27-28°C took 60 hours for hatching and 95 hours for yolk sac absorption, while it took 120 hours and 238 hours respectively when maintained at 20-24°C in Harangi.

Tripathi (1978) attempted breeding of *T. putitora* by stripping on a small scale. Kulkarni and Ogale (1978) elaborated this method fertilizing more than five lakh eggs of *T. khudree* every year since 1974. Jan and Dogra (2001) developed the brood stock of *Tor putitora* in ponds collecting the fingerlings of the species from Anji stream (Reasi) in District Udhampur of Jammu & Kashmir. The breeders were fed on mustard oil cake and rice bran supplemented with sheep/goat lungs, six months prior to breeding. After a period of 3 years, the farm reared breeders were given a single dose of *Ovaprim* and fertilized eggs were obtained by stripping. Subsequent fertilization and hatching was achieved in trays at a specially designed hatchery yielding 5000 fry. Even though the production rate attained was low, the
effort taken by the team seems significant since it narrates the possibility of establishing small scale hatcheries with limited facilities. Another important achievement in the artificial breeding of mahseer was the effective transportation of fertilized eggs by air in moist cotton wool, without water, over long distances (Kulkarni, 1984).

Ogale and Kulkarni (1987) reported that *T. khudree* and *T. tor* could easily be hybridized using the eggs of the former and milt of the latter. Fertilization was almost cent percent and hatching rate was 90%. The resultant progeny showed intermediate characteristics of both and the growth rate was comparable to the parents. They have further bred these hybrids (females) with the *T. khudree* males and provided satisfactory results. Induced breeding of Golden mahseer was successfully done at Dhakrani, U.P. State Fish Farm with 80-85% fertilization and over 60% hatching rate (Panday *et al.*, 1998). It took a period of 72 to 120 hours for the hatching process. Mohan (2002) and Mohan *et al.* (1998) observed that finely emulsified chicken egg yolk followed by smashed goat's liver particles have given excellent results in the larval and post larval rearing of Himalayan mahseer. The advantage of providing egg yolk is that it breaks up into particle of few hundred microns in diameter which can easily be consumed by the larvae. As the goat’s liver is more expensive, a fine mixture of GOC and rice bran is followed after the first phase of feeding with egg yolk in some hatcheries.

Short term preservation of spermatozoa of the Deccan mahseer was carried out by Basavaraja and Hegde (2005). It was observed that total spermatozoa count obtained from Ovaprim-injected male (6.5×10^8-7.6×10^8) was much higher than that of the uninjected fish (1.3×10^8-1.8×10^8). But the spermatocrit values (38.7-39.4%) were lower in treated fish than that of the untreated fish (61.5-63.1%). They have also reported that the spermatozoa density varies with the season and proved that the spermatozoa of *T. khudree* could be preserved in a motile state for 4-5 days which suggests the application of this technology for implementing more effective propagation programmes. Patil and Lakra (2005) reported successful sperm cryopreservation protocol for two mahseer species, *T. khudree* and *T. putitora*.

The Tata Power Company Ltd., Lonavala, Maharashtra did pioneering work in conservation, breeding and artificial propagation of mahseers. Under the
leadership of Late Dr. C.V. Kulkarni and Mr. S.N. Ogale, TPCL standardized the commercial seed production of five species of mahseer, viz., *T. khudree, T. mussullah, T. tor, T. putitora* and *T. kulkarni* (?) and augmented the mahseer stocks in the reservoirs and rivers in many States in India by supplying fry and fingerlings. NRCCF established a flow through hatchery, and every year thousands of advanced fry of Golden mahseer are being produced and distributed for ranching the mahseer-depleted water bodies. The design is simple, small and temporary which can be dismantled at a very short notice in emergency conditions. In Karnataka, mahseer seed production is carried out in Harangi Hatchery of the Department of Fisheries since 1997 with the support of TPCL and College of Fisheries, Mangalore. The Department of Fisheries, Govt. of Kerala through its agency, Fisheries Resource Management Society (FIRMA) established a mahseer hatchery in Wayanad District and attempted the artificial seed production of *T. khudree* with the technical assistance from NRCCF (Sajiv, pers.com.).

The freshwater fish diversity of Kerala is facing serious threats as reported by many workers (Menon, 1993; Kurup and Radhakrishnan, 2007; Kurup, 2010). Biodiversity threats in the form of diverse types of human interventions are the main reasons for the alarming decline of fish populations in most of the rivers (Kurup, 2010). Indiscriminate fishing of mahseer was reported for the first time by William Mitchell, ESQ (in: Lacy and Cretin, 1905) while preparing notes on the ‘River Mahl’. He narrated that *machans* were placed over every pool and rapid, where fish were likely to show themselves and native sportsman with a loaded gun blazed fish at the moment they showed. The spawning grounds were the favourite places for the gunners. In addition to the gunners, every kind of fish trap that human ingenuity could devise, were laid along the river to catch the bigger ones. Menon et al. (2000) reported that since there are no restrictions on the use of gill nets of smaller mesh size and fishing activity is carried out through out the year, juveniles and brood fish are invariably killed. Unscientific and spurious fishing methods like explosives and ichthyotoxic plants which not only kill the desired fish but also pollute the water bodies are also affecting mahseer population adversely. Nautiyal (1989) listed two constraints, natural (delayed maturity, low fecundity, long hatching period of 60-80 hrs at 24-28 °C and slow growth rate) and created (such as
habitat fragmentation, overexploitation), as the factors responsible for the decline of Himalayan mahseer. Jayaram (1994) reported that the hatched out young ones will remain in semi-quiescent stage for about 6 days as clusters in corners and crevices which will lead to high rate of predation and mortality.

Jayaram (2005) discussed many reasons for the decline of the mahseer in the Western Ghats. It is pointed out that extensive deforestation has taken place in the Western Ghats during the last hundred years. The forest fragmentation that resulted as a consequence of deforestation affects the distribution of animal species by reducing their core habits. River courses have changed and some of them have been shrunk with less flow of water and discharge. Channelisation for irrigation purposes, loss of thick vegetation and want of foliage cover has resulted in greater evaporation and loss of prime habitats for fish survival. Harmful fragmentation accelerates extinction besides demographic pressures. Deforestation in the catchment areas is responsible for soil erosion, siltation and turbidity. Due to these factors fish do not breeds and even if they breed the eggs do not survive. Such environmental degradation decreases genetic diversity also. It is also noticed that majority of the streams in the Western Ghats do not show zonation of water quality parameters and biota and are extremely of short run from their source to the plains. As these streams are short lived and do not flow through tumultuous courses or through deep canyon, normally lack large-sized fish except in Cauvery, Bhadra and a few rivers of Kerala (Jayaram, 2005.).

D'Cruz (2010) reported that biodiversity of the Western Ghats is under severe stress due to a variety of factors. Deforestation, unsustained agricultural practices, sand mining, waste disposal and irresponsible and destructive fishing practices such as dynamiting, electric fishing, poisoning etc. are some of the threats to fish biodiversity. He further stated that unscientific construction of dams and reservoirs not only affects the migration and proliferation of fish, but also affects summer flows in the river system which sustains fish life.

Oliver et al. (2007) highlighted about a special type of bag net used by the fisherfolk which is operated across the water fall in the down stream of the reservoir in Harangi river in Karnataka during the breeding migration of mahseer. When the fishes try to cross over the water fall they fail to do so and fall back into the bag.
which is set up to cover half of the waterfall. It is also reported that fingerling and fry fishing of mahseer by fishermen for their subsistence is a major issue in Umiam reservoir of Meghalaya which leads to a drastic decline in their population (Vinod et al., 2007).

National Commission on Agriculture has recommended extensive surveys in 1976 to find out the status of mahseer in the rivers of India (Anon., 1976). As a result, Trans World Fishing Expedition (TWFE) and a mission by Boote (1979) were carried out to assess the stock of mahseer in various river systems. Indian Tourism Development Corporation (ITDC), Air India and Wild Life Association of South India (WASI) have collaborated with the missions. Department of Fisheries, Karnataka, launched a programme in 1987 “Rehabilitation and Development of Mahseer Fishery in the Rivers and Reservoirs of Western Ghats”. As a part of the programme, a 5 ha mahseer hatchery was commissioned to produce 500,000 mahseer seed for stocking rivers and reservoirs in the region. Fishery management of *T. khudree* is done effectively in Cauvery river as WASI is taking care of stocking the leased stretch of the river with mahseer fingerlings (Shanmukha, 1996). Currently, the fishing is open to licensed sport fishermen from October to May. Only rod and line fishing is allowed. Any captured mahseer has to be carefully unhooked and after recording its length and weight it must be released back. Dynamiting and poisoning are strictly prohibited in the region. This can be taken as a model and effectively extended to other rivers also.

In the North East Himalayan region, mahseer catch has been reported to be declined to the level of 45-60% and the tribes and new illegal migrants have started netting the fish of 100 g size (Raina et al., 1999). Kumar (1988) reported the disappointing situation of decline in catch and size of mahseer in Central Himalayan region. Even though the *Tor* species once contributed a significant proportion of the natural stock of fish in India, their populations have dwindled to such an extent that they have been categorized as critically endangered species (CAMP, 1998). Arunachalam et al. (1998) listed *T. khudree* as a vulnerable species and *T. mussullah* as a critically endangered species exhibiting a patchy distribution only in the Western Ghats. *Tor putitora* is today included in the endangered category (Sehgal, 1992; Tandon et al., 1992) but many scientists have difference of opinion
on this observation as the information is not matching with the IUCN published records (Nautiyal, pers. com.). It has to be admitted that depletion of mahseer population has been reported from all parts of the nation in recent years due to the reasons cited elsewhere (Sehgal, 1987; Joshi, 1988; Kulkarni, 1991; Agarwal, 1994; Desai, 1994; Dubey, 1994; Pathani, 1994; Sehgal, 1994; Sinha, 1994; Dhanze and Dhanze, 1994; Gupta and Khan, 1994; Pandey et al., 1994; Singh et al., 1995; Mahanta et al., 1998). Jayaram (2005) noticed mahseer specimens with fungus-infested fins mainly due to indiscriminate throwing of plastic bags containing remnants and left over of eateries in certain sanctuaries. There are reports stating that fish ladders provided in head waters of certain irrigation projects are ineffective and act as traps rather than fish passes (Raina et al., 1999). Thorough studies are required on the migration behavior of mahseer on a national basis, which could serve as a base for designing appropriate fish ways across the dams.

Based on the information collected from several streams/rivers covering twelve river basins representing the States of Karnataka, Kerala and Tamil Nadu part of the Western Ghats, ten mahseer sanctuaries are proposed in various rivers in Karnataka (Basavaraja and Keshavanath, 2000). They have also suggested in situ and ex situ conservation measures for mahseers. Traditional conservation measures- passive steps- like declaration of areas as sanctuaries, closed seasons for fishing, mesh size regulation for gears, reserving certain stretches for rod and line only, enforcement of 'bag-limits' and 'catch limits' and penalty for adopting destructive fishing methods etc. will help to a great extent. Government of Himachal Pradesh has incorporated a special clause in the Fisheries Act that fishing during the breeding season has been made a cognizable non-bailable offence inviting imprisonment up to three years. Sarma and Bhuyan (2007) suggested that the conservation of mahseers in Meghalaya can effectively be undertaken through the intervention of local ‘Dorbar’, a unique self village governing system prevailing in the State. In fact, the most critical aspect is creating awareness among the common man on the protection of the endangered fishes. Active steps include quantitative improvement of natural stock by transplantation of farm reared stocking material produced in the hatcheries.
Mohan et al. (1998) are of the opinion that there are two effective ways to conserve fish germplasm, the first method is to allow the left over stocks to multiply and second to stock the depleted water bodies. The first technique may sound good for only those areas where at least some stock is left. But for those areas from where mahseer has completely disappeared, stocking is the only alternative. Where ever impoundments have been built or are coming up, establishment of mahseer seed production units should definitely be a primary requisite. NRCCF stocked Golden mahseer in Shyamlatal lake, Kumaon in 2001 wherein it has survived very well, grown to mature sizes and turned out to be an attraction for tourists. It can be expected that stock so introduced may continue for generations and may be served as natural sanctuaries. These kind of efforts can be suggested in all the regions where ever mahseers exist.

A series of programmes were organized by NBFRG in the Kumaon region and “Mahseer Bachao Gosthis” launched to conserve endangered mahseer. Socio-economic aspects of conservation and the role of anglers have been evaluated in selected areas exploring the possibility of community participation. Since the pattern and regulation of fishing have a great impact on the fish population dynamics in the streams, detailed information on fishing methods under operation in Kumaon region were documented. This includes eight indigenous methods being used by the local community. In India, mahseer spermatozoa cryopreservation protocols have been developed by several workers (Ponniah et al., 1999a; Ponniah et al., 1999b; Basavaraja et al., 2002; Basavaraja and Hegde, 2004, Patil and Lakra, 2005). This technique may help to provide gametes for artificial propagation programmes in the off seasons also. A mini gene bank with the milt of T. putitora and T. khudree has been established by NBFRG.

Menon et al. (2000) suggested that suitable segments of the rivers with mahseer should be identified for establishment of ‘fish sanctuaries’. At present fishing is prohibited on religious grounds in certain stretches of Ganga (eg. at Har-ki-pairi, Haridwar and Muni-ki-Reti, Rishikesh) and also in some temple ponds along Gomti in the Kumaon region of Uttarkhand. Jayaram (2005) mentioned about some protected areas by the side of temples as in Dehu, Alandi on river Indrayani, Sringeri on Tungabhadra, Ramnathapura on Cauvery and certain water bodies of the
sacred groves where mahseer is guarded. Other places of mahseer conservation include Thingale in Sita river of Uduppi District, Shishila in South Canara District and Hariharapura in Thunga river. Mahseer reserves or sanctuaries existing in Kumaon Himalaya include Kali, Saryu, Ramganga (E), Ramganga (W), Gomti and Kosi (Anon., 2001b).

In Sringeri, depth of the mahseer habitat ranges between 15 to 50 cm and the water is very clear so that fishes are highly visible. As the biomass of the area is too high, minor changes in the water quality may affect the whole population. Such an incident was reported in 2004 where the local people applied copper sulphate in the up-streams for harvesting the fishes to celebrate the Sivarathri festival which caused mass mortality of mahseer in 4-5 km stretch of the river. It was stated by the local people that tones and tones of surige (local name for mahseer) had to be removed from the river in rotten condition by the Sringeri-temple authorities. Oliver et al. (2007) reported about another massacre of mahseers at Shishila temple in Karnataka wherein about 10 truck loads of mahseers were killed by poisoning with endosulphan as a result of rivalry between two communities. Such kind of incidents can be avoided only by creating awareness among the local people about the importance of species conservation and ill effects of using indiscriminate fishing methods. Also the legislation has to be strengthened against the culprits who directly or indirectly involve in killing the silent creatures.

In Ramnathapura of Cauvery, mahseers are conserved in protected areas separated by rubbles. Interestingly, different colour forms are noticed here like orange, silvery, and black. Villagers use this water body for taking bath and washing their clothes which may cause adverse effects on the fishes in the long run. The mid stretches of Cauvery characterized by sinuosity of riffles and deep pools also offer an ideal habitat for mahseer (Ganesh and Nagendra Babu, 2005). The deep pools around Galibore, Bheemeshwari and Doddamakkali having depth of 5-15m, width of 250 to 300m and length up to 300-400m even in summer, offer excellent refuge even for the larger fishes of 30-40kg. Certain areas are declared as sanctuary and poaching is almost nil due to strict vigilance. The same authors further reported that a few poachers in the stretch have been given an alternate avocation to perform the patrolling duty of watchmen!