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Mahseers in India: A review with focus on conservation and management

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ABSTRACT

Mahseers inhabit the rivers and freshwater lakes of South and Southeast Asian countries. In India, the group is well distributed right from the Himalayas up to the rivers of the Western Ghats. Most of the species belong to the genus *Tor*. Owing to their excellent sporting quality, the mahseers have been variously called as the 'king', 'lion', 'tiger', 'the great fighter', etc., by the anglers. In certain parts of the country, it has also been even given the status of a 'divine fish'. Due to the similarities in the morphometrics and meristics, difficulties have been encountered in the correct identification of this group of fishes and recently molecular techniques have been used to resolve such ambiguities. To the local fisher folk and the tribal people residing along the up-streams of rivers, mahseers have been of considerable importance as they contribute much to their livelihood as well as food security. Despite their abundance at one time, mahseers are declining rapidly in different parts of India making them a 'threatened' group. Breeding technology has helped in undertaking conservation programmes of the Himalayan mahseer (*Tor putitora*) and the Deccan mahseer (*Tor khudree*). Efforts have also been made to understand the nutritional requirements of these species and to culture these species along with other carps. Though the conventional farming of this fish is not promising because of the slow growth compared to the Indian and Chinese carps, however, by formulating practical diets and appropriate technologies there is scope to harness the potential of this group of fishes. The culture of mahseers has to be undertaken with a multifaceted approach considering their value in sport, food and aim at their conservation and scientific management. The involvement of the private sector like Tata Power Company Ltd., in the conservation of the mahseer has shown that long term commitment can bring desirable outputs. The Coorg Wildlife Society is also trying for the management of the group by promoting the 'ecosystem based fish habitat conservation'. These examples clearly demonstrate the involvement of the private and public sectors with the peoples' participation would provide the much needed support to protect this important group of fishes. In this review, an effort is made to assess the progress on various aspects of taxonomy, biology, nutrition, reproduction, aquaculture and conservation of mahseers. The opportunities available to improve the livelihood of people by increasing the research and development efforts on this group of fishes and its tourism potential are also discussed.

Key words: Aquaculture, Conservation, Food and feeding, Mahseer, Management, Molecular markers, Taxonomy, *Tor*

Indian Mahseers, the big scaled carps have been an excellent sport fish and attraction to anglers as well as naturalists from all over the world since the nineteenth century. Langer *et al*. (2001) while compiling the bibliography of mahseers of the Indian sub-continent described this group as the 'King of Indian aquatic systems'. The mahseers are not only well known sport and food fish, but they are also our national heritage (Oliver *et al*. 2007). They are generally known to prefer cold, clear and swift flowing waters with stony, pebbly or rocky bottoms and intermittent deep pools (Dinesh *et al*. 2008). Several authors have observed that mahseer is declining in different parts of India owing to the indiscriminate fishing of bloodstock and juveniles, fast degradation of aquatic ecosystems, construction of dams, barrages and weirs and other anthropogenic interventions/intrusions (Sehgal, 1992; Tandon *et al*. 1992; Bhatt *et al*. 1998a; Nautiyal *et al*. 1998; 2007; Kumar, 2000; Menon *et al*. 2000; Ogale, 2002a; 2002b; Chalkoo *et al*. 2007; Dinesh and Nandeesha, 2007; Vinod *et al*. 2007; Oliver *et al*. 2007; Kalita *et al*. 2007). Because of the decline in the fishery, all the Indian mahseers have been listed as 'threatened' (Oliver *et al*. 2007). Mahseer is reported to be present generally in the *Tor* zone (600–1200 m) of the glacier-fed Himalayan rivers (Singh and Kumar, 2000) with much more extended distribution to the lower reaches in the peninsular Indian rivers (Ajithkumar *et al*. 1999). However, Bhatt *et al*. (1998a; 1998b) observed Himalayan mahseer from 273 m near Hardwar (29°52' N; 78°10' E) in the Ganga to 560 m at Banghat (29°57' N; 78°45' E) in the Nayar.

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Surprisingly, in Kashmir , it is even reported from an altitude of 1800 m from asl (32º17' to 36º58' N, - Prof. M. Balkhi, Agricultural University, Srinagar, Kashmir- pers. comm.). Raina *et al*.(1999) reported that they have the capacity to migrate upto an altitude of 2000 m from asl during south west monsoon. Jhingran and Sehgal (1978) reported that it is the index of thermal tolerance of the group which does matter during their migration and they avoid low temperature-areas, whereas, Nautiyal (2002) attributed the triphased migration of the group as an evolutionary response towards efficient utilisation of the food resources in the habitats. While the adults or prospective brooders may migrate 3-4 months in advance of the spawning season because of the homing instinct and for priming themselves before reproduction, the juveniles and adolescents seem to accompany them as part of the 'learning migration'.

Undeniably, mahseer is one of the fiercest fighting freshwater game fishes that exists in India with unparalleled strength and endurance (Dhillon, 2004) and so this is the only one word, fighting about and fighting against (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 the game as 'playing a mahseer'. The book, 'With Gun and Rod in India' published by the Indian Government in 1958, described mahseer as an ever fascinating lure to the hunter. 'Circumventing the Mahseer and other sporting fish in India and Burma' (Mac Donald, 1948) could be considered as the best treatise of Indian mahseer in every respect. Hora (1951) deliberated the indigenous knowledge that existed about this fish. The Golden Mahseer (biggest among the group) has been known to reach 2.75 m (9 ft) in length and 54 kg (118 lb) in weight (Talwar and Jhingran, 1991). A maximum length of 274 cm was reported by Hamilton (1822) earlier. A female measuring 148.0 cm from the Saryu River, Kumaon Himalaya is the only report available over the last two decades. A size of 137.5 cm was reported in early eighties (Nautiyal and Lal, 1981). Maximum weight reported for *Tor mussullah* and *Tor khudree* is 90 kg and 22.5 kg respectively (Gupta and Gupta, 2006). A female specimen of *Tor khudree* with a weight of 19.5 kg and TL of 99 cm was collected in 2006 from Kerala (Dinesh *et al*. 2008).

Taxonomy

Taxonomic uncertainity still remain in the identification of mahseers especially while the morphological characters are looked into. Many authors have critically analyzed and explained the systematic position of the various species fall under the Genus *Tor* and allied genera (Gray, 1834; Day, 1873; 1878; Hora and Mukherji, 1936; Misra, 1959) and many species/sub species got either included or excluded; no wonder, contradictory observations and explanations have also been reported (David, 1953; Menon,1992; CAMP, 1998; Jayaram, 1997; Jayaram, 1999; Mirza and Bhatti,1996; Gopalakrishnan and Basheer, 2000). Desai (2003) stated that the carps 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 status of freshwater fishes of the country has listed eight species of mahseer, *Tor khudree*, *Tor khudree malabaricus* (Jerdon), *Tor kulkarni*, *Tor mosal*, *Tor mussullah*, *Tor progenius*, *Tor putitora* and *Tor tor*. Talwar and Jhingran (1991) described eight species of mahseer commonly found in India of which seven belonging to the genus *Tor*; *T. putitora*,*T. tor*, *T. mosal*, *T. khudree*, *T. mussullah*, *T.* (*Barbus*) *neilli* (Day) and *T. progeneius* and one belonging to the genus, *Neolissocheilus*, *N. hexagonolepis* (the Chocolate mahseer). A tentative list of species with their identification characters and geographic distribution is presented in the Table 1. (adopted from Sehgal *et al*.2007 with other inclusions).

The species/sub species like *T. mosal*, *T. neilli*, *Naziritor cheylinoides*, *T. moyarensis*, *T. kulkarni*, *T. malabaricus* and *T. remadeviae* (Kurup and Radhakrishnan, 2007) are not

Table 1. *Tor* species reported from India

No.	Valid Species	Characters	Distribution
1	*T. putitora* (Hamilton)-Golden/Putitor/ Yellow fin/Himalayan mahseer	Head-pointed; HL > Depth; LL: 23-28	Complete Himalayas
2	*T. tor* (Hamilton)-Deep bodied/Red fin/ Turia mahseer	HL < Depth; LL: 23-28	Himalayas and Narmada
3	*T. khudree* (Sykes)-Deccan mahseer	HL = Depth; fins bluish grey; LL: 24-26	Orissa and Peninsular India south of Tapti
4	*T. mussullah* (Sykes)-Hump-backed mahseer	HL < Depth; LL:24-27	Peninsular India - Krishna and Godavari
5	*T. progenieus* (McClelland)-Jungha mahseer	HL = Depth; LL:27-31	Eastern Himalaya

Note : HL – Head length; LL- Lateral line

included as their taxonomic status is yet to be confirmed. NBFGR developed a number of genetic markers and determined genetic variations not only among different species but also within the population of the same species of mahseers. The chromosomal banding techniques or NOR (Nucleolar Organizer Region- cytogenetic method) have been developed for different endangered and commercial species including *T. putitora*. Mohindra *et al.* (2004) have identified microsatellite loci in *T. putitora* and the loci were found to be suitable for genetic diversity analysis. 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; Anon., 2001b). A comprehensive work, linking the traditional and molecular taxonomy, is suggested to resolve the problem of taxonomic ambiguity. The attempt by Silas *et al*. (2005) to find out specific identity of *T. khudree malabaricus* described by Jerdon (1848) by using Random Amplified Polymorphic DNA (RAPD) markers is worth mentioning. This is the first report on the application of RAPD technique for identification of a *Tor* species from the Western Ghats (Silas *et al*. op. cit). Further, Silas *et al*. (2009) confirmed the taxonomical status of *Tor malabaricus* by comparing the mitochondrial DNA of the species with that of *Tor khudree*.

Food and feeding

Valuable and pioneering information on the biological aspects of mahseer are available from the observations of the anglers. MacDonald (1948) noted that mahseer is an intermittent feeder. Green filamentous algae and other water plants, slimy matter encrusted on rocks, insect larvae, etc., have been recorded from the stomach contents of the Putitor mahseer. Thomas (1897) observed aquatic weeds of all sorts, seed of *Vateria indica* or dhup of the west coast; bamboo seeds, rice, paddy, crabs, small fish, earth worms, water beetles, grasshoppers, small flies, water or stone crickets, shrimps, molluscs or freshwater snails etc. in the gut of the fish. Karamchandani *et al*. (1967) and Desai (1982) reported the same feeding habit for mahseer with more vegetative preference. Pisolkar and Karamchandani (1981) also indicated that macrovegetation forms the major part and the animal matter forms the subsidiary portion in their gut.

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 and categorized them as marginal-cum-column feeders. 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 Putitora and confirmed their carnivorous habit. Variation in the dietary habits was observed in the early larval stages, 1–7 mm was omnivorous and 7–10 mm was carni-omnivorous. There were no differences between the two sexes with respect to diet. A definite shift from omnivorous/herbi-omnivorous to carnivorous is reported to occur in fish attaining 7 cm size which prove that it is the size that influences change in food habit. However, fish of 1+, 2+ and 5 + years of 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 can be categorised as the 'most preferred' food item of *T. putitora* owing to high values of Strauss Linear Index. The food spectrum is found to vary according to age, river systems and habitat. The rate of feeding in golden mahseer varied according to the season and this is evident from the studies of 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 microbenthic 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, Fragilaria, Oscillatoria, Zygnema, Spirogyra, Tribonema, Arcella, Keratella* and *Chironomus*. In the case of *T. khudree*, the food items of all age groups include the filamentous algae, benthic diatoms, small crabs, fishes and insects (Dinesh, pers.obs.).

Reproductive biology

Information is available on the breeding behaviour, season and sex organs of mahseer since the nineteenth century itself from the anglers and naturalists. Beavan (1877) reported the breeding period of mahseer as May to August with conspicuous local migratory behaviour. MacDonald (1948) noted that 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. The pioneering observation on the spawning of mahseer dates back to Cordington (1946). The brooder fish migrates 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) believed 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. 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 reported that the fish breeds there only once a year from July to September with peak in August. However, Khan (1939) opined that mahseer spawns more than once a year. 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).

Thomas (1897) recorded that mahseer breed during the post monsoon month and lay eggs in batches. 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 snow-melt water induce 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 250 mm total length. Nautiyal and Lal (1985a) 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 -137.7 cm and weight range of 3.5 to 23 kg.

The females of Himalayan mahseer commence to attain first sexual maturity at 40 cm of length in the river Ganga and 30.9 cm in the lakes of Kumaon. The smallest mature male measured 36.5 cm (370 gm) and 20.7 cm in the respective environments. In the mountain stretch of the Ganga in Garhwal, the males mature at 30-50 cm and the female at 50-70 cm (Nautiyal, 1984). The calculated weight at the onset of sexual maturity was 1119.21gm- the observed average weight being 875.5 gm- and the age 3+ years (Nautiyal, 1990). It was further 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 higher 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. Desai (1973) after extensive studies on *T. tor* reported that the ova diameter increased progressively from April - 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.

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 during September-October (Basavaraja *et al*. 2006). 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. Since fingerlings are available in all seasons in the rivers of the Western Ghats, it can be believed that mahseer breeds not, less than two times in an year in these rivers. In Kerala also the breeding of Mahseer takes place in the June-July and Novemeber-December seasons. The minimum size at first maturity is recorded as 180 mm (320g) and 280 mm (740g) for the male and female respectively in *T. khudree*. The presence of fry and fingerlings of the species in the small channels (with average width and depth of 3 and 0.5 m , respectively) draining the Chalakudy River in Kerala clearly indicates that the brood stock migrate to these very small waterbodies for spawing. The lodging period of the spawners can only range from a few hours to a few days as far as the extremely low carrying capacity and erratic waterflow of these channels are concerned (Dinesh, pers.obs.). Kulkarni and Ogale (1991) reported a higher weight of 900g for attaining sexual maturity in *T. khudree*. Basavaraja *et al.* (2006) reported that pond-raised *T. khudree* males attained maturity after one and a half years at an unbelievably lower weight of 25-40g at Mangalore, where the temperature ranged between 25 and 31^0 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 2.5 mm (freshly laid) to 3.2 mm (after water hardening).

Aquaculture prospects

Mahseer was identified as a candidate species for

aquaculture because of its sporting quality and excellent flavour of flesh since the last century itself (Day, 1876). Dhu (1923) judging the growth of mahseer fry in Mahanadi river stated that it can be well cultured in the ponds. David (1953) indicated the possibility of culturing *Tor mosal mahanadicus* recording a growth of 170 - 200 mm within four months. But no attempts were reported on the culture of the group for the next two and a half decades, the major constraint encountered might have been the non-availability of the stocking material. There was an apprehension that these fishes could be reared only in cold waters which was contradicted by Karamchandani (1972). He concluded that though *T. 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.

Kulkarni (1971) proved that mahseer is a good species for aquaculture and attempted the commercial seed production of the group. National Bureau of Fish Genetic Resources, Lucknow 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 know how 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). After the culture period of 371 days, total increment in weight (g) in the three cages was 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 ($2m^2$) and 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%. While *Tor putitora* was used as a candidate species in cage culture, Kohli *et al*. (2005) could harvest the length and weight of 180-290 mm and 180-250 g respectively with a survival percentage of 68.89 after 356 days. 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 *Tor 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. 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 and 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 growers and cold-lovers (Pathak, 1991, Bazaz and Keshavanath, 1993; Keshavanath *et al*. 2002; Sharma, 2001). Therefore, lower growth rates are likely in confined environments with relatively high temperatures.

From the above account, it is quite clear that there have been very few attempts for assessing the aquaculture potential of the different mahseer species in India. Other than the NRCCF and College of Fisheries, Mangalore, no research organizations have come with encouraging results on mahseer culture. Freshwater aquaculture sector of the country has been mainly revolving around the Indian major carps and the Chinese carps since its inception aiming higher production rates. So the endemic fishes especially the mahseers had not received due attention in the culture scenario. Introduction of the exotics must have resulted in the intrusion of these species to the natural habitats of the endemics. At the same time, increased protein production due to the introduction also needs to be considered. So the need of the hour is to take up aquaculture programmes of different mahseer species in the pond and reservoir environments. Riverine fisheries and stock enhancement programmes can also be linked with mahseer seed production and culture.

Nutritional studies

Aquaculturists have been trying to find out nutritionally balanced diet by incorporating different ingredients in varied proportions to realize better production levels. 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) who 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% protein (Mohan, 2002).

Islam (2002) after conducting studies in indoor and outdoor systems on *T. putitora* under monoculture concluded that the indoor culture of mahseer is discouraging and

unprofitable and therfore, he suggested polyculture for better yields. 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* in 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*.

Srikanth (1986) reported that the ideal diet for *T. khudree* 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 average daily increment was 0.51g and net gain in weight was 54.68g while the experimental diet was used. Keshavanath *et al.* (1986) reported that incorporation of 17 á methyltestosterone @ 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).

Artificial propagation

Artificial fecundation of eggs of *Tor 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). The mature fishes could be spawned with injection of either pituitary extract or Ovaprim, 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 comparable (P>0.05) to the normal spermatozoa in terms of fertilization rate and quality of hatchlings. Fertilized eggs incubated in Mangalore at 27–28ºC took 60 hours for hatching and 95 hours for yolk sac absorption, while it took 120 hours and 238 hours respectively when maintained at 20–24ºC in Harangi.

Tripathi (1978) attempted breeding of *T. putitora* by stripping the eggs 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 Udhampur of Jammu & Kashmir. After a period of 3 years, the farm reared breeders were given a single dose of Ovaprim and fertilized eggs were obtained by stripping. Even though, the production rate attained was low, the effort taken by the team seems significant since it proved 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.

Short term preservation of spermatozoa of Deccan mahseer was carried out by Basavaraja and Hegde (2005) reporting that the spermatozoa density varies with the season and it 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 the successful sperm cryopreservation protocol for two mahseer species, *T. khudree* and *T. putitora.*

The Tata Power Company Ltd., Lonavala, Maharashtra did pioneering work on the conservation, breeding and artificial propagation of mahseers. Under the leadership of Late Dr. C.V. Kulkarni and Mr. S.N. Ogale, the TPCL standardized the commercial seed production of five species of mahseer, viz. *T. khudree*, *T. mussullah*, *T. tor*, and *T. putitora* and augmented the mahseer stocks in the reservoirs and rivers in many States by supplying fry and fingerlings. DCFR established a flow through hatchery, and every year thousands of advanced golden mahseer fry 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 the TPCL and the College of

Fisheries, Mangalore. The Department of Fisheries, Govt. of Kerala through its agency for the 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. Results are yet to be published.

Game fisheries, conservation and management

Importance of mahseer as a game fish has tremendous potential in India owing to the rich resources in terms of species diversity and water availbility. Kulkarni (1981) warned that mahseer, the king of Indian rivers, is in danger and highlighted the need to be protected. Raizada also (1981) gave a depressing account recommended to have more "mahseer projects" for conservation purpose. Menon *et al*. (2000) listed the reasons like use of gill nets of smaller mesh size, year round fishing activity, fishing with explosives, ichthyotoxic plants, *etc.,* for the disappearance of mahseer populations. Ogale (2002a) expanded the list to include (1) degradation of ecological conditions of aquatic systems, (2) indiscriminate fishing of broodfish and juveniles, (3) river valley projects, (4) industrial and anthropogenic intervention, (5) use of explosives, poisons and electrocution and (6) introduction of exotic species. Nautiyal (1989) pointed out two natural constraint like delayed maturity, low fecundity, long hatching period of 60–80 hrs at 24–28° C and slow growth rate and man made constraints like habitat fragmentation, and overexploitationas the factors responsible for the decline of Himalayan mahseer in the rivers. Oliver *et al.* (2007) reported about a special type of bag net used by the fishermen which is operated across the water falls in the down stream of the reservoir in Harangi River in Karnataka during the breeding migration of mahseer. 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 has resulted in the drastic decline of their population (Vinod *et al*.2007). Jayaram (2005) discussed many reasons for the decline of the mahseer specifically in the Western Ghats. It is pointed out that extensive deforestation that have taken place in the Ghats during the last hundred years might have been one of the major reasons. In the North East Himalayan region, mahseer catch is reported to be declined to the level of 45–60%. The tribes and the illegal migrants have started netting the fish of even 100 g size (Raina *et al*. 1999). Kumar (1988) has 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). Jayaram (2005) noticed mahseer specimens with fungus-infested fins mainly due to indiscriminate disposal of plastic bags containing remnants and left over of eateries in certain sanctuaries. There are reports depicting 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 the design of appropriate fishways across the dams (Nautiyal, pers. com).

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 the group. Traditional conservation measures 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 in the mission. Department of Fisheries, Karnataka, launched a programme in 1987 on "Rehabilitation and Development of Mahseer Fishery in the Rivers and Reservoirs of Western Ghats". Fishery management of *T. khudree* is done effectively in Cauvery River as Wildlife Association of South India 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. Angling is the only permitted fishing method.

Government of Himachal Pradesh has incorporated a special clause in the Fisheries Act that fishing during the breeding season is made a cognizable non-bailable offence with imprisonment upto 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 to create awareness among the common man about the need to protect the endangered fishes. 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. Whereever impoundments have been built or are coming up, establishment of mahseer seed production units should definitely be a primary requisite. Programmes organized by NBFGR in the Kumaon region wherein "Mahseer Bachao Gosthis" were launched to conserve the endangered mahseer have contributed positively in the conservation and they are worthy of replication in other places. Socio-economic aspects of conservation and the role of anglers have been evaluated in selected areas exploring the possibility of community participation. Menon *et al.* (2000) suggested that suitable segments of the rivers with mahseer should be identified for establishment of 'fish sanctuaries'. It is noticed that, 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 Kumaun region of Uttarkhand which helps to provide safer areas for the fish population. 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 Udupi District, Shishila in South Canara District and Hariharapura in Thunga River. In another place called Sringeri, the depth of the river ranges between 15 and 50 cm and with the clear water fishes are highly visible. As the biomass of the area is too high, minor changes in the water quality may affect the whole population. Oliver *et al.* (2007) reported about a 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 indulge in such activities. In Ramnathapura of Cauvery, mahseers are conserved in protected areas separated by rubbles. 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 5–15 m, width of 250–300 m and length up to 300–400 m even in summer offer excellent refuge even for the larger fishes of 30–40 kg. Certain areas are declared as sanctuary and poaching is almost nil due to strict vigilance. Interestingly, a few poachers in the stretch have been given an alternate avocation to perform the patrolling duty of watchmen to enable them to earn livelihood and prevent them from engaging in poaching activity. Another way of conservation of mahseers is also noticed in the west flowing rivers of Karnataka, viz. Bedthi, Aganashini, Sita and Nethravathi where these fishes are considered as Devarameenu (God's fish) and the people themselves take cudgels if the fish is caught.

Many places in India are becoming the important destinations for the global tourists as the new concept of eco-tourism has been strenghthened in many States. This can well be blended with mahseer fishing in the hill areas to attract the local as well as foreign anglers. Tourism generates much needed revenue, creates local awareness of the importance of species conservation and also provides incentives to the local people. In Madikeri of Karnataka such a practice has been initiated by Coorg Wildlife Society in a stretch of 28 km of the river. Recognizing the results obtained by the Society in terms of Mahseer conservation in the river, the Department of Fisheries has awarded the Society with an additional 92 km of the river stretch in Coorg since 2006 for the next 5 years. These include about 55 km of the river Cauvery, 21 km of the river Barapole and about 16 km of Madapur River.

It is also worth mentioning about the opinion that the conservation programmes of mahseer by artificial stocking has led to the production of hybrids and the quality of these off springs are not known. Recently, Das (2007) also cautioned about the alteration/extinction of gene pools of the species/stocks by cross breeding or hybridization and back crossing. This issue need to be addressed with due importance as far as the gene pool conservation is concerned. Of late, the Society is reported to have started the adoption of habitat restoration strategy, though it is expensive and time consuming. With this program, the Society has initiated the identification of Essential Fish Habitat (EFH) factors related to waters and substrates necessary for spawning, feeding and growth for attaining maturity of these endangered species. It is suggested that all the activities which have the potential to affect the EFH have to be discouraged. This can be taken as a model for conserving endangered fishes wherever possible. The Bhimeswari Camp is another location in the River Cauvery in Karnataka which attracts the anglers even from abroad. The anglers after obtaining licenses from Wildlife Association of South India (WASI) are permitted to fish with hook and line. The fishes caught are unhooked and released back to the river after taking weight and making other documentations. Likewise, in Jammu & Kashmir, Himachal Pradesh and Uttaranchal also fishing regulations allow angling of mahseer through permits issued on daily, weekly or yearly basis for the anglers and fishers (Chauhan *et al.* 2007). Hitherto no reports are available on the fate of the fishes after getting unhooked and released back to the river. But it can be assumed that many of them may die owing to the exhaustion, injuries and associated infections. These fishes will be more vulnerable to fishing gears because of the impaired swimmimg efficiency. Shyla *et al*. (2007) suggested that *Murivenna*-a herbal oil used in Ayurveda can be effectively used to heal the wounds and check the mortality of injured fishes after conducting preliminary trials in unhooked mahseers and catfishes. The use of this ayurvedic drug may be promoted after conducting comprehensive studies at the field level.

Livelihood and nutritional security

It is appropriate to discuss the role of mahseers in ensuring nutritional security of the forest inhabited primitive tribes of the Western Ghats. Kadar, Malayar and Muthuvar of the Ghats are dependent on the forest resources for their livelihood and the hill stream fishes serve as their major protein source (Dinesh and Abraham, 2007; Dinesh *et al*. 2007). In Nilambur forests of Kerala, Cholanaikkan (Manchery Tribal Colony) which is one of the most primitive tribal communities of Asia that depend heavily on mahseer for their daily bread. *T. mussullah* that has a patchy

distribution in the River Chaliyar is the major species caught. As the fish has thick scales and tough meat, the quality degradation is slower and that makes it a preferable species for the tribes both for consumption and sale. Although organized marketing system, fish preservation techniques and value addition are yet to be introduced in these places, tribes usually earn approximately Rs.100/- for a day's catch. Interventions on the marketing of the produces by the Department of Forests and Wildlife or other responsible agencies will help to reduce the exploitation by the middlemen during marketing. Another issue related with mahseer fishing and consumption is that local tribes believe that mahseer meat can not be consumed in certain seasons owing to the presence of some toxic material in it which is reported to cause severe vomiting problems when consumed. Further studies are required to investigate the issue in detail. Tribal empowerment issues of the Western Ghats could be better addressed by incorporating fish-related activities as a component which may indirectly help the mahseer conservation programmes. Angling facilities extended in these areas in association with eco-tourism would be a good suggestion, where tribes could be accommodated for related avocations to earn their livelihood. Kumar (2000) reported that mahseers have been of considerable importance to the local fishermen in North India because of their large size, hardy texture, high commercial value and longer shelf life. Kalita *et al*. (2007) observed that organized mahseer farming can become a vehicle for rural economic growth, apart from providing sustainable supplies of this fish caught during sport fishing and through commercial farming.

CONCLUSION

For the first time, an international conference on mahseers totally dedicated to this group of fishes was organised in 2006 by the Malaysian Fisheries Society with the active colloboration of INFOFISH, Food and Agriculture Organization (FAO) and Network of Aquaculture Centres in the Asia-Pacific (NACA) along with several other agencies. The conference highlighted the importance of this group of fishes and brought out a declaration based on the deliberations made in the conference.

- The mahseer is a cultural icon of diverse economic, recreational and conservational value in rivers of eleven Asian nations, with many species transcending country/ national boundaries.
- The mahseer is an integral component of the aquatic ecosystem and an important indicator of its health and supports the livelihood of many rural, indigenous, ethnic groups in Asia.
- The strategies that need to be developed to maintain the sustainability of mahseer populations are dependent on the effective utilization of available information on this important and iconic group of fishes.
- There is an urgent need to collate the available information and policy developments.
- The delegates also identified the necessity to use molecular techniques to sort out the taxonomic ambiguities as it is important from the view points of biodiversity and conservation.

The above points are of great relevance in the Indian scenario also and much bigger efforts are needed to conserve mahsers and exploit their potential as sport and food fishes. First, the rapid developments in the molecular taxonomy should be taken to advantage to solve the species identification and distribution issues in mahseers. Its value as a sport fish has been better recognised and the opportunities available to take advantage of the natural availability of this species in various locations to develop mahseer based eco-tourism should be exploited. The potential of mahseer as an aquaculture species in combination with other species has already been recognised, though growth rate in stagnant ponds seems to be low. Development of suitable feeds would help in improving the growth rate. Though nutritional studies conducted on this species have provided the basic information on the requirement for the macronutrients, studies on the requirement of micronutrients are almost unknown.

The technology of breeding of mahseer has been standardized by the TPCL and the DCFR. The breeding and conservation technologies for Deccan mahseers in Maharastra has opened up new opportunities for the conservation of fish through the involvement of private sector. Dissemination of this idea to various States of India and involvement of the private sector agencies would help in scaling up the results obtained in Maharashtra. Though many States have commissioned the mahseer hatcheries at the Government level, seed production in adequate numbers is not being carried out due to many constraints. The project initiated by the Coorg Wildlife Society on Essential Fish Habitat (EFH) restoration programme in Karnataka appears to have vast potential and this approach that helps to conserve fish in their natural environment could be replicated in other potential areas. As the tourism is likely to increase, creation of such EFH areas may help to attract tourists to those areas. As the fish respond to artificial feeding, the opportunities for developing such ecosystem based fish aggregation centres are very high. The recent effort of the Central Institute of Fisheries Education in bringing out a 'state -of- the knowledge book' on Mahseers that can be used by various stakeholders is a step in the right direction to conserve this species through education. Conservation programmes have been taken up in diverse geographical locations (Nautiyal, 2006) and worthwhile efforts need to be replicated to have great impact.

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