

Conservation biology of Indian Mahseers

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ABSTRACT

The populations of mahseers are declining very fast in different parts of India due to indiscriminate fishing of brood stock and juveniles, fast degradation of aquatic ecosystems, construction of dams, barrages and weirs under river valley projects etc and therefore the species deserves high conservation values in India. To save this prized resource, effective conservation and propagation assisted rehabilitation strategies need to be planned and implemented in the country. This requires knowledge of genetic variation and population structure of mahseers in the wild habitat, which is yet not available comprehensively. In the present paper, an attempt has been made to review evolutionary history, present status and need of conservation of mahseer and role of conservation biology and genetics for their germplasm conservation, sustainable utilization and enhancement. We propose new ideas and suggestions, which would help saving mighty mahseers across the country.

Key words: Conservation, India, Mahseer, *Neolissochilus* spp., *Tor*

Mahseers, under the family Cyprinidae and Genus *Tor* and *Neolissochilus* are described as the 'King of Indian freshwater systems and among mahseers, golden mahseer *Tor putitora* and *Tor tor* are important as potential game as

well as food fish. Being acknowledged as an outstanding game fish, they have been a core source of recreations for innumerable anglers from India as well as overseas since time immemorial. They have been of considerable

Table 1. Conservation status of Mahseer (*Tor* and *Neolissochilus* spp)

Species	Assessed for	Threats	CAMP, 1998	Lakra and Sarkar, 2007
<i>Tor khudree</i>	West flowing river system	Dm, Fd, I, H, Ov, Po, Sn, T	VU	VU
<i>T. khudree</i>	East and west flowing river system	Dm, Fd, E, F, I, G, L, Po, Pu, T	CR	NE
<i>malabaricus</i>				
<i>T. kulkarni</i>	West flowing river system	–	DD	NE
<i>T. mosal</i>	Upland cold water bodies & east flowing river system	F, I, Ov, Pu, T	EN/N	NE
<i>T. mussullah</i>	East flowing river system	Dm, Fd, F, Po, Pu, Sn	CR	NE
<i>T. progenius</i>	Brahmaputra river system	I, L, T	DD	NE
<i>T. putitora</i>	Indus, Gangetic & Brahmaputra river systems	Dm, Dr, Fd, F, I, H, L, Ov, Po, Sn, Lp, T	EN/N	EN
<i>T. tor</i>	Indus, Ganga & west flowing river systems	Dm, Fd, F, I, L, Po, T	EN/N	EN
<i>Neolisschilus spinulosus</i>	Teesta drainage	I	EN	NE
<i>N. wynaadensis</i>	West flowing river system	Dm, Fd	CR	NE

CR- Critically endangered; EN-Endangered; VU-Vulnerable; DD- Data deficient, NE- Not evaluated

Threat

D- Disease; Dr- Drowning; Dm- Damming; E- Changes in edaphic factor; F- Fishing, Fd- Dynamite fishing, G- Genetic problem; H- Harvest; I- Human interference; L- Loss of habitat, P- Predation; Po-Poisoning; PI-Pu-Pollution; Sn- Siltation; Ov- Over-exploitation; T- Trade

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importance as this group of fishes contribute much to the livelihood as well as food security of the local fisher folk

Table 2. List of Mahseer species adopted/proposed as a State Fish

Species	State
<i>Tor putitora</i>	Arunachal Pradesh
<i>T. putitora</i>	Himachal Pradesh
<i>T. putitora</i>	Uttarakhand
<i>T. mahanadicus</i>	Orissa
<i>Neolissochilus hexagonolepis</i>	Nagaland
<i>T. putitora</i>	Jammu and Kashmir

and the tribal people in the Himalayan ecoregion. India is considered as one of the richest megabiodiversity centres in the world having two important biodiversity hotspots, the Western Ghat and the Eastern Himalayas, which includes over 2200 finfish species. It is reported that a total of 73 coldwater finfishes are available in the country, which constitutes 3.32% of total available species (Das and Pandey, 1998). Among these coldwater fishes, mahseer (*Tor* and *Neolissochilus* species) is considered as one of the most important game fish of the world and classified as high conservation value fish species freshwater systems. Mac Donald (1948) narrated in his famous work “The Rod in India and Circumventing the mahseer and other sporting fishes” about the sport and fighting nature of fish. In addition, it has high food value due to good taste and attains a very large size up to 54 kg (Froese and Pauly, 2003).

Throughout the world, freshwater environments are experiencing serious threats to both biodiversity and ecosystem stability and many conservation strategies are being developed to solve the crisis. In recent years, the population of mahseer is declining in different parts of India due to indiscriminate fishing of brood stock and juveniles, fast degradation of aquatic ecosystems, illegal fishing, construction of dams, barrages and weirs under river valley projects, etc. (Nautiyal *et al.* 1998; Menon *et al.* 2000; Langer *et al.* 2001) and due to the above factors, several species of mahseer are listed as endangered (CAMP 1998, Lakra and Sarkar 2006) as per conservation assessments (Table 1). The fish has high conservation significance and recently, six Indian states have declared mahseer as a State Fish and special attention is being paid for their conservation (Table 2). To save this prized resource, effective conservation and propagation assisted rehabilitation strategies need to be planned and implemented in the country. This requires knowledge of genetic variation and population structure in the different wild habitat, which is yet not available comprehensively. In the present paper, an attempt has been made to review research carried out on mahseer with reference to its conservation biology and genetics for species enhancement, sustainable exploitation and rehabilitation. Some new ideas and suggestions for saving mighty mahseers have been suggested.

Evolutionary history

Beavan (1877) mentioned about the existing etymology of the name, mahseer for the first time. King Someswara (1127 AD) in his ‘Matsya Vinoda’ or a chapter on angling on the Manasollasa mentioned “Mahasila” which Hora (1951) took as a reference to identify *T. mussullah*. Hora (1930) described the possible evolution of the torrential sisorid fishes as induced by the rate of flow of water and the oxygen content of water. Lacy and Cretin (1905) opined that the derivation of mahseer from *Maha sher*- big tiger is rather fanciful. The native name “mahseer”, “mahasula” and ‘tora’ etc. probably refer to the large size of the scale or the head. Tilak and Sharma (1982) opined that the word mahseer is derived from the Sanskrit word ‘Mahasalka’. Kulkarni and Ogale (1995) agreed that the name must have been derived from the word ‘Mahasheel’ which is used even today by the fisher folk near Mulshi reservoir in Pune, Maharashtra for a medium- sized *T. mussullah* or a large sized *T. khudree*. What ever be the derivation, the name commonly accepted and widely used is mahseer and is popularly applied to the species of this group known from the Indian sub continent (Jayaram, 2005).

Distribution and ecology

The mahseer is distributed from Bangladesh, Nepal and India to Pakistan and Afghanistan (Jayaram, 1999; Menon *et al.* 2000 and Froese and Pauly, 2003). The eastern limit of this mahseer is Burma. They exist in the hub and the other rivers of Karachi coast. The fish is reported from most Trans-Himalayan countries ranging from Afghanistan to Myanmar (MacDonald, 1948 and Desai, 1994). Two species of mahseer, *T. putitora* and *T. tor* inhabit Nepalese torrential waters and lakes of mid hills (Shrestha, 1994).

In India, Mahseer is distributed all along the Himalayas including the freshwaters of Kashmir, Sikkim, Himachal Pradesh, Uttar Pradesh, Punjab, Haryana, Darjeeling district of West Bengal and Assam (Day 1873 and Sen and Jayaram, 1982). It inhabits the mountains and sub mountains regions, running streams and rivers. The commercial fishery of mahseer in Jammu, Himachal Pradesh and Uttar Pradesh consists largely of individuals either ascending streams for breeding or the spent once returning to perennial ponds in the plains. David (1953) reported the occurrence of mahseer in the Mahanadi river near the Huma sanctuary (South India). The rivers Beas and Satluj in Himachal Pradesh like other contemporary Himalyan rivers supports a good population of *T. putitora*. Besides those of the Indus river system (Pong and Govindsagar) there are some reservoirs of the Ganga river system especially Nanaksagar and Sardosagar which harbour Himalayan mahseer. The species is known to occur in the major river systems draining the lower Himalayan terrain, like the Indus, Ganga and Brahmaputra.

The fish shows variation in migration as reported by several authors. Beavan (1877) reported that *T. putitora* shows migration with respect to time (rain), direction

Table 3. Breeding seasons of different species of mahseers.

Species	Seasons	Reference
<i>T. putitora</i>	January–February May–June July–December	Khan (1939), Sehgal (1978) and Karamchandani <i>et al.</i> (1967)
<i>T. putitora</i>	August–September	Joshi (1984)
<i>T. mosal</i>	November–December	Ahmad (1948a)
<i>T. khudree</i>	July–September	Kulkarni (1971)
<i>T. khudree</i>	July–September	Cordington (1946)
<i>N. hexagonolepis</i>	April–October (peak August–September)	Ahmed (1948)

(upstream) and purpose (spawning). Khan (1939) reported the migration of *T. putitora* for spawning during August–September and returning of spent fish during October–November (Sehgal, 1978). Mahseer lives and grows to maturity in large rivers, migrate to headwater, stream, creeks to spawn during the wet season from June to October. Many authors reported many views on the variations in breeding season of the fish (Table 3). They forage in large groups over open gravel bed and their profound habitat are snowfed or rainfed running water broken in to pools and rapids with moderate depth of water. They are long lived, slow growing, predatory, column feeder feed on insects and fish fry of other species. Nautiyal and Lal (1984) described that fish is carnivore by habit and preferred to call it as an omnivore. A mature mahseer produces 45, 800 to 75, 000 eggs and are reported to deposit their spawn in several batches in a period of several months (Beavan, 1877). The ecological status of the Himalayan mahseers has been assigned as endangered (Singh and Sharma, 1998 and Anon, 2003).

Genetic resources

Biodiversity is defined as “variability among living organisms from all sources including, *inter alia*, terrestrial,

marine and other aquatic systems and ecological complexes of which they are a part, this includes diversity within species, between species and of ecosystems” (UN Conference on Environment and Development). In India freshwater resources in the form of rivers and canals (1, 73, 287 km), ponds and tanks (2.25 million ha), beels/lakes/derelict waterbodies (1.3 million ha), reservoirs (2.09 million ha) harbour important freshwater denizen which makes them a biodiversity rich ecosystem.

The report on the available genetic resources of mahseers in India is highly ambiguous. Day (1878) believed that mahseer constituted only one species. Later, Hora (1940) confirmed the validity of six different species. Sen and Jayaram, (1982) described some uncertain species of Mahseer (*Barbus hexastichus*, *B. dukai*, *B. neilli* and *Puntius chelynoides*). Rainboth (1985) proposed the new genus *Neolissochilus* to accommodate *hexagonolepis*. Talwar and Jhingran (1991) recognized seven species of true Mahseer in India, viz. *Tor putitora* (Hamilton), *T. mosal* (Hamilton), *T. progenius* (McClelland), *T. khudree* (Sykes), *T. mussullah* (Sykes) and *T. chelynoids* (McClelland) belonging to a separate genus. A recent critical study on the subject by Menon (1992) confirmed 6 valid species. He however, described a new species from the Darna River (Godavari drainage) at Deolali, Nashik District of Maharashtra and named it *Tor kulkarnii*, which he described as a dwarf cognate of *Tor khudree*. Presently seven valid species are recognized in India (Table 4). In addition to the those above, three sub-species, viz. *T. mosal mahanadicus*, *T. khudree malabaricus* and *T. khudree longispinis* (Desai, 2003) and other morphotypes like *Neolissochilus hexagonolepis*, *N. hexastichus*, *N. wayaanadensis* (Jayaram, 1999) and *N. paucisauamata*, *N. stracheyi* (Vishwanath *et al.* 2007) are reported from different parts of India.

Traditional taxonomical identification of mahseers based on morphological traits is quite ambiguous. Therefore, proper identification of the mahseers using different molecular markers is the need of the hour for conservation. In this context, molecular identification and phylogenetic

Table 4. Species diversity and distribution of mahseers in India

Scientific Name	Common name	Distribution
<i>Tor putitora</i> (Ham.)	Golden or putitora mahseer	All along Himalayas
<i>T. tor</i> (Ham.)	Turiya or tor mahseer	Foothills of Himalayas
<i>T. khudree</i> (Sykes)	Deccan or khudree mahseer	Peninsular India
<i>T. khudree malabaricus</i>	Deccan mahseer	East and West flowing rivers
<i>T. mussullah</i> (Sykes)	Humpback or mussullah mahseer	Southern India
<i>T. kulkarnii</i>	Dwarf mahseer	Southern India
<i>T. progenius</i> (McClelland)	Jungha of the Assamese	North East India
<i>T. mosal</i> (Sykes)	Copper or mosal mahseer	North East India, Manipur, Arunachal Pradesh
<i>Neolissochilus hexagonolepis</i>	Chocolate mahseer	North East Himalayas
<i>N. spinulosus</i>	Mahseer	Teesta river (Sikkim)
<i>N. wayaanadensis</i>	Mahseer	Westernghat (Kerala) and head waters of Cauvery river

relationship have been initiated at National Bureau of Fish Genetic Resources (NBFGR), Lucknow among mahseers (Mohindra *et al.* 2006).

Biodiversity loss

Irrational fishing practices, environmental aberrations in the form of reduction in water volume, increased sedimentation water abstraction and pollution over the years make freshwater fish biodiversity a declining trend. The increasing trend of human population coupled with other biotic and abiotic factors is the root cause for the loss of biodiversity. Often it is difficult to discuss the causative factors that influence loss of species. Moyle and Leidy (1992) listed five broad categories as responsible for reduced biodiversity of aquatic organisms, these being competition for water, habitat alteration, pollution, species introduction and commercial exploitation. Kottelat and Whitten (1996) considered the biological changes that environmental degradation brings about and enumerated pollution, increased sedimentation, flow alteration and water diversion as the main causes. The number of threatened species is likely to rapidly increase in regions where human population growth rates are high. Singh *et al.* (1995) reported a sizeable reduction of mahseer catch from Bhimtal lake, Kumaon Himalayas (Table 5).

Habitat destruction and associated degradation and fragmentation are the greatest threats not only to terrestrial species but also to aquatic species. Habitat degradation caused by soil erosion, siltation and turbidity due to deforestation in the catchment areas results in the alteration of ecological conditions. The changes in the ecological condition become uncongenial for survival of the endemic fish. Soil erosion also leads to the destruction of breeding and spawning as well as nursery grounds of mahseer. Irrational collection of boulders and gravels from the riverbed further deteriorates breeding ground by removing required materials of mahseer eggs for hatching.

Construction of dam and barrages put obstruction in migration of fish and thereby hampering breeding of mahseer.

Table 5. Trend of mahseer (*Tor spp.*) catch from Bhimtal lake, Uttarakhand, India

Year	Total catch (kg)	Catch of mahseer (kg)	% of mahseer in total catch
1979-80	850	707.00	83.17
1980-81	930.00	776.00	83.44
1981-82	835.00	562.00	67.30
1982-83	1230.00	892.00	72.52
1983-84	1300.00	635.00	48.85
1984-85	1310.00	503.00	38.40
1985-86	1090.00	603.00	55.83
1986-87	960.00	433.00	45.10
1987-88	960.00	—	—
1988-89	1210.00	635.00	52.48
1989-90	830.00	416.00	50.12

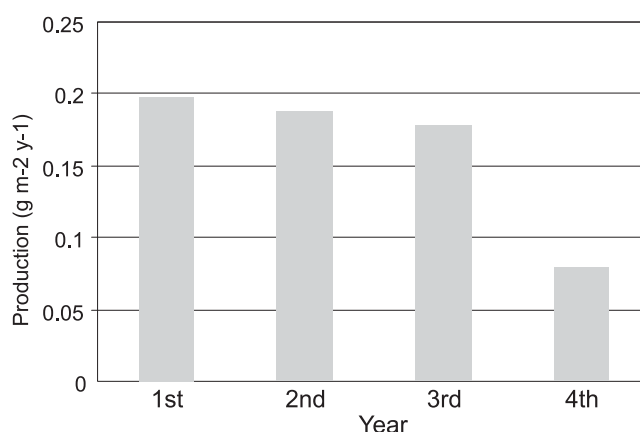


Fig 1. Impact of Tehri Dam Project in upper Ganga on annual productivity of Mahseer (*Tor spp.*)

The Tehri Dam Project in Garhwal Himalaya has an impact on production of mahseer (Figure 1). Excessive trapping of water through canals and channels for irrigation and drinking purposes deplete carrying capacity of river and finally depletes ichthyofaunal diversity (Dhanze and Dhanze, 1994). Indiscriminate killing of broodfish and juveniles by dynamiting and poisoning cause drastic decline in the population of mahseer. Large sized mahseers are the most convenient targets of the poachers being killed with explosives. Massive collection of fry and fingerlings of mahseer by local fisherman during downward migration is also one of the important reasons for fish population declination. Unless the consumer will be conscious about the gravity of the problem of species declination this illegal marketing of the endangered fish can't be stopped.

Pollution of rivers and lakes by domestic wastes, sewage and industries effluents results in the deterioration of water quality which in turn declines mahseer. It also affects reproduction capability of fish. The obvious outcome of pollution is stress and mass mortality of individuals. In cases of genotoxic pollutants, the effect can be more damaging but subtle. A number of fishes have been displaced or eliminated from their original habitats.

Inbreeding depression is the most serious problems of endangered fishes with small population sizes (Jensen, 1994). Stunted body growth and skeletal as well as body deformities have been noticed among a few specimens of the endangered mahseer (*Tor putitora*). Recent studies have demonstrated that introduction of certain exotic species in the reservoirs have greatly affected the mahseer fishery. Introduction of exotic species as a part of aquaculture for commercial gains has resulted in loss of diversity. For e.g. the Schizothoracine fishes in Kashmir valley have almost been exterminated by the exotic common carp *Cyprinus carpio* species. The Loktak fish of Manipur is fast disappearing, once again, due to the introduction of common carp for culture. The displacement of Catla species from many reservoirs and its associated

ecological disaster is noticed after introduction of silver carp as in Govindsagar and some other reservoirs. In Govindsagar reservoir *T. putitora* (from 63% to 3%) is almost replaced by the accidental introduction of silver carp and common carp (Sinha, 1994).

Conservation

Globally threatened species frequently require a combination of conservation responses to ensure their continued survival. These responses encompass research, species-specific actions, site and habitat based actions, policy responses and communication and education. Majority of the threatened species require substantially greater action to improve their status. While many species already receive some conservation attention, many others do not. Species can be saved and many already have been saved from extinction (IUCN/WCU). However, this requires a combination of sound research, careful co-ordination of efforts and, in some cases, intensive management. Improving the effectiveness of conservation action requires a better understanding of the needs for such action across species, the extent to which it is being applied and the effects it has had in preventing species extinctions. In view of the steady reduction of mahseer in numbers and sizes in different parts of the country, it is therefore imperative that proper management, conservation and propagation of these resources is ensured to protect them from further depletion. Some conservation strategies have been discussed and recommendations suggested.

Restoration of habitat

Several measures have been enumerated for their conservation (Kulkarni and Ogale, 1995 and Ogale, 1997). The artificial propagation and distribution of resultant fry and fingerlings into different waters constitutes are some of the most important steps to rehabilitate the species, as is being done for the well known salmon in American and European waters. However, for dependable and continued results, improved aquaculture practices for the breeding of mahseer under controlled conditions play a vital role. As a few conservation and rehabilitation programmes for mahseer have already been initiated, it appears that the fish is not endangered in lakes and reservoirs but it is endangered in some natural environments (rivers and streams).

Suitable stretches of the rivers should be considered for ranching of mahseer fingerlings. Ranching is defined as an aquaculture enhancement system in which juveniles are released to grow unprotected on natural foods in waters from which they are harvested at marketable size. Ranching is nothing but means of taking advantage of the natural environment to grow fish in open waters. Ranching could be a timely and promising measure for rehabilitation of the endangered mahseer. The lack of a well established hatchery facilities for mahseer and for rearing of its seed was one of

the major obstacles in introducing the mahseer ranching. Mahseer have a short return migration and will burn less fat while traveling back to their parent rivers. This makes it a very promising candidate species for ranching. The sole purpose of mahseer ranching would be the rehabilitation of this fish in all rivers, lakes and reservoirs where they were in abundance or could be established. Kulkarni and Ogale (1978) developed hatchery technology of *T. khudree* and experimented on successful propagation in Maharashtra, India. Further methods of transporting mahseer eggs in moist cotton (Kulkarni and Ogale, 1979) to different parts of the country facilitate mahseer ranching programme to be successful one.

Wild mahseer fry usually descend the streams in the winter and hatchery reared fry are released at the same time to synchronize their out migration with that of wild fry populations. Shreshtha (1994), developed a dynamic plan for river ranching. Hatchlings should be grown to the fingerling size and then released into reservoirs and downstream rivers. Habitat fingerprinting through elemental analysis of otolith is also an innovative approach to identify the potential breeding in spawning grounds of mahseers in the rivers/streams.

A method of artificial imprinting coupled with ranching is also suggested for conservation of the species. Imprinting is an irreversible learning process in which at a critical impressional age of its life span an animal gets a life-long imprint of any chemical or sound to which it is introduced and this has a bearing on its future behavior. Imprinting could be sound or chemicals. The large aquatic environment in which ranched fish stock may migrate to feed or for other reasons will make it potentially important to train and recall them by some means. It has been demonstrated that it is the sense of smell by which some fish recognize the waters in which they hatched and from where they migrate to the sea. This phenomenon has been termed 'imprinting' and such fish are called anadromous fish, such as salmon and hilsa. It has been observed at Tata Power Company Ltd., Lonavala (TPCL) fish farm it is possible to train the mahseer to congregate near a sound source in the ponds, lakes and reservoirs.

Ex situ conservation

Ex-situ conservation involves the collection, handling and management of germplasm and its storage, regeneration, characterization/evaluation, documentation and dissemination to users. *Ex situ* conservation may involve preservation of the gene pool as an insurance against loss in situ reserves. The ultimate *ex situ* measures are the gene banks where cryostorage of gametes and embryos are achieved. The technique of cryopreservation of mahseer milt has been successfully developed and gene banking of endangered mahseer is technically feasible. NBFGRI, Lucknow, India has standardized the long-term cryopreservation of milt of

T. putitora and *T. khudree* at an experimental scale. Patil and Lakra (2005) standardized a protocol for cryopreservation of spermatozoa of the endangered mahseer, *T. khudree* (Sykes) and *T. putitora* (Hamilton). Efforts on the induction of triploidy and gynogenesis in mahseer using heat shock treatment for manipulation of sex ratio are in progress. Basavaraja and Hegde (2004) and Basavaraja *et al.* (2006) cryopreserved the spermatozoa of the Deccan mahseer (*T. khudree*) using different strategies and evaluated viability of the cryopreserved spermatozoa. Immotile spermatozoa pooled from 2 to 4 males were diluted with modified fish Ringer's solution (pH 7.48) and protected with dimethyl sulfoxide (Me_2SO) at 5–15%. The fish produced from cryopreserved spermatozoa were as normal as normally produced fish.

In situ conservation

The concept mainly revolves the conservation of endemic and endangered species. This method has the advantage of being less expensive than *ex situ* measures in the long run and also allows continued co-evolution with other species in the natural system. Menon *et al.* (2000) suggested that suitable segments of the rivers with mahseer should be identified for establishment of 'fish sanctuaries'. Along the strophes of different rivers in India, there exist some important pockets of water-ways where the fish are preserved out of religious issues because of location of the holy places, shrives, temples on the bank of the rivers. At present fishing is prohibited on religious grounds in certain stretches of Ganga, eg. at Har-ki-paudi, Haridwar and also in some temple ponds besides areas of wild life protected area. Many Hindu traditions in India are related to the conservation of plants and animals by associating them with one or other deities. Jayaram (2005) mentioned about some protected areas by side of temples as in Dehu, Alandi on river Indrayani, Sringeri on Tungabhadra, Ramanathapura on Cauvery and certain water bodies of the sacred groves where mahseer is guarded. However, the fish sanctuary concept of freshwater fishes is yet to get policy and research support in India. Recent studies reported that fish protected areas can play significant role in maintaining or enhancing recruitment in unprotected areas, even many species which have become endangered in other places should stable population in the protected waters (Sarkar *et al.* 2005, 2008).

One of the prerequisites for undertaking conservation and management of fish germplasm is good mapping of water resources which can be addressed by remote sensing and geographic information system (GIS). Srivastava *et al.* (2001) studied habitat utilization pattern of *T. putitora* using satellite image in GIS and successfully identified optimum and degraded habitat areas of river Ladhya in Kumaun Himalayas. Sarkar and Bain (2007) developed a set of habitat classes of different life stages of Tor species of river Ganga and found defined habitat using multivariate and principal component

analysis. The experiences of Tata Power Company Ltd., Lunaval in collaboration with NBFGR, Lucknow could be utilized in setting up a live gene bank in the region.

Indiscriminate fishing should be stopped particularly during June-July to end of September to prevent killing of brood fish. Protective legislation on mesh size, closed season, declaration of sanctuaries, limit on catches, restriction of effort, prohibition of use of destructive method of fishing are required. 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.

Various conservation measures require mass awareness and sensitization among various stakeholders about the problem its methods and consequent people's participation can only probably bring out a desirable change. Prevention of environmental deterioration can be achieved through mass awareness programme and with active participation of the local population. Several workshops have been organized in the past to focus attention on the need for urgent steps to be undertaken to conserve this important game fish in India and Asia. The experience gained has shared with eminent scientists and other stakeholders from different states. Such activities indicate growing awareness towards protecting and conserving mahseer.

Angling as a hobby should be promoted and the revenue generated through the sport fishing would be a lasting way of strengthening conservation. Angling festival promotes public awareness on endangered mahseer so that destructive fishing methods and catching brooders during breeding season can be prevented. A few Anglers Associations including Assam Anglers Association (Bhoreilli), Tezpur, All India Anglers Association, New Delhi, the Environment and Anglers Club, Dehradun, Wildlife Association on the Cauvery etc. are also involved in the effort of mahseer conservation.

A series of mass awareness programmes were organized by NBFGR, Lucknow in the Kumaun region and North Eastern Himalayas. "Mahseer Bachao Gosthis" were launched at local scale to sensitize local people. 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 Kumaun region were documented (Srivastava *et al.* 2002). This includes eight indigenous methods being used by the local community.

Artificial propagation

The consumption of fishes suffers from the fact that the

finfish conservation comes under the purview of more than a single governmental agency, such as those responsible for management of fisheries, forestry, wildlife, irrigation etc. The artificial fertilization of eggs of the mahseer (*T. khudree*) was successfully carried out on a large scale for the first time by Kulkarni (1971) at the Tata Power Company's fish farm at Lonavala, District Pune (Maharashtra). Since then considerable knowledge has been gained and practical knowledge has been achieved in recent years on the spawning season and habits, methods of artificial propagation, hatchery management, rearing of fry, fingerlings and broodstock and most importantly, on the success of hypophysation (induced breeding) of pond-raised stocks of all the major species, i.e. *T. khudree*, *T. mussullah*, *T. tor* and *T. putitora* (Kulkarni and Ogale, 1986 and Ogale, 1997).

At Lonavala, *T. putitora*, like other species, is observed to spawn naturally in lakes from July to September. *Tor putitora* females have responded to stripping, with hypophysation (Kulkarni and Ogale, 1986). It would be worthwhile to try and breed *T. putitora* in the other two months, i.e. January and December, during which breeding has not been attempted due to shortage of brooders. Breeding season of all mahseer species extends from July to September with a peak in July–August and in exceptional cases to October, and even beyond. This has shown the adaptability of the species to different environments.

Attempts to breed *T. putitora* by hypophysation were first made by Sehgal and Kumar, (1977) at Baintwali mandi, Dehradun with little success. Artificial fecundation of *Tor putitora* has been reported by Tripathi (1977) and Joshi (1984) from the Kumaon hills of Uttar Pradesh. Ripe spawners were collected during the peak breeding season (July–September) and stripping was done. The spawners ranging from 365–450 mm in total length and 365–800 gm in weight yielded 4, 200 eggs/kg of body weight. The average fecundity of putitora mahseer ranged between 26, 998 to 98, 583 in the weight range of 3.5 to 23 kg (Nautiyal and Lal, 1985).

Female golden mahseer of 3–5 years old spawned without hormonal use when reared in ponds at the rate of 1 000 kg/ha with 30–40 percent crude protein supplementary feed. The majority of the fish attain sexual maturity in 70–77 cm size range, while 1/3rd of them may attain maturity for the first time soon after attaining length of 40 cm. Ogale (1997) opined that breeding of golden mahseer using ovaprim was successful. Studies on maturity and fecundity of *T. putitora* has shown that the fish carries multimodel ova and the eggs maturing in batches (Khan, 1939). The mahseer hatchery technology developed by Tata Power Company Ltd. Lonavala (TPCL), India, may well lead to the revival of mahseer fisheries in Indian waters, provided standardised simple mahseer hatcheries based on TPCL technologies could be set up in the rural areas adjacent to rivers and reservoirs (Ogale, 2006).

Aquaculture potential

For further promotion of mahseer aquaculture one alternative could be the development of suitable breeding and rearing technology, which requires knowledge of their nutritional requirement from hatchlings to adult stage. At present, there is only limited knowledge on feed, feeding and nutritional requirement of mahseer. Based on the growth performance, conversion and feed utilisation a 40% protein content in the feed is optimal (Keshavnath, 1986). The compatibility of mahseer with other major carps under composite fish culture was tested at different densities and feeding the fish on a fish meal based diet. Mahseer growth was higher under composite culture than that of monoculture.

Aquaculture of mahseer, *T. putitora* commenced in seventies with the success on the breeding of wild stocks at Bhimtal in Uttar Pradesh (Tripathi, 1977 and Pathani & Das, 1979). Subsequently the efforts made by Joshi and Malkani (1986) elaborated the techniques of artificial propagation of mahseer, *T. putitora* with the successful rearing. Mahseers were considered as carnivorous and slow growing and thus unsuitable for fish culture. However, a careful study of the feeding habits of mahseer indicating that it is omnivorous has dispelled the notion that mahseer are carnivorous. Studies on the anatomical adaptations of the alimentary canal system also confirm that mahseer are omnivorous. Tripathi (1995) suggested the inclusion of mahseer in polyculture, cage culture and river ranching.

The golden mahseer fry produced at Bhimtal, India have been raised in subtropical pond environment to raise large fingerlings up to 210 mm in length and 150 gm in weight by feeding the fish with specially developed balanced feed thus establishing the possibility for its culture in ponds (Vass, 2000). Recent trials with the monoculture of *T. putitora* in ponds at Lonavala were encouraging. The mahseer fingerlings were given only pelletized feed made of rice bran, groundnut cake and fishmeal (30:30:40), with a mineral mix. The average growth reported was 110 g and 90 g at stocking densities of 10 000 and 20 000/ha, respectively, at the end of eight months. Water temperature during the growth period was between 24°C and 28°C. The results of these studies indicate the suitability of mahseer not only for inclusion in composite fish culture but also for monoculture. Since mahseer accepts pelleted feed and is capable of utilizing it efficiently, the species can also be used for river ranching and cage culture. Studies carried out at the TPCL fish farm also confirm that mahseer grown on pelletized feed develops into excellent broodstock for induced breeding.

For the first time culturing of golden mahseer and Deccan mahseer in floating net cages has been tried at Walwhan Lake (Ogale, 2006). The size of the net cage is 9 m² (3m x 3m), with a depth of 3 m. The net cages are fixed in the lake over more than 4 meter depth. Fingerlings, each of 35 to 40 g, were stocked in January 2001 at a rate of 450 per cage. The stocking density is approximately half a million/hectare. The

fish are being fed twice a day for 10 to 15 minutes with pelletized feed. The mahseer has grown to an average of 170 g in 5 months. Recent observations predict excellent results and would promote cage culture in India. These cage culture experiments are being coupled with ranching and imprinting with sound. In earlier experiments the imprinted fish released in the ranching area of Walwhan Lake responds to the sound impulse to which they were trained while in cages and come to the shore (Ogale, 2006). Cage culture experiment of mahseer has been conducted. After 150 days of culture the average net weight of *T. khudree* increased from 35.2 g to 106 g and the average net weight of *T. putitora* from 14.6 g to 52.4 g.

Genetics and biotechnology

Since increasing number of species are reported to be endangered and threatened these needs to a focus on maintenance of the genetic component of biodiversity and the preservation of evolutionary process (Moritz, 2002). Devising methods of managing threatened species in order to maintain genetic variability requires the identification of evolutionary divergent population estimation of genetic variability within and between population and the assessment of conservation value of the population. Molecular genetic data are also useful particularly valuable in confirming translocation events and for assessing the genetic interaction. Therefore, to save this important mahseer genetic resource, effective conservation and propagation-assisted rehabilitation strategies are necessary. However, this may not be feasible unless data is available for on stock structure and genetic variation of mahseer throughout its distribution range. Identification of polymorphic markers with consistent scorable alleles is a crucial step to generate population genetics data (Ferguson *et al.* 1995).

The conventional morphological and osteological characters based on head length and body has been used for identification of various species of mahseer. There has been considerable plasticity in the morphological characteristics that lead to taxonomic ambiguities, which highlight the urgent need to resolve taxonomic conflicts in the *Tor* group using molecular markers irrespective of life history stage. In addition to solving taxonomic ambiguities, genetic relatedness between different species can also be studied and Randomly Amplified Polymorphic DNA markers for *Tor* species have been identified (Anon, 2003).

Polymorphic microsatellite markers identified through cross-species amplification of microsatellite primers from related species were used for differentiation of mahseer stocks from natural population across its natural distribution. Seven polymorphic microsatellite DNA loci were identified in golden mahseer, *T. putitora*, through cross-species amplification the. The results indicate that the identified microsatellite loci exhibit promise for use in fine scale population structure analyses of *T. putitora* (Mohindra *et al.*

2004). These will also provide potential tool, for assessing the genetic bottlenecks, occurring in natural populations of *T. putitora*.

Genetic population structure analysis of natural population of *T. putitora* has been carried out using the identified polymorphic microsatellite and allozyme markers from rivers of Indus, Ganges and Mahanadi river system (Ranjana, 2005). The study revealed moderate level of population sub-structuring in *T. putitora*. Allozyme markers were also detected based on screening of 16 enzyme systems which yielded 27 scorable loci (Anon, 2003). This information can be used to identify the population from a single homogenous random mapping population or not.

Cytogenetic characterization of mahseer has provided genetic information to resolve some of the taxonomic ambiguities among the *Tor* spp. All the four *Tor* species (*T. putitora*, *T. tor*, *T. khudree* and *T. mussulah*) exhibited diploid chromosome number (2n) is 100 (Khuda-Buksh, 1980, Lakra, 1996 and Nagpure, 2002). The development of silver neither staining technique to detect metaphase chromosome sites of NOR (Nucleolar Organizer Region) has significantly facilitated comparative studies of NOR variation within and between species of mahseer. NORs are present on four pairs of chromosomes in *T. putitora* and *T. tor* (Nagpure *et al.* 2002) whereas Barat and Ponniah (1998) reported NORs on two pairs of Chromosomes. Variations in karyomorphology and NOR banding pattern can be used as cytogenetic introgression among these closely related species. NOR banding pattern has also been used to study intraspecies polymorphism in *T. putitora* (Barat and Ponniah, 1998).

Short term and continuous cell cultures from a variety fish species have been reported in the past and applied extensively in virological, toxicological and cytogenetic studies (Chen *et al.* 1986 and Hightower and Renfro, 1988). Hence establishment of cell lines from economically important and endangered species would be of great importance for aquaculture and fisheries management. Lakra *et al.* (2006) developed a diploid cell line (TP-1) for the first time from the golden mahseer (*T. putitora*) which has potential application in biodiversity conservation of the species.

CONCLUSION

Since all the species of mahseer are considered as endangered, special attention from scientist, fishers and entrepreneurs is required in order to protect them from further declination. Mahseer conservation plan should be an integral part of the new hydel projects that are in the pipeline in the Himalayan region. The scope of breeding mahseer artificially and culturing in ponds should be properly utilized. The potential of the species as a cultivable and sport fish has to be exploited with further research and planning, keeping an eye on their conservation. At least one large size hatchery is required to be established in all Himalayan states, which

possesses mahseer resource. Efforts must be made to breed mahseer species on a large scale. Once the seed is available, state fisheries departments and fish farmers can use fry and fingerlings for hillstream aquafarming, river ranching, raceway ponds and running water culture. Introduction of mahseer in aquaculture will be excellent for increasing the spectrum of new potential fish species under culture system. There is need to change the present regulation of not allowing anglers to fish in major spawning season since fishes are extremely vulnerable to destructive ways while ascend for spawning. Local people should be allowed to catch fish for their livelihood by using line and hook, noose and cast nets and use of other illegal methods should be punishable. More research and monitoring of the potential streams and rivers are needed to strengthen knowledge about the fish in the context of recent climatic variation and adaptations. Thus, if the suggested remedial measures are implemented in stages the mighty mahseer of India can be restored to its glory. Conservation of fish genetic diversity is not only important for sustainable fishery but also it plays important role in National development. Proper taxonomic identification using different molecular markers is an essential step towards conservation of endangered mahseer.

The nations who have ratified the Convention on Biological Diversity (CBD) are required to inventorize and monitor their own biodiversity and biological resources. Poorly studied freshwater species with conservation significance must be studied and documented immediately with special emphasis on mahseer. Ecotourism can be blended with mahseer angling to generate more revenue vis-a-vis to conserve beautiful Indian mahseers. The efforts taken by the earlier workers especially the non-Indian anglers and fishery biologists, to study this group in a comprehensive manner have to be gratefully acknowledged. It was their studies, which have laid the strong foundation of mahseer research in India. It is expected that collaborative research programme on mahseers involving different conservation agencies (National Biodiversity Authority, Bombay Natural History Society, Wildlife Institute of India, Zoological Survey of India, Ministry of Environment and Forests, Directorate of River Conservation) will certainly give more comprehensive data with respect to conservation of these valuable biological resources.

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