



Mahseer in India: An Overview on Research Status and Future Priorities

U. K. Sarkar *, B. K. Mahapatra¹, S. Roy Saxena² and A. K. Singh³

ICAR- Central Inland Fisheries Research Institute, Barrackpore, Kolkata (West Bengal), India - 700120

¹ICAR- Central Institute of Fisheries Education, Kolkata Centre, Kolkata (West Bengal), India - 700091

²Barktullah University, Bhopal (M.P.), India - 462026

³ICAR-Directorate of Coldwater Fisheries Research, Bhimtal (Uttarakhand), India - 263136

Abstract: *The population 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 rehabilitation strategies need to be planned and implemented in the country. This requires knowledge of current status of fish, declining trend, aquaculture potential and population structure in the wild habitats, which is yet not carryout comprehensively. In the present paper, an attempt has been made to review evolutionary history, present status and role of conservation biology for their conservation, sustainable utilization and enhancement. Based on the review, discussed potential promising plans, priorities and suggestions, which would help saving mighty mahseers across the country.*

Keywords: Mahseer, Rehabilitation, Aquaculture.

Introduction

Fishes represent half of all extant vertebrates with more than 32,000 recognized species (Eschmeyer *et al.*, 2014) which have different morphology, behavior and habitat (Nelson, 2006). Cypriniformes constitute most important fishes of world and is one of the largest order of freshwater fishes amongst diverse range the groups. Mahseer are belonging to the order Cypriniformes and commonly known as “King of Indian freshwater systems”. It is a group of game/sport fish under genus *Tor* and also includes some other species of the genus *Neolissochilus*. Mahseer is famous for its delicacy as food but it gains much more attention due to its capabilities to be used as game fish and is one of the favorite choices of the anglers across World. Being so important, this fish is now declining in its natural habitats due to various anthropogenic activities. Mahseer

is so famous between anglers that some used to call it “Majestic Goddess” and several organizations are working for its conservation by organizing various angling programmes in Himalayas and Western ghats in India (Islam and Tanaka, 2007). Mahseer fishes are facing the threat of extinction and many of the fish species are categorized as endangered while others are threatened (IUCN, 2014). In order to save this prized resource, effective conservation and propagation assisted rehabilitation strategies have been planned and being implemented by the Directorate of Cold water Fisheries Research (DCFR) in the country. This is how knowledge of genetic variation, population structure and distribution of valid species of Mahseers in the wild habitat, are now comprehensively available (Jyoti *et al.*, 2013; Rohit *et al.*, 2015). In the present paper, an attempt has been made to review the present status and need of conservation

of Indian mahseer and future research and development needs for, sustainable utilization and enhancement of this important resource.

Occurrences and distribution status

Mahseer occurs mostly in upland rocky streams of India, Nepal, China, Myanmar, Sri Lanka, Pakistan, Thailand and Bangladesh. Mahseer are generally known to prefer cold, clear and swift flowing waters with stony, pebbly or rocky bottoms and intermittent deep pools (Ng, 2004; Dinesh *et al.*, 2008) and Indian climatic conditions are well suited for its existence. Out of the 47 species of mahseer that exist in the world, India is home to fifteen. Of the 15 species of mahseer belonging to the genus *Tor*, Tor mahseer (*Tor tor*); Golden mahseer (*T. putitora*), Deccan mahseer (*T. khudree*), Humpback mahseer (*T. mussullah*), Mosal mahseer (*T. mosal*), *T. neilli*, *T. progenies*, *T. remadevi*, *T. kulkarni*, Chocolate mahseer (*Neolissocheilus hexagonolepis*), *N. wynadensis* have received greater attention. Within India, many species of mahseer are discontinuously distributed and mostly endemic in the South, Central and Northeast India. *Tor remadevii*, a new species of *Tor* (Gray) from Chinnar Wildlife Sanctuary, Pambar River, Kerala, Southern India was identified (Kurup and Radhakrishnan, 2010).

Causes of decline

Various anthropogenic activities like Construction of dams, other developmental process have effected badly on mahseer population across country. 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. These problems are prevalent in most Mahseer habitats all across the country including the Himalayan foothills, the Vindhya-Satpura and the Western Ghats (Table 1). In order to save this prized resource, effective conservation and propagation assisted rehabilitation strategies have been planned and being implemented in the country. Causes of

decline of mahseer along different part of India are given below:

- (1) **Himalayan rivers:** In Himalayan rivers mahseer faces delayed maturity, low fecundity, long hatching period of 60–80 hrs at 24–28 °C and slow growth rate and other man made constraints like habitat fragmentation, and over exploitations are reasons for its decline (Nautiyal, 1988).
- (2) **Western ghats:** Extensive deforestation that have taken place in the western ghats during the last hundred years might have been one of the major reasons for its decline (Jayaram, 2005).
- (3) **Harangi river Karnataka:** Use of a special type of bag net by the fishermen operated across the water falls in the downstream of the reservoir during the breeding migration of mahseer has been adversely affecting its population (Oliver *et al.*, 2007).
- (4) **Umiam reservoir Meghalaya:** Fingerling and fry fishing of mahseer by fishermen for subsistence is a major issue which has resulted in the drastic decline of their population (Vinod *et al.*, 2007).
- (5) **Karnataka:** Oliver *et al.* (2007) reported about a massacre of mahseers at Shishila temple in wherein about 10 truckloads of mahseers were killed by poisoning with endosulfan as a result of rivalry between two communities.

Mahseer has been identified as a candidate species for aquaculture because of its sporting quality and excellent flavour of flesh since the last century (Day, 1889). National Bureau of Fish Genetic Resources, Lucknow has identified *mahseers* as a potential cultivable species. 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.*, 2006) in pond (Sharma and Parashar, 2013). Need of the hour is to take up aquaculture programmes of different mahseer species in

Table 1 Indian states that have declared mahseer as a State Fish

Sl. No.	Mahseer Species	State fish
1.	<i>Tor putitora</i>	Arunachal Pradesh
2.	<i>T. putitora</i>	Himachal Pradesh
3.	<i>T. putitora</i>	Uttarakhand
4.	<i>T. mahanadicus</i>	Orissa
5.	<i>Neolissochilus hexagonolepis</i>	Nagaland
6.	<i>T. putitora</i>	Jammu and Kashmir
7.	<i>Tor tor</i>	Madhya Pradesh

the pond and reservoir environments. Growth of mahseer in captivity is slow therefore by formulating practical diets and appropriate technologies there is scope to harness the potential of this group of fishes (Dinesh *et al.*, 2010). Among the studies, Shahi *et al.* (2014) demonstrated culture potential of *T. putitora* for hill aquaculture. Rahman *et al.* (2007) conducted an experiment on polyculture of mahseer with Indian major carps in ponds and concluded that polyculture of mahseer can be done. Sawhney (2014) studied growth response of mahseer, *T. putitora* fingerlings to different lipid levels in the diet and observed that a dietary lipid level of 6% was optimal for proper growth of *T. putitora* fingerlings. Gupta *et al.* (2014) described mahseer as flagship species (i.e. a charismatic animal that promotes awareness) for its management and in order to investigate its feasibility for use as flagship species and degree of stakeholder support for it in India, semi-structured interviews were conducted with forest managers, anglers and village members in Uttarakhand and got massive support for declaring it as flagship species.

Taxonomic ambiguities

Morphological taxonomy and phenotypic description of species play an important role in fish genetic resource management, despite the advent of biochemical and molecular genetic techniques. Taxonomy and systematic of the mahseer remains uncertain due to the morphological variations (Bagra *et al.*, 2009). The traditional taxonomy of mahseer has

been facing several problems due to lack of morphometric details in original description. Presence of very few holotypes of mahseer species, indiscernible morphological nuances in them and disagreements in recognizing specific morphological characters (Jayaram, 1999) are few reasons that questions taxonomic ambiguities in mahseer. In a recent study, Khare *et al.* (2014) examined nine mahseer species of *Tor*, *Neolissochilus*, and *Naziritor* with mtDNA data and indicated the need for integrating molecular and morphological tools for taxonomic revision of the *Tor* and *Naziritor* genera. It is also proved that *Tor mosal* that is synonymized as *Tor putitora* and *Tor mussulah* as distinct species while two valid species. *Tor macrolepis* and *T. mosal mahanadicus*, were not distinct from *T. putitora*. Therefore, more research efforts are required at larger scale on the evolutionary and phylogenetic hierarchy of the species as well as biogeographical distribution.

Success in artificial fecundation of golden mahseer collected from wild waters has been achieved at Directorate of Coldwater Fisheries Research, Bhimtal NRC-CWF (Jhoshi, 1982, 1988; Desai, 1970; Sehgal, 1991; Sehgal and Malik, 1991; Mohan *et al.*, 1994). The artificial propagation of *Tor khudree* was also reported by some workers (Kulkarni and Ogale, 1978).

Success in artificial fecundation of the chocolate mahseer, *Neolissocheilus hexagonolepis* (Mc Clelland) was also achieved (Mahapatra and Vinod, 2011; Sarma *et al.*, 2015). The principal

operations involved for artificial breeding of chocolate mahseer includes collection of brood stock, stripping for artificial fecundation, fertilization, incubation and hatching, rearing of spawn and fry.

Himalayas and mahseer are the most important and charismatic part of our Nation that have attracted people to visit India. Several programmes are organized every year In India where anglers across World visit India for the angling of mahseer. On the conservation front, the International Game Fish Association (IGFA) is playing an important role to promote ethical sport and productive science around the World. The Mahseer Trust is another UK based trust with the aim to conserve mahseer by organizing several workshops on angling of mahseer across Himalayas and Western ghats in India and involve to work in partnership with conservation organizations in India, with Indian scientists and universities for conservation of this fish. A series of workshops on science-based conservation and management of mahseer in India was organized in 2014 at Bangalore and Mussoorie, Uttarakhand India with a special focus on recreational fisheries and catch-and-release angling (Pinder and Rajeev, 2013). In Malaysia also the Kelah sanctuary in the Petang river provides a major tourist attraction for the area as *T. douronensis* (Malaysian mahseer) is a target of recreational fisherman due to its size and renowned fighting abilities thus forms an important source of income for commercial fisherman in Malaysia. The chocolate mahseer commonly available in the North Eastern states is a commercially important species and is widely recognized as a sport fish due to its tremendous size and being esteemed by the anglers (Vinod *et al.*, 2003)

Results and Discussion

The conservation of aquatic germplasm resources is an increasingly important field of scientific endeavour and NBFGR is playing crucial role in conservation of fish germplasm. Ten mahseer sanctuaries are proposed in

various rivers in Karnataka (Basavaraja and Keshavanath, 2000). 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). Six Indian states have declared mahseer as a State Fish (Table 2). 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. NBFGR, Lucknow, India has standardized the long-term cryopreservation of milt of *T. putitora* and *T. khudree* at an experimental scale. 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). Kumar *et al.* (2013) assessed the nature of the phylogenetic relationship among the five Indian mahseer species using the sequence of major ribosomal DNA (45S rDNA) and provided greater insights into taxonomic status.

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). 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. Basavaraja & 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. 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. The mahseer hatchery technology

Table 2 Problem and causes for decline of the Chocolate mahseer fisheries in Umiam reservoir

SI No.	Problem	Cause
1	Destruction of breeding ground	i) Alteration of breeding bed due to siltation and solid waste of Shillong municipality carried by river Umkhrah. The eggs sink into soft mud, get asphyxiated and die. ii) Turbidity due to entry of sewage water of Shillong would be detrimental for survival of mahseer egg and hatchling as they require clean water rich in oxygen. iii) The river Umkhrah is a major source of pollutant that threatens breeding.
2	Predation of egg and larvae	Excessive population of <i>Chanda nama</i> eating the eggs and larvae.
3	Destruction of juveniles	i) Predation by highly carnivorous exotic magur <i>C. gariepinus</i> and <i>C. punctatus</i> . ii) Harvesting of juveniles by small mesh size net and angling. The fry of chocolate mahseer were often found in the shallow bays and it is very easy to catch them.
4	Wanton destruction of brood fish	Gravid females are fished out abundantly from the bay region of reservoir during spawning migration to the upstream during July-September
5	Inter-specific competition with exotic fish, <i>C. carpio</i> .	Competition for food.

developed by the Directorate of Coldwater Fisheries Research (DCFR) and 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 developed technologies could be set up in the rural areas adjacent to rivers and reservoirs (Ogale, 2006). Nutritional status of endangered Chocolate mahseer, *Neolissocheilus hexagonolepis* (McClelland) observed from Meghalaya (Majhi *et al.*, 2004; Sarma *et al.*, 2013).

Mahseer is distributed in all the river system of the state viz, *Tor tor*, *Tor putitora*, *Tor khudree* and *T. mosal mahanadicus*. *T. khudree* was reported by Hora and Nair (1941) from Narmada. Presence of *T. khudree* has not been recorded from elsewhere in the state. Three sp. Of mahseer (*T.tor*, *T. putitora* & *T. khudree*) was reported from Narmada by Rao *et al.* (1991). However, presently only *Tor tor* has been reported from Narmada though the data is based on only morphometric and meristic study. It was observed from the study of morphometric phenology of mahseer in different

habitats of Narmada was studied during period of 2004 to 2005. It was found that out of total 13 studied character 7 were found to be genetically controlled which shows that the species is *Tor tor* and is restricted to its zoogeographical distribution and showing narrow range difference in morphometric characters and are genetically controlled. No sub speciation was observed (Shriparna *et al.*, 2007). There are also reports that earlier three sp of Mahseer was recorded from Narmada, viz *Tor pititora*, *Tor khudree* and *Tor tor* Earlier Narmada was well known for mahaseer fishery as this species formed major fishery constituting 46.5% of carp fishery and 28% of total landings during the period 1958-66 in the 48 km stretch in the river Narmada in and around Hoshangabad ie Central zone. (Karamchandani *et al.*, 1967). Shrivastava and Nath also reported decline in mahseer catch from 30.1% (1963-64) to 15.6% (1998-99) in central zone of Narmada. Though mahseer is considered to be a fish of clear running water but now after several dams coming on Narmada river and its tributary mahseer has established itself on these reservoirs too. During the year

1988 to 1997 the maximum no of mahseer caught in Ghandhi sagar reservoir was 333 after total decline bordering to non availability (1995-97) catches again increased. Similarly in case of bargi reservoir the maximum number of mahseer caught was 86 in 1997-98 and none in 1988-89. (Shriparna *et al.*, 2003). Similar decline was observed in annual rept (2005-2006) of Tawa Visthapit adivasi Matsayasangh maryadit Kesala hoshangabad. According to report catch was 1.38% in 1996-97 which drastically decline to 0.58% in the year 2005 - 06. Tawa reservoir is tributary of Narmada river constructed on Tawa river (Somdutt *et al.*, 2007). Same declining trend was seen in the study of two decades from 1982 to 1995 which came down from 16,950 in 1982 to 81,500 in 1996 to 6000 in 1995 (Dutt and Tiwari (2000). The decline in mahseer population from Narmada river is of great concern and needs a thorough study of the factors responsible for this alarming reduction of mahseer fishery. For these reason and to conserve it Mahseer has been declared as STATE FISH by M.P. Govt to protect this precious fish of the state. The chocolate mahseer, *Neolissocheilus hexagonolepis* (Mc Clelland) locally called as "Kha saw" is a commercially important species of Mahseer group and is widely recognized as a sport fish. This fish species, which is endemic to Meghalaya and popular among the anglers, had a good fishery in Umiyam reservoir, a decade back. One of the main reasons for the decline in population of indigenous chocolate mahseer in Umiyam reservoir may be the indiscriminate fishing of brood and juveniles. Moreover, a good number of fry and early fingerlings are destructed through cast nets and small meshed gill nets, which was also noticed in the haul of harvested weed fish from the reservoir. The increase in population of Chanda nama, prolific breeding of common carp and pollution from the river Umkhrah could be some of the other factors responsible for the decline in mahseer population in Umiyam reservoir. Mahseer, which is the most promising fish of the State, can be protected and conserved through concerted efforts from all the concerned stakeholders. Captive breeding and

farming and also ranching in Umiyam reservoir would probably help in the enhancement of their stock. This would help in the development of sport fishery, ornamental fishery and also the overall fish production of Umiyam reservoir and Meghalaya State. Ban on the capture of juvenile fishes should be enforced strictly. The juveniles caught in the net need to be released back into the reservoir. Breeding and stocking of chocolate Mahseer need to be initiated as an additional precautionary and supplementary measure. Proper registration of gill net fishery is needed. A suitable license fee may be levied for registration which will help for developmental process as well as it will help to check to keep the fishing units within the desired level i.e. to check the irrational proliferation of units. Rules should be made for sustainable sport fishing, giving details of fishing seasons, fish sizes, number of rods allowed per anglers, number of anglers allowed at a time, encouragement of catch and release, permit fee etc. Seasonal banning of fishing activities in the reservoir, particularly during the breeding season, need to be enforced. It is necessary to educate the local people about the importance of Mahseer fishery resources as well as to identify the small fry of these fishes and to create awareness among them for the conservation of these endangered species.

Conservation of 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. Since all the species of Mahseer are considered as endangered, careful attention from all the stakeholders is required in order to protect them from further declination. Mahseer conservation plan should be an integral part of the hydro projects that are in the pipeline hill region. *In-situ* conservation and Gene banking can also serve as best medium for conservation of Mahseer species. We need to further identify various areas across country that can be devoted to conservation of Mahseer by organizing various activities in that area. Along with various

conservation programmes we need to revisit and update lists of endangered status. The scope of breeding Mahseer artificially and culturing in ponds should be properly explored and utilized. At least one large size hatchery in the river side is required to be established in all Himalayan states, which possesses Mahseer resource. Ecotourism can be blended with mahseer angling to generate more revenue vis-a-vis to conserve mighty Indian mahseers.

References

- Bagra, K., Kadu, K., Sharma, K.N., Laskar B.A., Sarkar, U.K. and Das, D.N. (2009) Ichthyological survey and review of the checklist of fish fauna of Arunachal Pradesh, India. *Check List*, **5**, 330–350.
- Basavaraja, N. and Keshavanath, P. (2000) Conservation and management of fish genetic resources in Karnataka. In: Ponniah, A.G. and Gopalakrishnan, A. (Eds.). *Endemic Fish Diversity of Western Ghats*. NBFGR-NATP Publication-1, 347 p. National Bureau of Fish Genetic Resources, Lucknow, U.P., India. pp. 152–154.
- Beavan, R. (1877) *Handbook of freshwater fishes of India*. British library Cataloging Publication. 1st edition in India (Ed.), Narendra Publication House, New Delhi. London, pp. 300.
- Day, F. (1889) *The Fishes of India: Being a Natural History of the Fishes Known to Inhabit the Seas and Fresh Waters of India, Burma and Ceylon*. Text and atlas, London, B. Quaritch, pp. 1875–1878.
- Desai, V.R. (1970) Studies on fishery and biology of *Tor tor* (Hamilton), for river Narmada. *J. Inland Fish. Soc. India*, **2**, 101–102.
- Dinesh, K., Nandeasha, M.C., Nautiyal, P. and Aiyappa, P. (2010) Mahseers in India: A review with focus on conservation and management. *Ind. J. Animal Sci.*, **80**, 26–38.
- Eschmeyer, W.N. and Fong, J.D. (2014) Species by Family/Subfamily. Available online: <http://research.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp> (November, 2014).
- Gupta, N., Sivakumar, K., Vinod, B., Mathur, V.B. and Chadwick, M.A. (2014) The 'tiger of Indian rivers': stakeholders' perspectives on the golden mahseer as a flagship fish species, **46**, 389–397.
- Islam, M.d., Shahidul, and Masaru, T. (2007) Threatened fishes of the world: *Tor putitora* Hamilton 1822 (Cypriniformes: Cyprinidae). *Environ Biol. Fishes*, **78**, 219–220.
- Jayaram, K.C. (1999) *The Freshwater Fishes of the Indian region*. Narendra Publishing House, India. **551** p + 18 plates.
- Jayaram, K.C. (2005) *The Deccan Mahseer Fishes: Their ecostatus and threat percepts*, Rec. Zool. Surv. India, Occ. Paper No. **238**: 1–102+XV plates.
- Joshi, C.B. (1982) Artificial breeding of golden mahseer *Torputitora* (Ham). *J. Inl Fish. Soc. India*, **13**, 73–74.
- Joshi, C.B. (1988) Induced breeding of mahseer *Torputitora* (Ham). *J. Inland Fish. Soc. India*, **20**, 66–67.
- Khan, H. (1939) Study of the sex organs of mahseer (*Barbus tor*). *J. Bombay Nat. Hist. Soc.*, **40**, 653–656.
- Khare, P., Vindhya, M., Barman, A.S., Singh, R.K., Lal, K.K. (2014) Molecular evidence to reconcile taxonomic instability in mahseer species (Pisces: Cyprinidae) of India. *Organis. Divers. Evol.*, **14**, 307–326
- Kohli, M.P.S., Langer, R.K., Ogale, S.N., Dubey, K., Prakash, C. (2006) Cage culture of Deccan mahseer *Tor khudree* in Walwan reservoir, Maharashtra, India. In: Book of Abstracts, International Symposium on the Mahseer, 29-30 March 2006, Kuala Lumpur, Malaysia. Malaysian Fisheries Society, Malaysia.
- Kulkarni, C.V. and Ogale, S.N. (1978) The present status of mahseer (fish) and artificial propagation of *Tor khudree* (Sykes). *J. Bombay. Nat. Hist. Soc.*, **75**, 651–660.
- Kumar, R., Goel C., Sahoo, P.K., Singh, A.K. and Barat, A. (2015) Complete mitochondrial genome organization of *Tor tor* (Hamilton, 1822). *Mitochondrial DNA*. doi: 10.3109/19401736.2015.1038795.
- Kurup, B.M. and Radhakrishnan, K.V. (2010) *Tor remadevii*, a new species of *Tor* (gray) from Chinnar Wildlife Sanctuary, Pambar River, Kerala, Southern India. *Journal of the Bombay Natural History Society*, **107**, 227–230.
- Lakra, W.S., Bhonde, R., Sivakumar, N. and Ayyappan, S. (2006) A new fibroblast like cell line from the fry of golden mahseer *Tor putitora* (Ham). *Aquaculture*, **253**, 238–243.
- Lakra, W.S., Sarkar, U.K., Kumar, R.S., Pandey, A., Dubey, V.K. and Gusain, O.M. (2010) Fish diversity, habitat ecology and their conservation and management issues of a tropical River in Ganga basin, India. *Environmentalist*, **30**, 306–319.
- Laskar, B.A., Bhattacharjee, M.J., Dhar, B., Mahadani, P., Kundu, S. and Ghosh S.K. (2013) The Species Dilemma of Northeast Indian Mahseer (Actinopterygii: Cyprinidae): DNA Barcoding in Clarifying the Riddle. *PLoS One*, **8**, e53704.

- Mahapatra, B.K. and Vinod K. (2011) Reproductive biology and artificial propagation of chocolate mahseer *Neolissocheilus hexagonolepis* (Mc Clelland) in Meghalaya, India. *Indian J. Fish.*, **58**, 35–40.
- Mahapatra, B.K., Vinod, K. and Mandal, B.K. (2004) Studies on chocolate mahseer, *Neolissocheilus hexagonolepis* (Mc Clelland) fishery and the cause of its decline in Umiam reservoir, Meghalaya. *J. Natcon.*, **16**, 199–205.
- Majhi, S.K., Mahapatra, B.K., Vinod, K. and Mandal, B.K. (2006) Nutritional status of endangered Chocolate mahseer, *Neolissocheilus hexagonolepis*. (Mc Clelland). *Environ. Ecol.*, **24**, 582–585.
- Mohan, M., Shyam Sunder and Raina, H. S. (1994) A modern cost efficient hatchery for mahseer aquaculture in the Himalayan region. Proceedings of National Symposium 'Aquacrops', CIFE, Bombay.
- Nautiyal, P. (1989) Mahseer Conservation – Problem and Prospects. *J. Bom. Nat. His. Soc.*, **86**, 32–36.
- Nautiyal, P., Lal M.S. (1988) Natural history of the Garhwal Himalayan Mahseer *Tor putitora*: Racial composition. *Indian J. Ani. Sci.*, **58**, 283–294.
- Nelson, S.J. (2006) *Fishes of the World*, 4th Ed., New York: John Wiley and Sons Inc.
- Ng, C.K. (2004). King of the rivers: mahseer in Malaysia and the region. Inter Sea Fishery (M) SDN BHD, Kuala Lumpur. pp. 170.
- Oliver, K., Sangma, N., Basavaraja, N. (2007) Deccan Mahseer (*Tor khudree*) of Karnataka- on location of its wild brooders and fry and breakthrough in the hatchery production of its seed. *Fishing Chimes*, **26**, 32–6.
- Pinder, A.C. and Raghavan, R. (2013) Conserving the endangered Mahseers (*Tor* spp.) of India: the positive role of recreational fisheries Current Science, **104**, 1472–1475.
- Pisolkar, M.D. and Karamchandani, S.J. (1981) Fishery biology of *Tor tor* (Hamilton) from Govindgarh lake (Madhya Pradesh). *Inland Fish Soc India*, **13**, 15–24.
- Rahman, M.R., Rahman, M.S., Khan, M.G.Q. and Mostary, S. (2007) Suitability of Mahseer *Tor putitora* (Hamilton) in Polyculture with Indian Major Carps. *Progr. Agric.*, **18**, 175–182.
- Ranjana, L.K. (2005) Molecular characterization of golden Mahseer (*Tor putitora*) for stock identification. Ph.D. Thesis. A.P.S. University Rewa, India
- Sarma, D., Akhtar, M.S., Das, P., Ganesh, G., Ciji, A. and Mahanta, P.C. (2015) Observations on larval development of chocolate mahseer *Neolissochilus hexagonolepis* (McClelland, 1839). *Indian J. Fish.*, **62**, 135–138.
- Sarma, D., Akhtar, M.S., Das, P., Shahi, N., Ciji, A. and Mahanta, P.C. (2013) Nutritional quality in terms of amino acid and fatty acid of five coldwater fish species: implications to human health. *Nat. Acad. Sci. Lett.*, **36** (4), 385–391.
- Sati, J., Kumar, R., Sahoo, P.K., Patiyl, R.S., Ali, S. and Barat, A. (2013) Genetic characterization of Golden mahseer (*Tor putitora*) populations using mitochondrial DNA markers. *Mitochondrial DNA*, 1–7. doi: 10.3109/19401736.2013.823170.
- Sehgal, K.L. (1999) Cold water fish and fisheries in the western ghats, India. FAO Fisheries Technical Paper, No. 385, Rome, FAO, 304.
- Sehgal, K. L. (1991) Artificial propagation of golden mahseer, *Torputitora* (Ham.) in the Himalaya. NRC-CWF Sp. Publ. 2. pp. 12.
- Sehgal, K.L. and Malik, D.S. (1991) Efficiency of flow-through system for seed production of *Tor putitora* (Ham.) at KumaonHimalaya. *Indian J. Fish.*, **38**, 134–137.
- Shanmukha, S.N. (1996) Status of mahseer fishery in Karnataka. *Fishing Chimes*, June 1996, 26–29.
- Sharma, J., Parashar, A. (2013) Fertilization regime in culture pond – An attempt for rehabilitation and conservation of endangered fish mahseer (*Tor tor*). *Indian J. App. Pure Biol.*, **28**, 39–44.
- Vinod, K., Mahapatra, B.K. and Mandal, B.K. (2007) Umiam reservoir fisheries of Meghalaya (Eastern Himalayas)- Strategies for yield optimization. *Fishing Chimes*, **26**, 8–15.
- Vinod, K., Mahapatra, B.K. and Mandal, B.K. (2003) Recreational Fishing In a Meghalaya Community Pond: A case study. *Fishing Chimes*, **23**, 76–77.
- WWF, (2013). Mahseer Conservation in India Status, Challenges and the way forward.