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REVIEWS

# Endangered Golden mahseer *Tor putitora* Hamilton: a review of natural history

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**Abstract** Golden mahseer, *Tor putitora* Hamilton, one of the largest freshwater fish of the Indian sub-continent, inhabits mainly Himalayan rivers in the foothills. Among numerous freshwater fishes of the sub-continent, Golden mahseer is the most striking due to its large size, attractive golden colour, sustenance and sporting values. *Tor putitora* is known by various common names such as king mahseer, mighty mahseer and the tiger of water. Being a migratory fish, Golden mahseer undertakes periodic upstream migration during pre-monsoon and monsoon seasons from large rivers and higher order streams in the foothills to lower order streams for spawning. In recent years, conservationists, anglers and commercial fishermen have expressed concern over the declining populations of Golden mahseer due to indiscriminate fishing of brooders and juveniles besides the adverse effects of dams. Despite its ecological and economic importance, specific conservation measures by way of protective legal provisos are lacking for Golden mahseer in India. In view of its physical features, ecology and vulnerable conservation status, there is an exigent need to promote the Golden mahseer as a flagship conservation species of the Himalayan rivers. In view of the recent reports of unprecedented river regulation projects on the Himalayan rivers and need to draw global attention of conservationists, we review various aspects of ecology, life history, interesting features, traits and threats associated with the reduced chances of survival of Golden mahseer.

**Keywords** Himalaya · Golden mahseer · Endangered species · Threats · Conservation

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## Introduction

*Tor putitora* Hamilton (Golden mahseer), promoted as a 'flagship' species, is one of the most interesting freshwater fish species of the Indian sub-continent. (Everard and Kataria 2011; Gupta et al. 2014a). It is a highly popular game, "elusive and intelligent" fish species (Gupta et al. 2014a) and an angler's delight compared to other fishes of the Himalayan waters because of its large size, attractive golden colour and large body scales. The large size of the fish, its culinary quality and its fighting trait have interested native

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human population, anglers and researchers for a long time (e.g. Hamilton (1822); Day 1878; Thomas 1897; Hora 1939; McDonald 1948). Anglers have traditionally found more sport in mahseer than salmon (Thomas 1897). In Indian waters the fish can grow to the length and weight of up to 275 cm and 54 kg, respectively (Everard and Kataria 2011; Nautiyal et al. 2008). The head length of the fish exceeds that of the body depth (Hora 1939; Bhatt et al. 1998a). Large head, body and scales are important morphological characteristic features of mahseer and various vernacular names such as mahseer (large head), mahasaul and Mahasalka (Large scale) are probably derived from these features (see Nautiyal 2014).

The name mahseer is often used for species belonging to genus *Tor* as well as for other species of the genera *Neolissochilus* and *Naziritor*. Across the global range, a total of 46 species are known as mahseer, of which 23 species belong to the genus *Tor*, 22 to *Neolissochilus* and one to *Naziritor* (Eschmeyer et al. 2004). Lack of uniform and standard taxonomic diagnostic features for the genus *Tor* have resulted in numerous synonyms that have made mahseer taxonomy equivocal (Everard and Kataria 2011; ZiMing and JunZing 2004). As a result, much confusion has arisen with respect to the validity of species' names of *Tor* (e.g. Jhingran 1982; Talwar and Jhingran 1991; Menon 1992; ZiMing and JunXing 2004). Due to such taxonomic uncertainties, reliable estimates of the number of mahseer fish in Indian waters are unavailable so far (Nautiyal 2006; Pinder and Raghavan 2013; Pinder et al. 2014, 2015).

That said, the taxonomy *T. putitora* is well understood as compared to other species of the genus. Hamilton (1822) first identified the species as *Cyprinus putitora* which was later placed under the genus *Tor* as *T. putitora* (Gray 1833–1834). Hora (1939) described it as *Barbus putitora* whereas Menon (1954) described it as *T. putitora* and restored its name proposed by Gray (1833–1834). The literature on Golden mahseer (*T. putitora*) is larger compared to that of any other freshwater fish of the Indian sub continent. Some of the important works on the species include researches by Hora (1939), McDonald (1948), Desai (1972), Das and Pathani (1978), Pathani and Das (1979), Johal and Tandon (1981), Nautiyal (1984, 1989, 2002, 2006, 2011, 2014), Nautiyal and Lal (1985a, b, c), Shrestha et al. (1990), Shrestha (1994), Dasgupta (1991a, b, 1993), Bhatt et al. (1998a, b, 2000, 2004), Rahman et al. (2005), Nautiyal et al. (2008), Everard and Kataria (2011), Naeem et al. (2011), Arora and Julka (2013), Sati et al. (2013), Khajuria et al. (2013), Gupta et al. (2014a, b) and Ali et al. (2014). Much of the literature cited here is devoted to the ecology, biology, conservation and population dynamics of Golden mahseer. However, it is noteworthy that much of this literature on natural history comes from Western and Central Himalaya, i.e. Jammu & Kashmir, Himachal Pradesh, Uttarakhand and Nepal. Except for a few aspects like distribution, biometry, food and feeding habit (Dasgupta 1991a, b, 1993; Khan and Sinha 2000), natural history of Golden mahseer remains largely unknown from Eastern Himalaya (Sikkim, Bhutan, Arunachal Pradesh) and the Northeast region like Meghalaya etc. Despite its biological and commercial importance, *T. putitora* has not received as much attention globally as the salmonids. It is not clear whether lack of international interest in Golden mahseer studies is related to its restricted geographic distribution, but the fish certainly deserves the status of flagship species of the Indian freshwaters (Everard and Kataria 2011; Pinder and Raghvan 2013; Gupta et al. 2014a; Pinder et al. 2014).

As a result of its overexploitation, Golden mahseer population sizes have significantly declined and the fish has been categorised as an 'endangered' species in the IUCN redlist (IUCN 2015). Concern for the species' conservation in India dates back to mid 1970s when the National Commission on Agriculture (1976) highlighted the threats to mahseer from indiscriminate fishing of brooders and juveniles, and the adverse effects of dams. The threats have continued unabated despite the longstanding concern. In fact alarming decline in the number and size of mahseer populations especially from mountain rivers of the sub continent have been reported by many researchers (Nautiyal 2006, 2014; Nautiyal et al. 2008; Dinesh et al. 2010; Gupta et al. 2014a, b). Most of these works have focused on the biology and ecology of the fish, but not as much attention has been paid to the status of its habitats. A new set of threats have emerged and intensified that are likely to jeopardise the future survival of this important species. It is, therefore, timely to reassess the conservation status vis-a-vis threats to the Golden mahseer. This review aims to fill that gap and integrates available information on distribution, diversity, commercial exploitation and migratory behaviour of the fish, and focuses on the sensitivity of its habitats with respect to threats and challenges to its survival. We also focus attention on life history attributes of Golden mahseer, which may be linked to the species' intrinsic vulnerability to rarity and population losses.

## Geographic distribution

*Tor putitora* is widely distributed in south Asian countries (India, Afghanistan, Pakistan, Nepal, Bhutan, Myanmar), but with a restricted area of occupancy (IUCN 2015). Its longitudinal distribution extends from Hindukush–Kabul–Kohistan in the Northwest Himalaya to Sadiya (Brahmaputra) in the Northeast Himalaya in India. The species is distributed in the rivers along the Himalayan foothills and its tropical relief up to 850 m (Talwar and Jhingran 1991), Garo hills of Meghalaya (Dasgupta 1991a, b, 1993) and Challou river of Manipur in India and hilly streams of Sylhet, Mymensingh, and Dinajpur and Kaptai reservoir of Chittagong Hills in Bangladesh (Rahman 1989). Reports indicate that prior to the 1960s the Golden mahseer populated rivers up to northern Gangetic plains (Nautiyal et al. 2008) and Mahanadi river near Huma Sanctuary (David 1955). Desai (1972) and Bakawale and Kanhere (2013) reported it from Narmada river. Earlier, reports of Golden mahseer are from Gomal, Gunti and Kurram areas of Baluchistan and Waziristan (see Nautiyal 1994). However, the actual geographic range of Golden mahseer has been suggested to be Himalaya and its river systems. Therefore, the reports of its distribution beyond the Himalayan rivers creates considerable ambiguity (Nautiyal 2011). There is little recent information on the status of Golden mahseer in the rivers of Gangetic plains, of Central India and in Mahanadi river indicating to the likely shrinkage of its habitats in India. Interestingly, *T. putitora* along with other carps was introduced in inland waters of Papua New Guinea in 1995 (Kolkolo 1996), but no information is available on its self sustaining populations in the introduced range.

## Habitat

*Tor putitora* inhabits natural running waters, but is now thriving in semi lacustrine waters especially in the Himalayan region. It was introduced into selected Himalayan lakes in Kumaun like Bhimtal, Naukuchiatal, Nainital and Sattal by Sir Ramsay around 1858 (Walker 1888), where its self sustaining populations have been surviving since. Gobindsagar and Pong reservoirs in Himachal Pradesh and Kalagarh reservoir in Uttarakhand are other examples where sizeable populations of *T. putitora* have existed for a long time (Johal et al. 1994; Johnsingh et al. 2006). The fish was introduced in the reservoirs of Tehri and Koteshwar dams in Uttarakhand in 2006 onwards. We witnessed thriving populations of adolescent and adult Golden mahseer in these reservoirs during our surveys in 2013–2014. Our field studies over a period of two decades also indicate that many potential unexplored habitats of *T. putitora* exist in the Northeast India such as Rimbi–Riyang river (tributary of Teesta river in West Bengal), Simang and Hrit rivers (tributaries of Siang river), Siang and Subansiri rivers in Arunachal Pradesh. More detailed studies are perhaps needed in these regions so as to adequately circumscribe the exact habitat and distribution of this species.

Golden mahseer is essentially a rheophilic species inhabiting hill streams with rocky/stony substrate (Nautiyal 2014). The foothill stretches of the Himalayan rivers are reported to be the stationary or feeding grounds of the Golden mahseer; these habitats have large volumes of water and the river bed is mostly covered with sand, silt and small boulders (Bhatt et al. 2004). The physico-chemical nature of the feeding grounds is characterised by water temperature in the range of 14–22 °C and an alkaline pH (>7). Dissolved oxygen in these habitats varies from 5.2 to 12.9 mg/l (Bhatt et al. 2004). The species is potamodromous (migrating within freshwaters) and uses smaller hill streams as the spawning grounds. Likewise, in the semi lacustrine ecosystems like Gobindsagar reservoir in Himachal Pradesh the fish uses small streams or reservoir creeks for spawning (Johal et al. 1994; Joshi 1994). In general, the spawning grounds of the fish are characterised by riverbeds with large boulders, pebbles and gravel. The spawning grounds are characterised by water temperature varying from 11 to 30.5 °C, alkaline pH and dissolved oxygen concentration in the range of 6.4–11 mg/l (Bhatt et al. 2004; Joshi 1994).

The important spawning habitats of Golden mahseer across the Indian subcontinent are spread across the Himalayan river system -Alikahd, Seerkhad and Gamberkhad (tributaries of Sutlej river) in Himachal

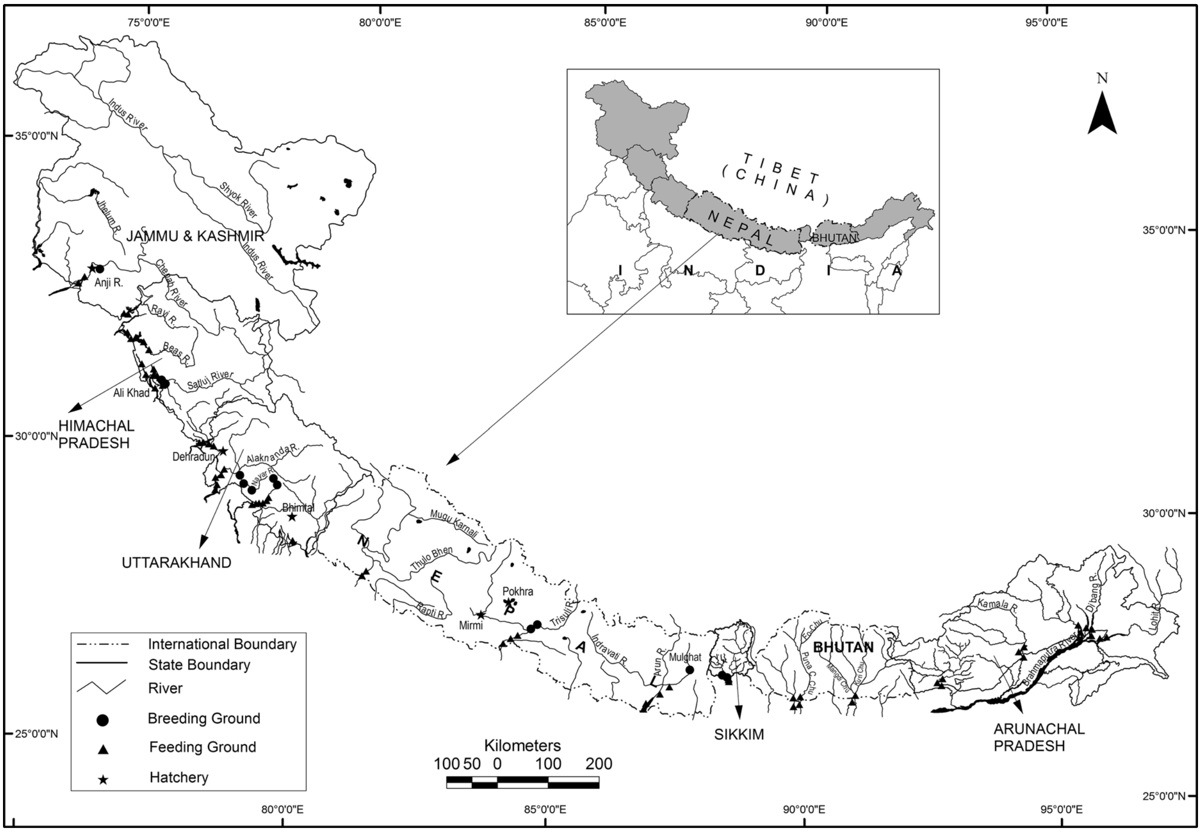


**Fig. 1** Important feeding and spawning habitats of Golden mahseer in Himalyan rivers. The locations of a few hatcheries of Golden mahseer are also shown in the figure

Pradesh (Joshi 1988), Nayar and Song rivers (tributaries of Ganga) in Uttarakhand (Bhatt et al. 2004; Nautiyal et al. 2008), Mandal and Khoh rivers (tributaries of Ramganga) in Uttarakhand (Atkore et al. 2011), Tadi and Khahare Khola (tributaries of Trishuli river) in Nepal (Shrestha 2002) (Fig. 1), streams of Garo hills in Meghalaya (Dasgupta 1991a, b) and Korang river near Islamabad, Pakistan (Zafar et al. 2001). Credible information on the spawning grounds of Golden mahseer in the rivers of Northeast Himalaya is sparse, but during our surveys, we recorded adolescents and juveniles of the species from Rimbi - Riyang river (tributaries of Teesta river) in Sikkim and Darjeeling Himalaya during 2013–2014.

## Phenotypic and genotypic characterisation

Various morphometric and meristic characters are useful for the phenotypic studies and for precise description of any differentiation among the stocks of fish. In mahseer, morphological characters have been largely used for studying the differentiation between *T. putitota* and *T. tor* (Day 1878; Hora and Mukerji 1936). Hora (1939) provided a detailed description of *T. putitora* on the basis of four morphometric characters, viz. total length, standard length, head length and body depth. Such studies depict whether or not morphometric characters increase with an increase in length. More studies on the species have added more morphometric and meristic characters as the phenotypes of Golden mahseer from Garo hills in Northeast India, Gobindsagar reservoir in Himachal Pradseh, Ganga river in Uttarakhand and tributaries of Chenab river in Jammu & Kashmir are described (Dasgupta 1982, 1991a; Johal et al. 1994; Bhatt et al. 1998a; Sharma et al. 2015). These studies established a relationship of standard length (SL), head length (HL), head depth (HD), maximum body depth (MBD), minimum body depth (MiBD) and length of caudal fin

(LCF) with total length (TL), eye diameter (ED) and head depth (HD) with head length (HL). These morphometric characters range from 1.1 to 1.3 (TL/SL), 3.7–5.7 (TL/HL), 6.0–10.0 (TL/HD), 4.2–7.4 (TL/MBD), 8.3–15.8 (TL/MiBD), 3.7–.5.9 (TL/LCF), 4.4–10.0 (HL/ED) and 1.3–2.2 (HL/HD), respectively.

Following the criterion of Vladykov (1934) subsequent researchers used three categories of morphometric characters of *T. putitora*, viz., genetically controlled characters (showing narrow range of difference in their measurements), environmentally controlled character (showing wide range of difference in their measurements) and intermediate characters in their studies (Johal et al. 1994; Bhatt et al. 1998a). These researches concluded that if the species is widely distributed, the morphological and meristic characters are influenced by environmental factors like latitude, temperature and water current velocity which lead to species differentiation and divergence. A comparative study (Bhatt et al. 1998b) on the morphometry of different populations of *T. putitora* showed that out of 15 morphometric characters in proportion to total body length, 12 were non plastic (genetically controlled), one was plastic and two were intermediate. In proportion to the head length 2 characters showed plasticity while three were intermediate (see Bhatt et al. 1998b).

Cytogenetical studies have revealed that *T. putitora* has a high number of chromosomes (2n = 100) and appears to be a tetraploid (Khuda-Bukhsh 1980, 1982). Polyploidy has been reported to be related to invasiveness in animals and plants with geographic range extensions (see Pandit 2006; Pandit et al. 2014). It would be, therefore, interesting to find out whether *T. putitora* populations that are thriving in lacustrine environments have something to do with polyploidy. Population genetics studies on *T. putitora* are limited, but have been undertaken by some researchers in recent years. Studies on genetic variability of *T. putitora*, based on the Polymerase Chain Reaction (PCR), have been carried out by various researchers in the rivers of Himachal Pradesh, Uttarakhand, North-east India (Ranjana et al. 2004; Nguyen et al. 2008; Singh et al. 2011; Sati et al. 2013; Laskar et al. 2013; Arora and Julka 2013). In general, these studies revealed that there is substantial mixing of gene pools in at least those populations which do not have confined distribution and have free migratory routes. This work revealed a higher degree of genetic similarity between *T. putitora*, *T. tor* and *T. khudree* and lower proportion of polymorphic loci in *T. putitora* reflecting low levels of genetic variability. Low genetic variability is attributed to the failure of species to withstand changes in the environment (e.g. Lakra et al. 2007). But contrary to this, we witnessed populations of Golden mahseer able to thrive well in the riverine and lacustrine waters. More in-depth studies are perhaps required to understand the population genetic structure of these fish populations and their ecological amplitude and adaptive potential.

## Feeding habit

The food of *T. putitora* comprises insects, algae, macrophytes, rotifers, small fish, crustaceans, etc. (Badola and Singh 1980; Dasgupta 1991a). Numerous studies have indicated that the species' food habits change with increasing size. Examination of guts of fry of *T. putitora*, for example, revealed diatoms as the chief food (Sehgal 1971), while in fingerlings and juveniles researchers have found 81.4 % insect material and 15.9 % plant material in their guts and categorised this stage of fish as insectivorous (Nautiyal and Lal 1984). However, Kishor et al. (1998) recorded 40–100 % animal matter and 0–60 % plant matter in the gut of adult mahseer from the foothills of Ganga. Notably, Dasgupta (1991a) observed variations in the food material in the gut of *T. putitora* of Garo hills with changing size and seasons. A more generalised picture that emerges from various studies indicates that smaller sized fish prefer animal matter whereas large sized fish consume more plant material. Researchers have revealed that algae and other vegetation matter constitute a fraction of fish food during winter and summer, but comprise most of the diet in the monsoon season (Dasgupta 1991a).

As noted above, the feeding preferences of *T. putitora* vary largely. This has prompted different researchers to designate the species differently-insectivore, carnivore, herbi-omnivore, carni-omnivore, etc. (e.g. Nautiyal and Lal 1984; Das and Pathani 1978; Badola and Singh1980). Clearly, feeding habit of the Golden mahseer varies with the availability of food and it takes advantage of what is on offer in a particular season. For example, in Ganga at Rishikesh, tourists feed the fish with artificial food and large shoals of mahseer can be seen pouncing at the feed. We witnessed the voracious feeding habit of *T.*

*putitora* in Koteshwar dam reservoir (downstream of Tehri dam) in Uttarakhand. In an unusual feeding behaviour, one of the authors (JPB) witnessed a shoal of *T. putitora* leaping inside the burning pyre (partially submerged in water) and the individuals were observed to be nipping at partially burnt human dead body. Hindus commonly burn their dead bodies on the river banks and in the case of Koteshwar dam as the water levels rise in the reservoir fish are able to reach the cremation sites. Whether this unfamiliar feeding behaviour of Golden mahseer is attributable to meagre food availability in the reservoir, which cannot support much insect larvae, needs more in-depth studies. Considering that cremation sites along the Ganga river are not uncommon, such type of foraging behaviour of Golden mahseer has not been reported earlier.

## Age and growth

*Tor putitora* of 15+ and 17+ year have been recorded from Gobindsagar reservoir in Himachal Pradesh and Ganga river in Uttarakhand (Johal et al. 1999; Bhatt et al. 2004). Bhatt et al. (2000) reported 5+ age classes in males while 9+ age classes in females in the foothills of Ganga. The most common age classes of *T. putitora* that are harvested belong to 2+ to 4+ year, which comprise about 73 % of the total catch in Ganga river (Bhatt et al. 2000). In the initial phase of life (1+ year) fish grows faster, thereafter growth become steady. Individuals do not reach sexual maturity till 4+ year age class (e.g. Nautiyal 1994), therefore, large-scale harvests of the fish prior to its achieving breeding maturity leads to population size depression. *T. putitora* essentially follows an isometric pattern of growth (Ali et al. 2014) and is known to have slow growth rate as compared to that of other fish of the same habitats (Pathani and Das 1980). That the lotic waters are considered to be more conducive for its growth than the lentic ones, unprecedented river regulation and water withdrawals through a series of dams are likely to seriously jeopardise population growth of the fish in the Himalayan rivers (Pandit and Grumbine 2012; Gupta et al. 2014b).

## Migration

Golden mahseer exhibits a phased migration in the Himalaya (Nautiyal 1989). The first phase of migration is undertaken by the adults along with adolescents during the months of March–April when fish ascend to tributaries from larger rivers in the Himalayan foothills such as Chenab (Jammu & Kashmir), Ganga, Ramganga (Uttarakhand), Narayani (Nepal), etc. However, they do not enter the smaller tributaries for breeding (Nautiyal 1989; Shyam and Joshi 1977; Bhatt et al. 2004). The spawning grounds of the fish are generally low elevation rain-fed tributaries in the middle elevation hills, which do not possess adequate water till monsoon to sustain adults and adolescents. The fish, therefore, prefers to continue migration in the main channel upstream and enters higher order tributaries, mostly with perennial water source and cooler temperatures (Nautiyal 1994). This first phase of migration in *T. putitora* has been described as the learning behaviour (Nautiyal 1994). Second phase of migration takes place with the onset of monsoon when water becomes more turbid. Only the brooders ascend higher up in the smaller tributaries in the Himalayan rivers Like Anji (tributary of Chenab), Alikhad (tributary of Sutlej river), Nayar (tributary of Ganga river), Mandal, Palan and Khoh (tributaries of Ramganga river) and Tadi and Khahare Khola (tributaries of Trishuli river in Nepal) (Shyam and Joshi 1977; Joshi 1994; Nautiyal 1989; Johnsingh et al. 2006; Shrestha 2002). These are rain-fed streams and swell greatly due to monsoon rains and are able to sustain brooders of Golden mahseer. After reaching suitable breeding grounds, which provide optimal conditions for breeding, the fish spawn in these tributaries and it is followed by third phase of migration when these brooders along with juveniles descend to large streams in the foothills (Nautiyal 1994).

Large volume of water, high discharge and higher number of predators in the lowland rivers do not constitute a conducive environment for ova and fry of mahseer (Bhatt et al. 2004). Besides, fertilized eggs take 58–192 h to hatch, and being demersal the eggs can sink and perish in the muddy beds of the lowland rivers (Johnsingh et al. 2006). The eggs best hatch at temperature ranges between 16 and 25 °C in river water with high turbidity (see Johnsingh et al.2006). These ecological requirements are met essentially in the rain-fed hill streams. Turbid waters and higher water temperature are considered to be stimuli for migration for breeding (Nautiyal 1994; Bhatt et al.

2004). Monsoon is the most opportune time for migration because of high water turbidity in the Himalayan rivers that provides a protective cover to fish and reduces the risk of being attacked by visual predators (e.g. Abrahams and Kattenfeld 1997; Bhatt et al. 2004).

## Reproductive potential

Strong sexual dimorphism in *T. putitora* is not evident, although a few secondary characters have been reported in hatchery stocks of males and females especially during the spawning season. Males are bright coloured and have elongated body with rough pectoral fins, while females are deep-bodied with a dull colour (Arjamand et al. 2013). In spite of these specific features there is high probability of misidentification of males and females. The reports on spawning seasons of *T. putitora* are rather equivocal with some reports of three spawning seasons (Khan 1939), which was contested by Hora (1940). Later reports suggested that the species spawns twice in a year, during April–May and July–October (Johal and Tandon 1981; Malik 2011). However, the most accepted season for spawning in *T. putitora* is the high floods during monsoon (Beavan 1877; Thomas 1897; Nautiyal 1984). Fish undertake a long migration that lasts from March to September and lay eggs in shallow waters with 0.5–3.5 m depth with stream beds of gravel, pebbles, silt and sand (Pathani 1994a). Nautiyal (1994) observed that river banks are suitable spawning niches where the fish creates depressions to deposit eggs. While depositing eggs, females show vent, ragged and frayed appearance of caudal and ventral fins (Thomas 1897).

The reproductive potential of *T. putitora* in terms of fecundity is considerably low as compared to the commercially exploited fish and its associates (Table 1). The average fecundity in *T. putitora* in both lotic and lentic waters ranges from 7 to 25 eggs/g body weight (Pathani 1981; Nautiyal and Lal 1985c; Khan 1994; Nautiyal 2014). The ovary in the brooders ready to spawn is pale yellow and cylindrical. Eggs are visible to the naked eye and range from 2.86 to 3.08 mm in size (Bhatt et al. 2004). The size of a sexually mature fish has been recorded to be 47.1 cm by Nautiyal (1994).

**Table 1** Comparison of intrinsic characteristics of *Tor putitora* with other associate fish species (source: Online Resource 1)

| Species | Average growth (cm) per year | Size (cm) and age (year) at sexual maturity | Fecundity (no. of eggs/g body weight) | Incubation time (in hours) | Citation no. at Online Resource 1 | Other features |
|---|---|---|---|---|---|---|
| *Tor putitora* | 5.0–11.0 | 47.0 (4–5 years) | 7.0–25.0 | 58.0–192.0 | 1,2,3,4,5 | Migratory, distributed mainly in Himalaya |
| *Tor tor* | 3.4–21.4 | 3.4.0–38.0 (3–4 years) | 24.0–36.0 | 82.00 | 6 | Migratory, distributed mainly in Himalaya and Narmada basin |
| *Schizothorax richardsonii* | 10.0–13.0 | 13.0–16.0 (2–3 years) | 25.0–80.0 | 264.0–287.0 | 7,8,9,10 | Distributed throughout Himalaya |
| *Labeo rohita* | 38.0–48.0 | 46.0–51.5 (2–3 years) | 211.0–413.0 | 17.0–20.0 | 11 | Throughout Indian sub continent |
| *Catla catla* | 9.4–35.0 | 44.0–56.0 (2nd year) | 20.0–246.0 | 16.0–24.0 | 12 | Throughout Indian sub continent |
| *Cirrhinus mirigala* | 20.0–65.0 | 35.0 (2nd year) | 31.0–252.0 | 16.0–24.0 | 13 | Throughout Indian sub continent |
| *Neolissochilus hexagonolepis* | 7.0–8.0 | 19.0–25.0 (2–3 years) | 7.0–11.0 | 40.0–62.0 | 14,15,16 | Eastern Himalaya |
| *Cyprinus carpio* | Up to 28.0 | 25.0–34.0 (2–4 years) | 239.0–285.0 | 48.0–144.0 | 17,18,19 | Exotic, worldwide distribution |

## Commercial exploitation

Not so long ago *T. putitora* was a commercial species in the lower reaches of the Himalayan rivers. In Jhelum, Chenab and Ravi rivers the fish accounted for an average of 21.4 % of total fish catch (Khan and Sinha 2000). In Sutlej river and its tributaries, namely Alikhad, Gamber Khad and Seer Khad, it contributed as much as 6, 26, 35 and 34 %, respectively of the total fish catch (Joshi 1988). Likewise, Sharma and Mishra (2002) recorded 0.8, 9.7, 0.9, 32.8, 3.1 and 2.6 % of Golden mahseer in total fish catch of Hiyunl, Song, Khoh, Nayar, Bhilangana and Bhagirathi rivers, respectively in Garhwal Himalaya. During 1993–1994 Bhatt et al. (2004) reported Golden mahseer to be the predominant species of the foothill stretch of Ganga river contributing about 19 % of the total annual catch. In the lotic waters of Kumaun, Golden mahseer constituted about 15 % of total catch (Pathani 1994b). It contributed significantly to commercial fishery in the tributaries of Brahmaputra and in a few lacustrine water bodies like Gobindsagar reservoir, Pond reservoir and Bhimtal (e.g. WWF 2013; Johal et al. 1994).

Concerns about the decreasing trends in the contribution of Golden mahseer to the commercial fishery in the Himalayan rivers have been raised by various workers (Khan and Sinha 2000; Sodhi et al. 2013). Long term studies on the fish indicate that mahseer populations in the Himalayan waters, including India and Nepal, have not only been declining at an alarming rate, but the number of large and well grown individuals have also reduced (Rana et al. 2012).The angling records of mahseer are available from 1999–2000 to 2011–2012 and from 1981 to 2010 in the rivers of North and Northeast India (see Gupta et al. 2014b; WWF 2013). Report indicated that the mahseer population is not affected adversely by control angling activities like 'catch and release' (Gupta et al. 2014b). On the other hand, uncontrolled catch record of the fish in the rivers of Northeast India revealed that seasonal catch and average size of mahseer has decreased from 56 to 2 kg and 3 to 0.75 kg, respectively (WWF 2013). However, the main reasons behind the depletion of Golden mahseer are its habitat destruction resulting from river regulation, introduction of exotic species, over harvest of brooders and indiscriminate fishing (Khan and Sinha 2000). Smaller streams like Song and Nayar (tributaries of Ganga) in Garhwal and Alikhad (tributary of Sutlej) in Himachal Pradesh, Mandal (tributary of Ramganga) in Kumaon are known breeding grounds of Golden mahseer and that the Golden mahseer is a predominant species in these waters (Joshi 1988; Bhatt et al. 2004; Nautiyal et al. 2008; Atkore et al. 2011). These tributaries are visited by brooders in high floods during monsoon season only, but fishing activities are carried out throughout the year. Notably, juveniles constitute an important fishery in these streams, and are subjected to considerable harvesting before reaching sexual maturity. The spawning grounds are shallow due to low water discharge during non-monsoon months and are most impacted by destructive fishing practices, like the use of dynamites and poisoning, and diversion of water (Everard and Kataria 2011). All these activities have been reported to contribute substantially to the declining populations of mahseer in the Himalayan rivers (Srivastava et al. 2002).

## Threats

Habitat alteration by dams, barrages, and illegal sand/boulder mining, poaching and indiscriminate fishing of brooders are largely responsible for the endangerment of *T. putitora* (Pathani 1994a, b; Lakra et al. 2010; Nautiyal 2011, 2014; Pandit and Grumbine 2012; Khajuria et al. 2013; Gupta et al. 2014a, b, 2015a; Sharma et al. 2015).Over the past two decades, rapid human population growth in the Himalaya coupled with India's faster rates of energy requirement and ensuing building of hydropower projects have forced changes in the Himalayan landscape (Grumbine and Pandit 2013; Pandit et al. 2014). To meet the rising demands of energy, the Government of India enunciated the policy to exploit the vast hydro-electric potential of the Himalayan rivers which have been reported to lead to serious ecological changes and biodiversity losses (Pandit 2009; Pandit and Grumbine 2012). Construction of multiple dams on the Himalayan rivers are reported to result in habitat fragmentation of migratory species, habitat degradation, submergence of large terrestrial and river bed areas which bring about significant changes in the quantity, quality and regime of water flow in the downstream sections of these rivers (see Everard and Kataria 2011; Gupta et al. 2015a; Quinones et al. 2015). These human–induced changes result in habitat loss, changes in fish reproductive environments, cut off migration routes, and result in substantial decline of biodiversity (World Commission on Dams 2000; Pandit and Grumbine 2012; Pandit 2013).

As many as 292 small and large dams envisaged on the Himalayan rivers will greatly compromise the habitats and sustainable population sizes of the fish (Pandit and Grumbine 2012; see Park et al. 2003). In addition, recent studies have shown that the fish species richness is primarily driven by the quantum of water discharge in the rivers (Bhatt et al. 2012), therefore, water withdrawals will greatly undermine the fish species diversity and distribution in these rivers. The primary impacts anticipated due to dams on the Himalayan rivers are decreased water flow, diurnal flow variation, rise in channel water temperature, interruption in the longitudinal connectivity and low turbidity of downstream waters (Bunn and Arthington 2002). All these effects are likely to hamper fish migration due to: (i) absence of migration stimulus, (ii) higher predator attacks both because of lack of adequate flow and turbidity needed for cover during migration for reproduction (see Abrahams and Kattenfeld 1997; Bunn and Arthington 2002).

Equally important are the life history and ecological traits of *T. putitora,* which will be useful in evaluating the species' vulnerability to decline (e.g. William et al. 2005) (see Table 1). Some life history characters such as migratory habit, low fecundity and delayed sexual maturity combined with numerous external threats like damming of rivers are responsible for declining numbers of Golden mahseer. Migration is closely related to mahseer's life cycle and the fish completes the early phase of its life cycle in smaller streams in upper reaches after long journey to the spawning grounds. This makes the fish vulnerable to risks and dangers from predators and exploitation by humans (Ogle 2002) besides being hampered by river regulation. High mortality in Golden mahseer has been reported while undertaking upstream and downstream migration (Shrestha 1997). Low fecundity in the species results in its declining numbers (William et al. 2005), therefore, this trait partially contributes to its vulnerability to decline. The delay in the attainment of sexual maturity is reported to be one of the important factors resulting in declining mahseer populations (Nautiyal and Singh 1989) and studies indicate that prior to the attainment sexual maturity (Table 1) the fish attains a harvestable size (see Bhatt et al. 2000).

## Conservation of Golden mahseer

*Tor putitora* is a widely distributed species and it can thrive in lentic as well as lotic waters. Its distribution and adaptability to varied habitats and food sources are potential arguments that can be made against its endangered status under IUCN category. IUCN (2015) justified its status and mentioned it to be "a widely distributed species with restricted area occupancy". The species is estimated to have declined by more than 50 % in the past and may decline by 80 % in future, especially due to regulation of the rivers it inhabits (IUCN 2015; Sharma et al. 2015). The Himalayan rivers are prominent habitats of Golden mahseer where over 292 dams are proposed or/and under construction (Pandit and Grumbine 2012). Conservation of endangered and economically important Golden mahseer in the Himalayan rivers is, therefore, a serious challenge. Even as the majority of critical riverine habitats of mahseer have been subjected to or are under the process of regulation for irrigation and hydropower, it is important to make serious efforts for the conservation of this remarkable fish species. Clearly, the existing regulatory framework in the Indian subcontinent has failed to protect this and many other species of conservational significance (Gupta et al. 2014c, 2015a). Any conservation planning measures need to follow judicious and combined efforts of state environment regulatory authorities, ecologists, conservationists, dam engineers and local communities. At present there is little support for an integrated effort because of various constraints: (i) general lack of communication between scientists, policy makers and society on conservation issues (see Bernard et al. 2005), (ii) prioritization of fisheries for commercial benefit compared to environmental protection (see Dudgeon 2011), (iii) lack of awareness among public regarding importance of these keystone species (e.g. Nautiyal 2006, 2011), (iv) poor conservation measures of fish by legislation in India (Sarkar et al. 2008; Gupta et al. 2014c), and (v) lack of an ecosystem approach to river and fisheries management (see Gupta et al. 2014c).

Our investigations show that nearly 20 hatcheries have been established for exotic trout (*Salmo trutta* *fario* and *Oncorhynchus mykiss*) in various Himalayan states of India. There are no <25 trout hatcheries in Northern Pakistan (Yaqoob 2002). Trout hatcheries have also been established in Nepal and Bhutan at Haa and Wangchutaba, respectively. In contrast, fewer hatcheries for *T. putitora* exist on the Indian sub continent. Some of the hatcheries of Golden mahseer are located at Lonavala in Maharastra, Harangi and Kadagu in Karnataka, Anji in Jammu and Kashmir, Dehradun and Bhimtal in Uttarakhand (Basavaraja 2007), Mirmi near Kali Gandaki, and Pokhara in Nepal (Gurung et al. 2002) (Fig. 1) and Attok in Pakistan. Clearly, commercial fishery development is prioritized over conservation of indigenous fish, which may prove an equal, if not a better, economic alternative.

The first step towards the conservation of *T. putitora* would be to use it as 'flagship' species to raise awareness about the significance of its ecological and ecosystem values (Laskar et al. 2013; Gupta et al. 2014a). Because of its ecological value the species is often referred to 'tiger of water' or 'tiger of rivers', therefore, it has been suggested as a 'flagship' species to promote awareness among common public, conservationists and anglers (see Nautiyal 2006; Everard and Kataria 2011; Gupta et al. 2014a). Attempts to initiate 'Project Mahseer' similar to 'Project Tiger' by scientists to plan an effective and goal-oriented conservation movement for mahseer have been made in the recent past (Nautiyal 2011; WWF 2013). Conservation of mahseer may not succeed without some kind of legal protection to Golden mahseer in various countries in the Indian sub continent. In India the fish must be covered under the Schedule list of Wildlife (Protection) Act (1972). Thus far not a single fresh water fish species has been included in this list. Unlike terrestrial species, various socio-economic constraints are associated with aquatic species, especially fish, as livelihoods of people largely depend on them. Thus, ecosystem based conservation management for *T. putitora* should be a preferred choice. This approach aims to include a selective fishery strategy with respect to place, size and season (e.g. Zhou et al. 2010). The strategy entails identification and protection of potential breeding grounds and complete ban on fishing during monsoon season. In the non-monsoon months, sustainable fishing may be allowed with regulation on gear size and penalty on landing fingerlings and juveniles of the fish. Similar strategies have been successfully implemented in marine fisheries (see Zhou et al. 2010).

Gupta et al. (2014a) suggested *T. putitora* to be included under Schedule list of Wildlife (Protection) Act (1972) with controlled and monitored 'catch and release angling'. Various stakeholders, such as recreational fisheries associations across the nations where the fish is distributed, can play an important role in the mahseer conservation; some of them are directly involved in the fish conservation projects (Gupta et al. 2014b, 2015b, c). Preliminary findings suggest that the recreational fishing bodies and angling activities (especially catch and release) provide not only employment opportunities and economic benefits to local fishermen, but have played a positive role in the conservation of mahseer in India (Pinder and Raghvan 2013; Gupta et al. 2014b, 2015b, c).

We also suggest integrated efforts to identify important river stretches in the Himalaya that constitute critical habitats of Golden mahseer for conservation and restoration. Some of the critical areas, still unaffected by dams, need to be notified as protected areas of "Freshwater Fish Safe Zone" as suggested by Gupta et al. (2014c) by the environment regulatory authorities, where human activities like fishing, extraction of sand, gravels and boulders, etc. should be banned (Gupta et al. 2014a). A positive impact on the Golden mahseer is anticipated due to such activities. Gupta et al. (2013) observed a healthy population of mahseer from the river stretches which fall within the boundaries of protected areas as compared to those outside the protected areas which was attributed to less anthropogenic activities. The state and central governments would do well to withdraw some of the proposed dam projects from these stretches. In one of its recent reports, Wildlife Institute of India has suggested giving up of a number of hydro projects in favour of biodiversity conservation in the Himalaya (Rajvanshi et al. 2012). Those projects that have already been commissioned must ensure at least near natural flows in the reduced flow section of the rivers and that the flows are maintained throughout the year in order to allow continuity of ecological processes and services. To ensure this a mechanism of institutional and civic monitoring of flow regimes in the protected areas have been suggested (see Choudhary et al. 2012). Ex situ conservation of mahseer through development of hatcheries would be a sustainable conservation action.

However, many constraints are associated with the hatchery production and release of species inside/outside indigenous ranges. Experts have opined that hatchery stocks lead to loss in genetic integrity every year and may have negative consequences on wild populations while propagating in natural waters (e.g. Stickney 1994; Pradhan et al. 2011; Bingham et al. 2014). Pradhan et al. (2011) observed less genetic variability in hatchery stocks of *T. putitora* as compared to its wild populations. In order to propagate the hatchery spawns in natural waters, there is need to follow the IUCN's guidelines especially on release, site selection for release and longitudinal connectivity, if releasing habitat is fragmented (IUCN/SSC 2013). Suggestively, sufficient spawns of Golden mahseer can be produced in hatcheries and first generation's spawns could be propagated in same natural waters from where brooder stocks of hatchery were collected (Stickney 1994). Successive generations' spawns could be propagated in artificial water bodies like reservoirs because successive years' hatchery stocks show high genetic divergence from sourced stock (Pradhan et al. 2011).

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