



# From scientific obscurity to conservation priority: Research on angler catch rates is the catalyst for saving the hump-backed mahseer *Tor remadevii* from extinction

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## Abstract

1. The mahseer (*Tor* spp.) fishes of South and Southeast Asia are iconic megafaunal species that are highly valued by recreational anglers. Knowledge on their populations is limited owing to the challenges associated with sampling these large-bodied fishes (>50 kg) in remote monsoonal rivers.
2. Despite its global iconic status among recreational anglers, the hump-backed mahseer of the Cauvery River (South India) lacked a valid scientific name and was on a trajectory towards extinction until its rapidly declining population status was established by analyses of angler catch records.
3. Angling records from 1998 to 2012 showed that mahseer catch rates had increased in this period. The resulting publication in *Aquatic Conservation* (AQC) highlighted the positive role of catch-and-release angling in providing information on data-poor species. However, further analyses showed that these catches comprised not one but two distinct phenotypes.
4. Before 1993, all mahseer captured were hump-backed; since then, a blue-fin phenotype appeared in catches and subsequently dominated them. These results triggered further studies indicating that the hump-backed mahseer was the endemic *Tor remadevii* and that the blue-fin was the invasive *Tor khudree*, introduced in 1976 and then stocked periodically from hatcheries.
5. The initial AQC publication successfully demonstrated the high value of organized angling as a monitoring tool for data-poor fishes and its application to assessing the temporal population patterns of large-bodied fishes in monsoonal rivers. It was also the catalyst for initiating subsequent studies on *T. remadevii* that, together, enabled its recent assessment as 'Critically Endangered' on the International Union for Conservation of Nature (IUCN) Red List. In the absence of the AQC paper, and the subsequent studies that it triggered, it is highly probable that the species would have remained on a trajectory towards rapid extinction. Instead, the first major steps to safeguarding its future have been taken.

## KEYWORDS

conservation, endemic, fish, invasive species, megafauna, red list

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## 1 | INTRODUCTION

The iconic hump-backed mahseer, endemic to the Cauvery River in South India, was brought to the attention of the scientific community in 1849 (Jerdon, 1849) and to the sport angling community in 1873 (Thomas, 1873). Despite its popularity and global recognition as a premier sport fish for a century and a half, the scientific information available on this fish was so scarce that it remained to be scientifically described (Pinder & Raghavan, 2013). It took another 5 years and systematic integrative taxonomic studies (morphology, genetics, historical photographs, and museum specimens) to reach a conclusion regarding the identity and nomenclature of the hump-backed mahseer (Pinder et al., 2018). Subsequently, in November 2018, the hump-backed mahseer *Tor remadevii*, was assessed as being 'Critically Endangered' on the Red List of the International Union for Conservation of Nature (IUCN, 2019; Pinder, Katwate, Dahanukar, & Harrison, 2018), and was incorporated in India's National Wildlife Plan (2017) as requiring urgent conservation management actions (Ministry of Environment, Forests and Climate Change, 2017). Here, the process by which these outcomes were achieved are outlined, including the demonstration of how a paper published in *Aquatic Conservation* (AQC) (Pinder, Raghavan, & Britton, 2015a) was the key starting point in this story.

### 1.1 | Scientific obscurity: the unknown mahseers of the Cauvery River

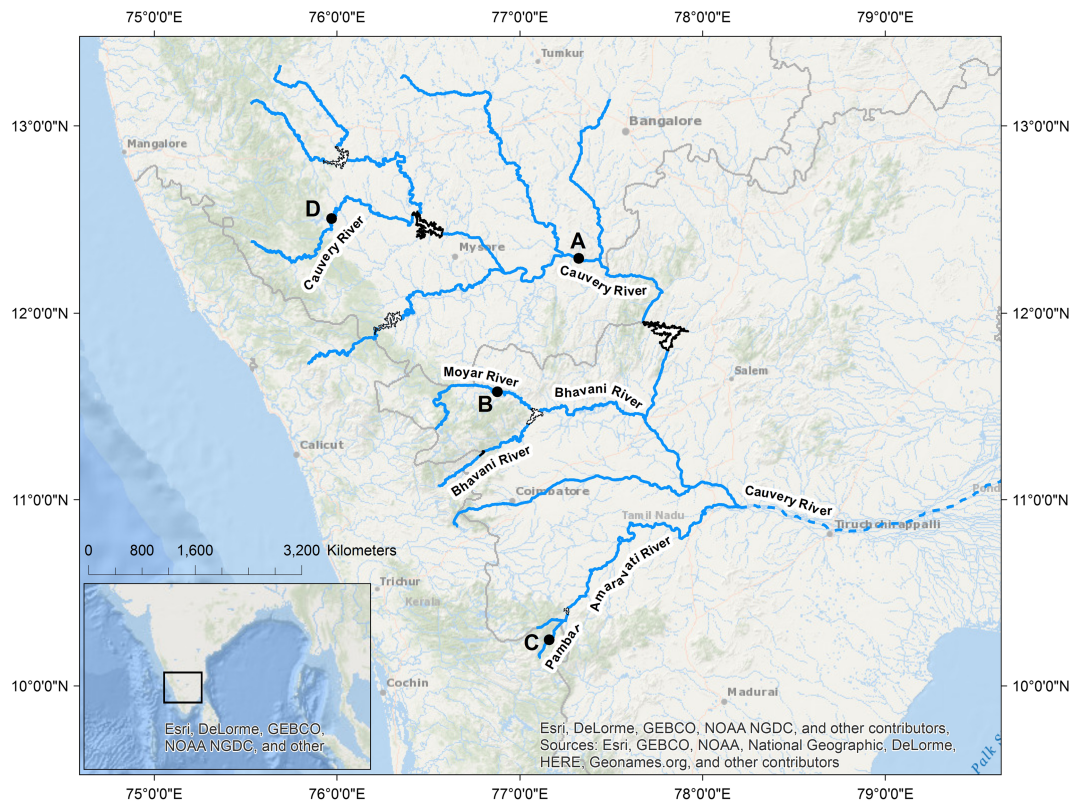
The starting point for this large-bodied and iconic species of freshwater megafauna going from scientific obscurity to a global conservation priority in less than 5 years was the publication of our paper in AQC: 'Efficacy of angler catch data as a population and conservation monitoring tool for the flagship Mahseer fishes (*Tor* spp.) of Southern India' (Pinder et al., 2015a). In this paper, the multiple challenges associated with the effective assessment of fish populations (such as mahseer populations) in large tropical monsoonal river systems (such as the Cauvery River) were outlined. These include high flows, deep water, and high habitat heterogeneity that, in combination, preclude the use of conventional scientific sampling gears (i.e. fishery-independent monitoring tools such as netting and electric fishing) (Casselman et al., 1990). As the hump-backed mahseer attains sizes in excess of 50 kg and can inhabit areas of extreme flows, this further inhibits attempts to assess their population status. This is compounded by the remoteness of the rivers that they inhabit and the wildlife associated with these jungle environs (Jung, 2012). Consequently, there is still no known example of a robust 'fishery-independent' population assessment of any *Tor* species across their entire genus and associated biogeographical ranges (Pinder et al., 2019). This is consistent with the findings of Cooke, Paukert, and Hogan (2012), who highlighted that sampling difficulties represent a major obstacle in generating knowledge on the spatial and temporal patterns in the population abundances and conservation management of many threatened riverine fishes.

In the former mahseer sport fishery of the middle reaches of the Cauvery River (Figure 1), this paucity of information on the temporal patterns in the mahseer population was overcome through the analyses of sport angler logbooks that had been maintained by the Galibore catch-and-release (C&R) fishery between 1998 and 2012 (see Pinder & Raghavan, 2013 and Pinder et al., 2015a for context). In the study period, 23,620 hours of fishing effort was recorded in this fishery, during which time 6,161 mahseer had been captured and released at sizes ranging between 0.45 and 46.8 kg. Although the numerical catch per unit effort (CPUE) of mahseer had increased significantly over time, this was concomitant with a decrease in CPUE by weight, suggesting a pattern of strong recruitment in the mahseer population overall and a shift in population size structure (Pinder et al., 2015a). These results suggested a positive conservation influence of the fishery, via the generation of alternative livelihoods and the employment of local villagers, driving the community-led protection against the illegal exploitation of their assets (i.e. mahseer stocks), upon which the sustainability of the C&R fishery and the local economy then relied. Moreover, this afforded the mahseer exemplar 'umbrella' species status, owing to their economic value, supporting the broader conservation of non-target fauna (e.g. fish, amphibians, and reptiles) and associated higher trophic levels (terrestrial and avian) vulnerable to the effects of illegal and non-species-selective dynamite fishing (Pinder & Raghavan, 2013). At this point, however, the taxonomy of the mahseers being captured in the river remained uncertain (Pinder et al., 2015a).

### 1.2 | Invasive mahseer

Although Pinder et al. (2015a) was important in demonstrating a strong and positive response in the Cauvery mahseers to the C&R policy and the reduced illegal fishing, and the high utility of using angler C&R data to monitor populations of large-bodied fishes, the paper also acted as a springboard to investigate in more detail which mahseer species were being captured by anglers. This was because it was apparent that the angler catch records comprised two distinct mahseer phenotypes – a golden ('hump-backed') mahseer (marked with 'G' in the records) and a silver ('blue-finned') mahseer (marked with 'S' in the records) (Figure 2).

At this point, the taxonomic identity of these phenotypes remained unclear and the fish were referred to only as *Tor* spp. Subsequent analyses showed that the catches of these two mahseer phenotypes could be decoupled temporally, and demonstrated that there had been a comprehensive shift in the mahseer community structure over the duration of the study period (1998–2012) (Pinder, Raghavan, & Britton, 2015b). Numerical catch rates of the blue-finned phenotype had increased substantially over time, whereas the hump-backed phenotype showed the opposite pattern, with a marked decrease in CPUE (Figure 3; Pinder et al., 2015b). Although the catches of the blue-finned phenotype revealed relatively small fish present in catches in all years, this was not evident in the hump-backed phenotype (Pinder et al., 2015b). Indeed, between 2007 and



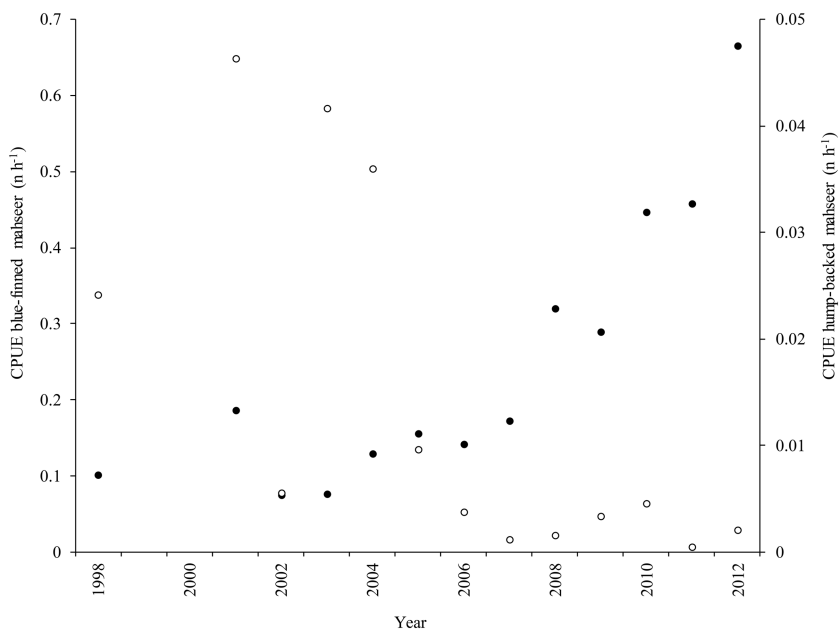
**FIGURE 1** Map of Cauvery River basin and key sites of interest. Locations: A, Galibore Fishing Camp; B, collection site of *Tor remadevii* on Moyar River; C, type locality of *T. remadevii* on Pambar River; D, upper Cauvery River, Kodagu District (Coorg). The dashed line represents the tidal reach of Cauvery River



**FIGURE 2** The non-indigenous blue-finned (silver) mahseer, since confirmed as *Tor khudree* (top) and the endemic hump-backed (golden) mahseer, since confirmed as *Tor remadevii* (bottom); both contributed to angler catches during the study period 1998–2012

2012, only 25 hump-backed mahseer were captured in the fishery and all but five were over 40 lb (18.1 kg), with the mean weight of captured individuals increasing from  $21.1 \pm 2.8$  lbs ( $9.6 \pm 1.3$  kg) between 1998 and 2006 to  $59.0 \pm 2.7$  lbs ( $26.8 \pm 1.2$  kg) between 2007 and 2012. This reduction in the number of smaller hump-backed fish in the catches suggested a collapse in recruitment (Pinder et al., 2015b).

It was at this juncture that it became apparent that further investigation was needed into the blue-finned mahseer phenotype that had dominated catches in the latter years of the recreational fishery. This was because when historical images of Cauvery mahseer were viewed in angling books, they were all – without fail – the hump-backed phenotype (Boote & Wade, 1992; TWFT, 1984; Wilson, 1999), with the earliest photographic records of the same species dating back to 1919 (Wild Life, 1977). Following some initial investigations by the authors of Pinder et al. (2015a, 2015b), there was conclusive evidence that the study reach had been stocked with hatchery-reared mahseer since 1976, when the Tata Electric Company (TEC) had initially gifted large numbers (10 000) of blue-finned mahseer fingerlings to the Wildlife Association of South India (WASI). These fingerlings had been produced at Tata's Lonavla hatchery in Maharashtra and then were used to stock the controlled angling sections of the Cauvery River (Wild Life, 1976). Sehgal (1999) and Desai (2003) later reported the release of 150 000 advanced fry and fingerlings to the Cauvery River by the Department of Fisheries of the State of Karnataka. In investigating this further, Pinder et al. (2019) concluded that brood fish of this species had been procured from the River Krishna River basin and were the mahseer species *Tor khudree* (Kulkarni & Ogale, 1978). Furthermore, by 2002, hatchery-reared *T. khudree* fingerlings had been stocked in waters in the majority of Indian states and even shipped outside India to Laos (Ogale, 2002). The increase in the catch rates of



**FIGURE 3** Catch per unit effort ( $n h^{-1}$ ) of blue-finned mahseer (filled circles) and hump-backed mahseer (clear circles) recorded at Galibore Fishing Camp between 1998 and 2012 (from Pinder et al., 2015b)

the blue-finned mahseer (*T. khudree*) in the angler catches of the Cauvery River reported by Pinder et al. (2015a, 2015b) thus represented the increased presence in the river of a non-indigenous and invasive fish of relatively high trophic level.

Further analyses of photographic records of mahseer captured in the Cauvery River then suggested that their initial appearance in angler catches was not until 1993, when a notably blue-finned fish of approximately 5 kg was captured during the mahseer world angling championships (A. Clark, pers. comm.), with photographic evidence indicating that mahseer captured up to that point in the river (since at least 1919) were all hump-backed mahseer (Wild Life, 1977). Although circumstantial, this suggested that it was the hump-backed mahseer that was the endemic mahseer of the Cauvery River, and yet despite apparently being imperilled by the presence of the invasive *T. khudree*, this endemic species was yet to be taxonomically described.

### 1.3 | Taxonomic classification

Although Pinder et al. (2015a, 2015b) had demonstrated that the hump-backed mahseer, endemic to the Cauvery River, was now highly imperilled, the lack of a valid scientific name impeded the more formal assessment of its conservation status. This was only overcome following the taxonomic determination of the hump-backed mahseer as *T. remadevii* by Pinder, Manimekalan, et al. (2018). This species had already been described from the Pambar River, which is the southernmost tributary of the Cauvery River catchment in the Southern Indian state of Kerala (Kurup & Radhakrishnan, 2007). Its original description, however, was based on the examination of individuals between 114 and 332 mm in length, and lacked both molecular characterization and comparative morphometric information (cf. Kurup & Radhakrishnan, 2007). As a result, the original description had

previously been overlooked, both because of a lack of rigour and because it was based on a small and morphologically confusing endemic *Tor* species that was believed to be restricted to the Pambar tributary.

Now that the endemic *T. remadevii* of the Cauvery River finally had a valid scientific name (Pinder, Manimekalan, et al., 2018), when combined with the temporal patterns in the angler catch rates reported by Pinder et al. (2015a, 2015b), its conservation status could be formally assessed. Given the first appearance of the hump-backed mahseer in the scientific literature in 1849 (Jerdon, 1849), and in angling catches in 1873 (Thomas, 1873), this represented a major step forward in affording this iconic species of megafauna some level of protection and conservation management.

## 2 | IMPACTS OF THE AQC PUBLICATION AND RELATED STUDIES

### 2.1 | Primary impacts

#### 2.1.1 | The importance to conservation of the IUCN Red List

The IUCN Red List of Threatened Species ('Red List', hereafter) is the world's most widely accepted, objective, and authoritative database detailing the global extinction risk and conservation status of plant and animal species (Vié et al., 2009). At present, 105 700 species have been assessed for their conservation status on the Red List, 28 000 (27%) of which are threatened with extinction (IUCN, 2019). Supported by an extensive network of >10 000 voluntary experts who provide information, assessment, and peer review, the Red List is based on scientifically rigorous criteria and categories (IUCN, 2012). Red List categories and criteria are supported by data on distribution,

population status, threats, and conservation actions for the focal species (Rodrigues, Pilgrim, Lamoreux, Hoffmann, & Brooks, 2006). In addition, the Red List provides a source of critical information that is essential to guide conservation investment and effort (Rodrigues et al., 2006), including recovery plans for species identified at least as Threatened (Cumberlidge & Daniels, 2007), and systematic conservation planning, including the identification and design of protected areas (Hoffmann et al., 2008).

### 2.1.2 | Red List assessment of *Tor remadevii*

The hump-backed mahseer *T. remadevii* is the only Critically Endangered species of the genus *Tor* (Pinder et al., 2019; Pinder, Manimekalan, et al., 2018). The Red List assessment of the species has been based on the 'A' criteria, which take into account the population status and trends. Populations of *T. remadevii* are estimated to have been reduced by more than 90% over three generations owing to the combined effects of illegal and unsustainable fishing, the effects of introduced taxa (*T. khudree*) and declines in their critical habitats. Historical records dating from before the 1950s also indicate that even more significant declines have occurred, with the species now absent from the majority of its historical range. Population information underlying this assessment is based entirely on the analysis of C&R fisheries data in the main stem of the Cauvery River (Pinder et al., 2015a, 2015b), supported by anecdotal information and the local knowledge of fishers in the three major tributaries (Pambar, Bhavani, and Moyar rivers; Figure 1) that suggest steady declines in catches over the last two decades (Mahseer Trust, pers. obs.). Surveys in the various tributaries of the Cauvery where the fish was known to be abundant in the late 1800s and early 1900s have yielded only very few individuals. For example, only 13 fish were captured in the Pambar River in 2007, dropping to just one individual in 2017, a single specimen has been caught in the past 10 years in the Bhavani River, and nine individuals have been caught from a 'single pool' since 2015 in the Moyar River. Following the closure of the mid-Cauvery angling camps, since 2012 the records of hump-backed mahseer from the main stem of the Cauvery River have been limited to fewer than five large fish (>20 kg) from the upper reaches of the river in the Coorg region (Figure 1). It is probable that the recruitment of this species in the Cauvery River is now limited entirely to the Moyar and Pambar tributaries, where a small number of immature specimens ( $n = 9$ ) have been recorded (<40 cm total length, TL) since 2015 (Pinder, Manimekalan, et al., 2018).

### 2.1.3 | Revised mahseer stocking programmes in the Cauvery River

Following the publication of Pinder et al. (2015a, 2015b) and a further popular article summarizing this research in the Sanctuary Asia magazine (Pinder, 2015), Tata Power convened a workshop engaging a range of stakeholders, including Mahseer Trust, the World Wide Fund

for Nature (WWF) India, and Bombay Natural History Society, at their Lonavla hatchery, Maharashtra, from where the Cauvery's *T. khudree* population had originated. In addition to committing to support a research and outreach programme to conserve the endemic hump-backed mahseer, the company also pledged to cease the supply of the non-native *T. khudree* to rivers beyond its natural biogeographic distribution range, including the Cauvery River (Dutt, 2019).

## 2.2 | Secondary impacts

Both mahseer species were included in India's National Wildlife Action Plan 2017–2031, even before the formal identification of *T. remadevii* had been confirmed (Ministry of Environment, Forests and Climate Change, 2017; Pinder et al., 2019). Within this Plan, actions included in 'Chapter 7, Conservation of inland aquatic ecosystems' include the initiation of special breeding programmes for threatened fish species, such as orange-finned (i.e. hump-backed) and golden mahseer, where 'adequate care should be taken to prevent any genetic contamination or deterioration during these breeding and restocking programmes' (Ministry of Environment, Forests and Climate Change, 2017). Actions also include the undertaking of measures '... for reviving the population of native species of fish by removal of blue-finned mahseer in the Cauvery ... through angling or other suitable means to reduce the population of these undesirable species. This should go hand in hand with the release of captive stocked orange-finned and golden mahseer in [the] Cauvery ...' (Ministry of Environment, Forests and Climate Change, 2017). Acting on these recommendations, other Indian states and authorities are now starting to apply ex-situ conservation strategies for mahseer (e.g. Madhya Pradesh Forest Department). Having recognized the risk to endemic biodiversity from stocking non-indigenous mahseer, these strategies have focused their attention on the exclusive culture of *Tor* species native to individual river systems (S. Saxena, pers. comm.). Furthermore, the 'Development and Implementation of Responsible Fish Stocking Policies' now features as one of the seven key recommendations within the declaration, proclaimed at the First International Mahseer Conference held in Paro, Bhutan, 2–8 December 2018 (WWF Bhutan, Ministry of Agriculture and Forests, and Fisheries Conservation Foundation, 2019).

In addition to driving the recommendations for responsible stocking policies across the range of mahseers, the value of recreational fishery-derived data for mahseer (Pinder et al., 2015a, 2015b; Pinder & Raghavan, 2013) has been recognized and incorporated in the recommendations of an Indian national strategy paper on conservation policies for hilsa and mahseer (National Academy of Agricultural Sciences (NAAS), 2018). This paper specifically recommends 'a need to develop science-led angling protocols to monitor population response to ecosystem restoration interventions', with a view to providing evidence-informed policy development.

The lack of funding in support of developing new knowledge on this potadromous species was considered to be constraining the development of conservation strategies beyond the ex-situ measures

outlined above. Indeed, the next steps in the conservation of *T. remadevii* is the development of knowledge on their movements, behaviour, and ecology, something that is applicable to the entire genus (Pinder et al., 2019). In 2019, 'Project Mahseer' was launched by the non-governmental organization (NGO) 'Shoal', a 'new partnership aimed at engaging a wide range of organisations to accelerate and escalate action to save the most threatened fish and other freshwater species' (Shoal, 2019a). Project Mahseer was launched by Shoal, with the initial priority being to conserve the hump-backed mahseer of the Cauvery River (Shoal, 2019b). Although it is not yet known how successful this will be, simply having this project structure in place represents a major advance on the pre-Pinder et al. (2015a) situation, where the hump-backed mahseer languished in scientific obscurity.

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