COMMUNICATION

LENGTH-WEIGHT RELATIONSHIPS OF TWO CONSERVATION-CONCERN MAHSEERS (TELEOSTEI: CYPRINIDAE: TOR) OF THE RIVER CAUVERY, KARNATAKA, INDIA

Adrian C. Pinder, Rajeev Raghavan, Shannon D. Bower & J. Robert Britton

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Length-weight relationships of two conservation-concern mahseers (Teleostei: Cyprinidae: Tor) of the river Cauvery, Karnataka, India

Adrian C. Pinder1,2, Rajeev Raghavan2, Shannon D. Bower3 & J. Robert Britton4

1,4 Faculty of Science and Technology, Bournemouth University, Poole, BH12 5BB, UK.
2 Mahseer Trust, c/o Freshwater Biological Association, East Stoke, Wareham, Dorset, BH20 6BB, UK.
3 Department of Fisheries Resource Management, Kerala University of Fisheries and Ocean Studies (KUFOSS), Kochi, Kerala 682506, India.

Abstract: Length-weight (LW) relationships are presented for two conservation-concern species of mahseer (Tor spp.) from southern India’s river Cauvery. Constructed from angler catch data, these are the first available LW relationships for the Critically Endangered Tor remadevii and the non-native and locally invasive Tor khudree. For T. remadevii, the value of b, the allometric parameter, was 2.94 (95% CI: 2.75–3.14) and was not significantly different from 3.0, indicating isometric growth (t = 0.61, P = 0.54). For T. khudree, b was greater at 3.18 (95% CI: 3.01–3.38), but with this also not significantly different from 3.0 (t = 1.91, P = 0.06). Outputs are discussed with reference to species conservation and recreational catch-and-release fisheries.

Keywords: Angling, Critically Endangered, invasive fish, Tor khudree, Tor remadevii.
INTRODUCTION

Despite its global iconic status as a premier sport fish and the largest growing of all mahseers (*Tor* spp.) (Pinder et al. 2019), the formal taxonomic identity of the mega-faunal Hump-backed Mahseer has until recently eluded ichthyologists since first being brought to their attention in the 19th century (Jerdon 1849). Now known to be endemic to the Cauvery River catchment (Pinder et al. 2015a), recent research has confirmed this fish to be conspecific with *Tor remadevii* (Pinder et al. 2018a), a species for which the formal description was based on 19 juvenile specimens collected from the river Pambar, the southernmost tributary of the river Cauvery in Kerala, India (Kurup & Radhakrishnan 2007, 2010). Due to estimated population reductions in excess of 90% and an extremely limited distribution range, *T. remadevii* was recently assessed as Critically Endangered on the IUCN Red List of Threatened Species (Pinder et al. 2018b), making it the most imperilled of all *Tor* species.

Introductions of *T. khudree* into the river Cauvery from the 1970s has been implicated in the collapse of the endemic *T. remadevii* population (Pinder et al. 2015a; Pinder et al. in press). In recognition of the non-native and invasive status of *T. khudree* outside its native distribution range, India’s current National Wildlife Action Plan 2017–2031, includes the action of actively removing *T. khudree* from Cauvery, through angling or other suitable means, to reduce the population of this undesirable species. This goes hand-in-hand with a further recommendation, that captive bred ‘orange-finned’ mahseer *T. remadevii* should be stocked to assist the recovery of this endemic species (Ministry of Environment, Forests and Climate Change, 2017). Furthermore, due to the establishment of *T. khudree* beyond its native range throughout much of southern India (see Pinder et al. in press), this species has recently been reassessed on the IUCN Red List from Endangered to Least Concern (de Alwis Goonatilake et al. 2020).

Here, the derivation of length-weight relationships from data collated from angling catches on the river Cauvery provides important biological parameters for both species for the first time. The results are discussed in relation to their indication of body allometry, their contributions to existing knowledge and persisting knowledge gaps which require urgent attention to better understand the biological and ecological mechanisms which may drive competitive interactions between these two species. Outputs are also discussed in the context of recreational catch-and-release fisheries and how stakeholders can utilise the data presented here to assist the urgent conservation of *T. remadevii*.

MATERIALS AND METHODS

Historic length-weight statistics for *T. remadevii* were recovered from the former angling camps and protected reaches of the middle River Cauvery that extend across 24 km between Doddamakali Nature Camp (12.307°N & 77.215°E) and Mekedatu Gorge (12.259°N & 77.447°E), Karnataka, India (Fig. 1). Data used in the analysis date from 1976 to 1990 and were seasonally restricted between the months of December and May when river flows are suitably reduced to allow the recreational fishery to operate. These fish were captured by rod-and-line angling, with their fork lengths and weights recorded before release. Lengths were measured using non-rigid tape measures and weights from ‘spring-balances’. For the latter, due to the combination of the size of some of the fishes (>40kg) and their recording in field conditions, the weights were typically recorded to the nearest 250g.

For *T. khudree*, length-weight data of individual fish were collected from the upper river Cauvery (Ammangala Village, Valnur; 12.457°N & 75.960°E, in Kodagu District (Coorg), Karnataka, India (Fig. 1) during March 2014 and between February and April 2015. Captured using rod and line tactics, the data for each fish were recorded by trained fishery professionals. Fish lengths (FL) were recorded using a standard rigid measuring board (to 0.1 cm) and weights recorded using a protective weigh sling and a spring balance appropriate to individual fish size (models: Salter Super Samson 20 kg/100g and 5 kg/25g). All fish were released following their processing.

To assess the length-weight relationships of each species, and to, thus, investigate allometry, their data were fitted to the linear form of the length-weight power function $W = aFL^b$, where $a$ is the intercept parameter (shape coefficient) and $b$ is the regression coefficient (allometric parameter), and where the linearised form of the equation is $\ln(W) = \ln(a)+b\ln(FL)$. In fishes, when the value of $b$ is not significantly different from 3.0 (tested here via a 2-tailed t-test), it implies isometric growth, where there is a cubic increase in fish weight as length increases (Ali et al. 2013). If $b$ is significantly lower than 3.0, it implies negative allometric growth and significantly higher than 3.0 implies positive allometric growth (Riedel et al. 2007). Should non-isometric growth be apparent then the factors driving this deviation can be explored (Ali et al. 2013).
RESULTS

The length-weight relationships were derived from a sample of 90 T. remadevii and 59 T. khudree. The subsequent values of \( a \) and \( b \), and their associated statistical information, are provided in Table 1. For T. remadevii, the value of \( b \), the allometric parameter, was 2.94 (95% CI: 2.75–3.14) and was not significantly different from 3.0, indicating isometric growth (\( t = 0.61, P = 0.54 \)). For T. khudree, \( b \) was greater at 3.18 (95% CI: 3.01–3.38), but with this also not significantly different from 3.0 (\( t = 1.91, P = 0.06 \)). Linearised relationship of fork length (cm) versus weight (g) for both species is provided in Figure 2.

DISCUSSION

The results suggest that the growth of both the Tor species analysed were isometric, i.e., there was a cubic increase in fish weight as length increased. These data are important in the context of biological information on these fishes that, to date, has been extremely limited.

Indeed, the substantial population decline of endemic T. remadevii that has occurred in the last 15 years now prevents the contemporary sampling of their populations to obtain new biometric data (Pinder et al. 2015a, 2018b). The high historical recreational and trophy value of this fish has, however, resulted in collection of data by anglers in previous years, enabling these data to be used here and highlighting the inherent value of angler log books to provide important biological data from catch data (Cooke et al. 2000; Pinder & Raghavan 2013; Pinder et al. 2015b). This did, however, result in the use of data collected by anglers in extreme field conditions (e.g., high air temperatures) using relatively crude equipment (spring-balances recording to an accuracy of 0.25kg). Nevertheless, some of the fish in the dataset were large, over 40kg, and thus would be inherently difficult to weigh to a greater level of accuracy.
**Length-weight relationships of two conservation-concern mahseers**

Pinder et al.

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**Table 1.** Length (fork, cm) weight (g) relationship for *Tor remadevii* and *Tor khudree* from the river Cauvery, southern India, where $W = aL^n$, $n =$ sample size; $r^2 =$ coefficient of determination. All length-weight relationships were significant at $P < 0.001$. All data represent the first reporting of the length-weight relationship for the species.

| Species     | n  | Length range (cm) | Mean length (cm) | Weight range (kg) | Mean weight (kg) | $a$          | 95% CI $a$ | $b$          | 95% CI $b$ | $r^2$ |
|-------------|----|-------------------|------------------|-------------------|------------------|--------------|------------|--------------|------------|-------|
| *T. remadevii* | 90 | 40–175            | 111.83           | 1.5–45.3          | 19.7             | 0.016        | 0.006–0.040 | 2.94         | 2.75–3.14  | 0.91  |
| *T. khudree*   | 59 | 15.5–83           | 34.92            | 0.06–8.8          | 0.87             | 0.007        | 0.003–0.012 | 3.18         | 3.01–3.38  | 0.95  |

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**Table 2.** Summary of maximum length and weights reported from this study and previous studies (*Kurup & Radhakrishnan 2007; **http://www.fishbase.org/, version 12/2019)

| Species     | Previous maximum reported size | Data presented here |
|-------------|--------------------------------|---------------------|
|              | Max length (cm) | Max weight (kg)     | Max length (cm) | Max weight (kg) |
| *T. remadevii* | 33.2 (TL)*     | N/A                 | 175 (FL)        | 45.3           |
| *T. khudree*  | 50 (TL)**      | 2.7**               | 83 (FL)         | 8.8            |

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unless killed and also were unable to be captured by alternative methods to angling. Consequently, despite the method of data collection, it is argued these data have high value in the context of this conservation-dependent species that is currently close to extinction (Pinder et al. 2015a) and for which no adult length-weight data currently exist.

Due to the previous taxonomic confusion regarding the taxonomy of southern Indian *Tor* species (Pinder & Raghavan 2013; Pinder et al. 2018a, 2019) many previous studies have erroneously synonymised the ‘nom de plume’ *Tor* (or *Barbus*) mussullah (under the guise of the Hump-backed Mahseer (now known to be *T. remadevii*)) with *T. khudree*. As a consequence, much of the biometric data presented in the scientific literature, and open access resources (e.g., FishBase) for *T. khudree* need to be treated with appropriate caution. With reference to previous scientific studies where a high level of confidence can be applied to correct taxonomic use, the data reported here dramatically revise the maximum lengths and weights for both species (Table 2). Moreover, despite an absence of length records, other published data sources report weights of the Hump-backed Mahseer (*T. remadevii*) to 54.4kg (Wild Life 1977) and *T. khudree* to 27.9kg (Pinder et al. 2015a).

The results presented here provide the first biological data that can act as a base on which to build knowledge that is urgently required in a conservation context to both better understand the invasion consequences of *T. khudree* and to inform planning for the population restoration of *T. remadevii*, including understanding novel species interactions, and the range of biological parameters and ecological plasticity that may drive

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![Figure 2](image-url)
competitive advantages between these species (Pinder et al. in press).

Given the isometric growth of both species, these data can now be applied in a conservation context by enabling sport anglers using catch-and-release angling techniques to keep the fish in the water for unhooking, with weights then estimated from measured lengths. This would eliminate a high proportion of the manual handling and air exposure of the fish, minimising the stress that this is known to cause, along with the associated elevated risk of post-release mortality (Cooke & Suski 2005; Cook et al. 2015; Bower et al. 2016).

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