Big fish in small tanks: Stunting in the Deccan Mahseer, *Tor khudree* (Sykes 1849)

Running Title: Stunting of Deccan mahseer in captivity

Vishwanath Varma[1] Rajeev Raghavan[2] V. V. Binoy[1]

[1]Animal Behaviour and Cognition Programme, School of Natural Sciences and Engineering, National Institute of Advanced Studies (NIAS), Indian Institute of Science (IISc) Campus, Bangalore, India

[2]Department of Fisheries Resource Management, Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India

*Correspondence: V.V Binoy, Animal Behaviour and Cognition Programme, School of Natural Sciences and Engineering, National Institute of Advanced Studies (NIAS), Indian Institute of Science (IISc) Campus, Bangalore, India, Email. vvbinoy@nias.res.in; vvbinoy@gmail.com

ABSTRACT

The diminished growth and stunting of the Deccan mahseer, *Tor khudree* (Sykes 1849), a mega-fish, endemic to peninsular India is recorded for the first time under high-density laboratory conditions, and its implications for conservation and aquaculture discussed.

KEYWORDS: conservation, cyprinidae, growth, high density, laboratory rearing

Mahseers (*Tor* spp.) are freshwater megafish of conservation concern that are facing high levels of population decline (Pinder *et al.*, 2019). As a result, many species of mahseers are being artificially propagated (Keshavanath et al., 2006) in hatcheries, and released into various rivers and reservoirs with an aim of stock enhancement (Ogale, 2002). However, the large size of these fish limits the possibility of laboratory research for improving the outcomes of such restocking interventions. While high density, elevated competition for food resources, and space constraints (Amundsen et al., 2007; Grant & Imre, 2005) have been reported to cause stunting in many fish species, such stunting has not been reported in mahseer.

Deccan mahseer, *Tor khudree* (Sykes 1849) is the most popular and studied mahseer species of the Western Ghats Hotspot, whose local populations have significantly declined in its native range (northern part of the Western Ghats), including being extirpated from their type locality (Goonatilake et al., 2020). However, they have been considered 'invasive' in other parts of the Western Ghats (Southern and Central parts), competing with, and resulting in the population decline of other endemic mahseer species (see Pinder et al., 2020, 2015). This fish grows to large sizes in the wild (>1.2 m in Total Length/T_L and up to 50 kg in Total Weight/T_W, Froese & Pauly, 2019) and is hence of importance to recreational fisheries and aquaculture. These characteristics of deccan mahseer make them a priority for conservation interventions (National Wildlife Action Plan of India, 2019). Here, we report a serendipitous observation that *Tor khudree* maintained under standard laboratory conditions exhibit stunted growth.

Fingerlings of *T. khudree* (4.18 ± 0.08 cm Standard Length/S_L and 60 day old) were obtained from the hatchery of the Department of Fisheries, Government of Karnataka at Harangi, Kodagu,

India. In the laboratory, they were divided into groups of eight individuals and maintained in aquaria of dimensions 40 × 25 × 27 cm for observing behavioural patterns, which is a major knowledge gap in the mahseer literature. Water level was maintained at a height of 25 cm and steel grills covered with mosquito nets were placed as lids to prevent fish from jumping out. Constant aeration was provided to avoid reduction of dissolved oxygen in the tank. There was no restriction on the provision of food, the fish were fed every evening with Taiyo food pellets (*ad libitum*), and water was changed every ten days. Twenty-five tanks were prepared following this protocol, and maintained at room temperature under a natural photoperiod of 12L:12D cycle for a period of 12 months. At the end of the experiment, 50 randomly selected individuals were measured for length (S_L) and weight (T_W).

Fish maintained under laboratory conditions for 12 months exhibited stunting and grew to an average size of 5.52 ± 0.13 cm S_L (mean ± SE) and 4.08 ± 0.24 g T_W, in contrast to the studies of Singh et al. (2012) who reported an increase of 1 g in body weight (in individuals with average weight 0.10 ± 0.12 g), when reared on high-protein diets over 60 days and Sangma & Basavaraj (2012) who found an average increase of 9.72 cm T_L and 88.8 g in 120 days in concrete tanks (500 × 500 × 100 cm). A specific growth rate of 0.03 mm/day was observed in our study (Table 1) against 0.81 mm/day by Sangma & Basavaraj (2012). In natural waters, *T. khudree* is known to grow to lengths of 38.3–120.2 mm T_L in a year (Raghavan et al., 2011).

Fulton's condition factor *K* (Froese, 2006) of the stunted individuals was high (2.35 in our study *vs*. 1.68, estimated from Sangma & Basavaraja, 2012), indicating that high density rearing does not negatively impact the body condition of *T. khudree* (Table 1). Similarly, the survival rate of *T. khudree* reared at high density in the laboratory was 97%, which was not different from the mortality reported at lower densities under captive conditions (Sangma & Basavaraj, 2012).

Stunting is primarily thought to be caused by socio-environmental constraints experienced by the fish, with little role of genetics (Mohapatra et al. 2017). Nevertheless, such retarded growth has not been described in mahseer populations in either natural or captive environments. The diminished growth and stunting exhibited by *T. khudree* in laboratory conditions may be the result of high-density rearing conditions (8 individuals/tank), since density has been observed to

be a husbandry-related stressor in other cyprinids (Nandeesha *et al.*, 2013). Though lack of exercise, which is essential for increasing both food intake and food conversion (Jobling et al., 1993), may be considered a potential cause for stunting, preliminary studies that quantified activity levels of *T. khudree* in laboratory conditions revealed high activity throughout the day (Varma et al., Unpubl.).

Stunting of *T. khudree* could have wider implications for both its farming and conservation. For example, farmers in Andhra Pradesh, India, stunt fingerlings of Indian carps for six to twelve months by subjecting them to high rearing densities (up to 100,000/ha and feeding at a rate of 2–3% of body weight; Nandeesha et al., 2013). Stunted fingerlings exhibit greater feeding, feed conversion efficiency and faster weight gain when they are subsequently transferred to lower densities and improved environmental conditions in production ponds (Nandeesha et al., 2013). If *T. khudree* is capable of such compensatory growth similar to other cyprinids, stocking large numbers of fingerlings in a cost-effective manner and making them available throughout the year for farmers could help in promoting the culture of this species in artificial and natural waters. Additionally, such stunted individuals may be more suitable for ranching and restocking programs due to the ease of transportation from hatcheries to natural habitats, and potential increase in growth rate after release. Miniaturized *T. khudree* could also evolve into a popular aquarium fish due to their morphological features (e.g. bright and large scales), coloration during their juvenile phases, highly active nature under captive conditions, and symbolic status in many states of India (Dinesh et al., 2010).

Providing 'life skills' training such as familiarizing with natural prey items and fine-tuning predator avoidance behaviour may be required to prevent early mortality of hatchery reared individuals that are released into the wild (Sloychuk et al., 2016). Stunted *T. khudree* are suitable for experimental arenas and holding conditions that are used for testing popular fish model systems in the laboratory (such as guppy, medaka, zebrafish etc.). Further studies on the morphology, behaviour, physiology and fitness traits of stunted mahseers could improve the outcomes of conservation efforts and restocking interventions.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Table 1. Growth, survival and condition factor of the Deccan mahseer, *Tor khudree*, reared in the laboratory condition for 12 months

Parameters	Value
Initial length (cm)	4.18
Final length (cm)	5.52
Specific Growth Rate (mmday^{-1})	0.03
Survival (%)	97
Condition Factor (*K*)	2.35