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

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Running Title: *Stunting of Deccan mahseer in captivity*

ABSTRACT

The diminished growth and stunting of the deccan mahseer, *Tor khudree*, 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

Individuals that are noticeably smaller in body size compared to their age-matched counterparts have been reported in a variety of fish species, both in natural and artificial habitats (Ylikarjula *et al*., 1999; Chizinski *et al*., 2010). In many fish species, stunted individuals are morphologically dissimilar to their normal conspecifics, and may even lack sexual dimorphism (Chizinski *et al.*, 2010). Reduced growth can also affect the fitness of individuals and populations, and result in significant ecological impacts (Ylikarjula *et al*., 1999; Aday *et al.*, 2002). For instance, stunted individuals deviate from normal ones with regard to the duration of reproductive season, mating success and spawning periodicity (Aday *et al*., 2002).

Stunting is primarily thought to be caused by socio-environmental constraints experienced by the fish, with little role of genetics (Ylikarjula *et al*., 1999). Maintaining juvenile fish in high density conditions can limit their growth via space constraints, elevated competition for food resources (Amundsen *et al*., 2007; Grant & Imre, 2005), deterioration of water quality due to low dissolved oxygen and build-up of waste products such as ammonia and carbon dioxide (Kolding *et al*., 2008; Fivelstad & Binde, 1994). Limitation in the availability of prey and the lack of predator pressure can also induce stunting by modifying morphological and life history traits of populations in natural habitats (Heath & Roff, 1996; Fagbenro, 2004; Holopainen *et al.*, 1997).

Stunted fishes are generally not preferred by fish farmers as well as food and recreational fishers, due to reduced market value and low 'trophy status' (Ylikarjula *et al*., 1999; Gabelhouse, 1984). However, if utilized properly, stunting can be a useful tool to increase productivity of fish farms (Jena et al., 2017). For instance, farmers in Andhra Pradesh, India, stunt fingerlings of the Indian

carps for a period of 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). This practice not only reduces the cost of stocking but also ensures availability of fingerlings throughout the year. The stunted fingerlings exhibit greater feeding, feed conversion efficiency and faster weight gain when they are subsequently transferred to lower density and improved environmental conditions in production ponds (Nandeesha *et al.*, 2013). These results raise the intriguing possibility that stunting could be used as a tool in conservation programmes to enhance the survival of hatchery-reared individuals that are restocked or reintroduced to the natural habitat.

Knowledge of behaviour and cognitive abilities of the species released in restocking programs is helpful in reducing mortality and increasing the success of such interventions (Brown & Laland, 2001; Brockmark *et al*., 2010; Johnsson *et al.*, 2014). However, studying the behaviour of species that grow to large sizes is very difficult due to space and resource constraints. In such contexts, stunted individuals can be used to gain insights into their behaviour under laboratory conditions, though subsequent validation of such results in the natural habitat would be necessary. Mahseer (family Cyprinidae) comprise a group of mega-fish growing to large sizes (>1.2 metre in T_L and up to 50 kg in T_W, Froese & Pauly, 2019) and are widely regarded as a prime game fish, and a fighter (Nautiyal, 2014). The Deccan Mahseer, *Tor khudree* is one of the most popular species of the rivers of the Western Ghats Hotspot where their populations in the native rivers have declined significantly so much so that they have now disappeared from its type locality (Goonatilake *et al.*, 2020). While restocking of hatchery reared Deccan Mahseers has been practiced since the 1980s (Ogale, 2002), a greater understanding of their behavioural development is essential to improve survival in the wild. Transfer of individuals of this species to the laboratory and maintenance under captive conditions for significant periods of time is essential to empirically analyze the development of fitness-related behavioural traits. The present study shows that deccan mahseer, a mega-fish, that grows to large sizes in the wild, exhibits stunting upon maintenance under standard laboratory conditions.

Fingerlings of *T. khudree* (4.18 ± 0.08 cm S_L and 60 days) 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 40X25X27 cm. 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 the reduction of dissolved oxygen in the tank. 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 experimental period, 50 randomly selected individuals were measured for length (S_L) and weight (T_W).

Interestingly, fish maintained under laboratory conditions for 12 months exhibited an extreme level of stunting and grew to an average 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 1g 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 (500X500X100 cm). This yields a specific growth rate of 0.03 mm/day in our study (Table 1) compared to 0.81 mm/day in Sangma & Basavaraj (2012). In natural waters, deccan mahseer is known to grow to lengths of 38.3–120.2 mm T_L in a year (Raghavan *et al*., 2011).

Our observation of diminished growth and stunting may be the result of increased density (8 individuals/tank) at which they were reared, which has been observed to be a husbandry-related stressor in other cyprinids (Ramaswamy *et al*., 2013; Nandeesha *et al*., 2013). However, keeping juveniles and adults of smaller species in higher densities for conducting laboratory studies is a common practice (Ayanda *et al*., 2015). Although lack of exercise, which is essential for increasing both food intake and food conversion (Leon, 1986; Jobling *et al*., 1993), may be considered a potential cause for stunting, preliminary studies aimed at quantification of the activity of mahseer in captive laboratory conditions revealed high activity throughout the day (Varma *et al*., Unpubl.). Compared to mahseer kept in large rearing tanks and low density (Sangma & Basavaraja, 2012), Fulton's condition factor *K* (Froese, 2006) of the stunted individuals was high (2.35 in this study *vs*. 1.68, estimated from Sangma & Basavaraja, 2012), indicating that high density rearing does not negatively impact the body condition of mahseer

(Table 1). Similarly, the survival rate of mahseer 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).

Our preliminary observation of significant reduction in growth rate and stunting of deccan mahseer kept in captivity reveals extraordinary plasticity of their life history traits. This could have wider implications for both farming and conservation of this conservation-concern species, provided these undersized individuals can undergo a rapid grow-out phase after being transferred to lower density and enriched conditions, as observed in other cyprinids (Nandeesha *et al*., 2013). If Deccan mahseer is indeed bestowed with such ability, 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 ease of transportation from hatcheries to natural habitats, and potential increase in growth rate post release. Miniaturized mahseers could also evolve into a popular aquarium fish as a result of their morphological features (e.g. bright and large scales), colouration during their juvenile phases, highly active nature under captive conditions, and symbolic status in many states of India (Dinesh *et al*., 2010).

As a conservation measure, the species is being artificially propagated (Keshavanath *et al.*, 2006) and large numbers have been released into various rivers and reservoirs of India with the aim of increasing their population (Ogale, 2002; but see Pinder *et al.*, 2019). However, 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). Unfortunately, very little information on behaviour and cognitive abilities of any species of mahseer is available, perhaps due to the unavailability of facilities required to rear them in large numbers for experimental purposes. However, filling this gap in literature is a priority given the fact that many species of mahseer are threatened, and/or of conservation concern (Pinder *et al.*, 2019), and face high levels of population decline. Stunting in mahseer opens up a novel avenue for studying their behaviour and physiology under controlled laboratory conditions. Reduced growth rate makes mahseer suitable for experimental arenas and

holding conditions that are used for testing popular fish model systems such as guppy, medaka, zebrafish etc. in the laboratory. However, comparison of behaviour and physiology of stunted populations with those occurring in natural habitats, and tracing out divergence due to reduced growth is required to gain a better understanding of the life-history adaptations of this species. Hence, future studies focusing on the influence of various ecological and genetic factors on the morphology, behaviour and physiology will elucidate the flexibility present in various fitness traits of the deccan mahseer and provide insights into the adaptive strategies exhibited by this species in response to environmental change.

ACKNOWLEDGEMENTS

The authors are grateful to the Karnataka State Fisheries Department for kindly providing the fingerlings, and to Darshan Pramod (District Fisheries Department, Kodagu), H.Vasoya, A.Jain, J.Vijayan and A.Singh for their support during the study. VV thanks the Department of Biotechnology, Government of India, for a Research Associate Fellowship.

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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