



ORIGINAL ARTICLE

Population dynamics of an endemic cyprinid (*Hypselobarbus kurali*): Insights from an exploited reservoir fishery in the Western Ghats of India

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Abstract

The Western Ghats of India harbours an exceptional diversity of endemic freshwater fishes, which are threatened because of various anthropogenic stressors, including biological resource use. Lack of organized studies on the population dynamics and exploitation levels of endemic species, however, has hindered the development and implementation of systematic conservation action plans in this region. This is especially true for large cyprinid fishes threatened because of overharvest. This study examined length–weight relationships and length-structured population dynamics of an endemic large cyprinid (*Hypselobarbus kurali*), based on data obtained from an artisanal gill-net fishery in Malampuzha Reservoir. Length–weight analysis suggested the fish exhibited significantly lower exponents than expected under isometry, indicating the growth of *H. kurali* in the reservoir was negative allometric. The von Bertalanffy growth formula fitted to the length–frequency data indicated *H. kurali* grew relatively slower than other large cyprinids in this region. Statistical analysis of recruitment revealed two peaks, implying the fish have two spawning bouts each year. Analysis of mortality and exploitation of the species revealed large-sized individuals were targeted by the fishers, resulting in an exponential decline in the survivors in the virtual population analysis. Relative yield-per-recruit and relative biomass-per-recruit analysis indicated the current exploitation rate for the population was greater than the exploitation rate under which the stock would be reduced to half its unexploited biomass. Further, the current exploitation level was more than 60% of the expected maximum exploitation above which the population could collapse. The results of this study identify a serious need to develop and implement management plans to guide the future sustainability of the reservoir fishery of *H. kurali*.

KEYWORDS

exploitation, growth, large barb, length–weight relationship, mortality

1 | INTRODUCTION

The Western Ghats of Southern India is globally recognized for its diversity (>300 species) and endemism (>60%) of freshwater fish species (Dahanukar, Raghavan, Ali, Abraham, & Shaji, 2011),

as well as the associated small-scale fisheries it supports (Keskar, Raghavan, Kumkar, Padhye, & Dahanukar, 2017; Raghavan, Ali, Dahanukar, & Rosser, 2011). Unprecedented development activities in the region, however, have negatively impacted this extraordinary freshwater diversity, resulting in nearly 100 species

being assessed as threatened on the IUCN Red List (Dahanukar et al., 2011). Further, the lack of adequate governance and management is threatening the sustainability of the region's inland fisheries sector, which is concentrated mainly in the reservoirs and lower reaches of small coastal rivers. Several endemic and threatened species continue to be harvested at unsustainable levels through open-access fisheries throughout the Western Ghats (Prasad, Ali, Hari Krishnan, & Raghavan, 2012; Raghavan, Ali, Philip, & Dahanukar, 2018; Raghavan et al., 2011). Further, the development of management plans is hindered by the absence of reliable information on the life history and demography of a vast majority of native species (Dahanukar et al., 2011).

The cyprinid genus *Hypselobarbus*, comprising 13 species, is endemic to the Western Ghats (Knight, Rai, D'Souza, Philip, & Dahanukar, 2016), occurring in the major rivers and their associated reservoirs, as well as occasionally being observed in backwaters and brackish water lakes during the monsoon season. As a result of their large sizes, many *Hypselobarbus* species are highly preferred as food fish, having been indiscriminately exploited, leading to severe population declines (Ali & Raghavan, 2011a,b). As an example, *Hypselobarbus dubius*, constituting 55% of the landings from Amaravathy Reservoir (on the Cauvery River) in the mid-1960s, dwindled to 2% within a span of three to 4 years, before finally disappearing from the fish catches (Sreenivasan, 1976). Similarly, *H. micropogon* populations in the Cauvery River and tributaries are known to have declined by 50% over a 10-year period (Ali & Raghavan, 2011b). As a result of combined threats from overexploitation and habitat loss, eight species of *Hypselobarbus* (more than half of the species within the genus) are currently assessed as "threatened" on the IUCN Red List (IUCN 2017).

Hypselobarbus kurali, assessed as "Least Concern" on the IUCN Red List and having a widespread distribution throughout the southern part of the Western Ghats (WG), is highly popular as a food fish (Williams, Vijayalekshmi, Benziger, Karim, & Nair, 2016), although little is known regarding its natural history. Using length-frequency data of *H. kurali* exploited through an artisanal gill-net fishery, this study focused on determining its population dynamics as a means of inform future management plans for this endemic and highly exploited species and, in the process, generate first of its kind information on the demography of any species of *Hypselobarbus*.

2 | MATERIALS AND METHODS

2.1 | Study area

Malampuzha Reservoir (2,313 ha; 10°51'N, 40°26'E, 100 m.a.s.l), located in the Indian State of Kerala, is an irrigation and drinking water project formed by damming the 209-km-long Bharathapuzha River in 1952. It was among the first to be developed in the region for fishery and stock enhancement purposes, and also selected for management interventions under the Indo-German Reservoir Fisheries

Development Project (IGFP) in the 1990s (Peters & Feustel, 1998). About 122 families, including both resident and migrant communities, derive their livelihoods from fishing in the reservoir, through participation in a fisherman cooperative and self-help group (Kutty, Nair, & Salin, 2008).

2.2 | Biological data collection and analyses

Specimens of *H. kurali*, which form the basis of this study, were procured on a monthly basis for a 1-year period (2011–2012) from the fisher cooperative at the Malampuzha Reservoir. Fish were caught using monofilament gillnets. Although a total of 274 individuals were examined for length-frequency data, reliable weight estimates were available only for 198 specimens, mainly because (a) weight data were unavailable because of logistic issues or (b) weight data were unreliable as they exhibited an outlier tendency, mainly because they included spent females. The outliers were excluded on the basis of the recommendations of Froese (2006). There was no size bias in further analyses, however, because the excluded specimens were not of a particular size class. The length and weight of the fish were plotted to determine the power of the length-weight relationship, as follows:

$$W = aL^b \quad (1)$$

where W = weight (g); L = standard length (cm); a = normalization constant; and b = scaling power. The null hypothesis of isometric growth (i.e., $b = 3$) was tested using a two-tailed t test as described by Zar (1984).

The frequency distribution of the 274 individuals was used to study the growth pattern, mortality and exploitation. Data were arranged in a length-frequency table (with 0.5 cm as the smallest midlength and 1 cm class intervals thereafter). A contour plot was prepared to examine the distribution of length classes in relation to different months. Growth, mortality parameters and exploitation levels were estimated from the length-frequency data using FAO-ICLARM Stock Assessment Tools II (FiSAT II) software (Gayanilo, Sparre, & Pauly, 2005). The von Bertalanffy growth formula (VBGF) was fitted as follows:

$$L(t) = L_{\infty} * [1 - \exp(-K(t - t_0))] \quad (2)$$

where L_{∞} = asymptotic length; K = growth constant; $L(t)$ = growth at time t ; and t_0 = hypothetical age at which the organism will have zero size, using ELEFAN 1 (Pauly, 1984). Based on the values of L_{∞} and K , the growth performance index ($\phi' = 2 * \log L_{\infty} + \log K$) and potential longevity ($3/K$) were estimated (Pauly & Munro, 1984). Growth parameters were used to determine the recruitment pattern of the young (Moreau & Cuende, 1991) by reconstructing the recruitment peaks from a time series of length-frequency data to estimate the number of pulses per year and the relative strength of each peak (Gayanilo et al., 2005). The total mortality (Z) was estimated from the length-converted catch curve. The length at first capture (L_c) was determined using a logit function on the probability of capture. The natural mortality (M) was determined using Pauly's

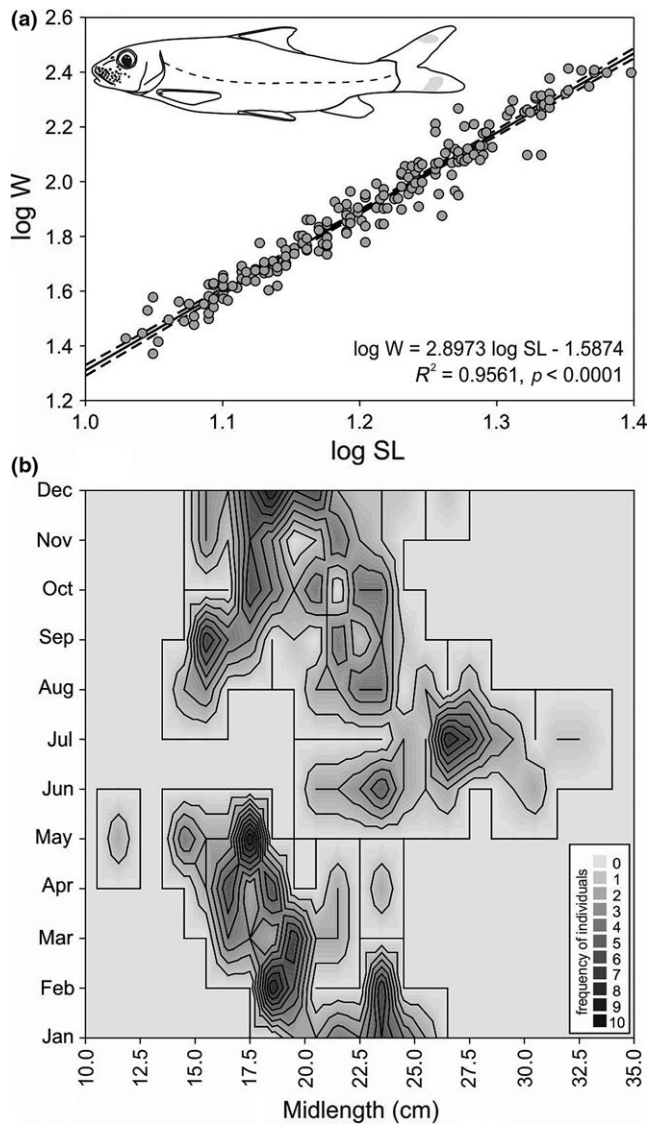


FIGURE 1 Length-based analysis of *Hypselobarbus kurali* from the Malampuzha Reservoir, India: (a) length–weight relationship; (b) monthly length–frequency contour graph

M equation, which is known to work well, particularly for tropical fishes, as follows:

$$\ln(M) = -0.0152 - 0.279 \ln(L_{\infty}) + 0.6543 \ln(K) + 0.463 \ln(T) \quad (3)$$

where T = average annual temperature (26°C for the study area). The fishing mortality (F) was calculated as $F = Z - M$, and the current exploitation level (E) was calculated as $E = F/Z$ (Pauly, 1984). The growth- and mortality-related parameters were used to model the virtual population analysis or VPA (Hilborn & Walters, 1992), and for estimating the exploitation level of the species using relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) analysis with a knife edge selection procedure (Beverton & Holt, 1966). Plots of Y'/R vs. E and of B'/R vs. E were used to estimate E_{\max} (i.e., exploitation rate producing maximum yield) and E_{50} (i.e., exploitation rate under which the stock has been reduced to 50% of its unexploited biomass).

3 | RESULTS

The length–weight relationship of *H. kurali* in Malampuzha Reservoir (Figure 1a) was explained by the function $W = 0.0258 SL^{2.8973}$. The exponent $b = 2.90$ ($SE = 0.04$) was significantly different from the cubic value ($t = 2.32$, $df = 196$, $P = 0.0216$), indicating the growth was not isometric, and rather exhibiting a negative allometric tendency.

The frequency distribution of different length-class across months (Figure 1b) indicated the occurrence of smallest individuals (11–12 cm) in May and largest individuals (32–33 cm) in July. The largest *H. kurali* exploited during the study period measured 32 cm, while the asymptotic length (L_{∞}) was an estimated 34.13 cm. Growth-related parameters based on the von Bertalanffy growth curve fitted to the length–frequency data (Figure 2a) and mortality-related parameters based on length-converted catch curve (Figure 2b) are provided in Table 1. Statistical analysis of recruitment revealed two peaks of approximately the same height (Figure 2c), indicating the fish has two spawning bouts each year in the reservoir. The total mortality rate of the population was 0.57 (CI: 0.51–0.64 year⁻¹), the fishing mortality was 0.26 year⁻¹ (CI: 0.19–0.32 year⁻¹), and the length at first capture (L_c) was 16.98 cm.

The virtual population dynamics (Figure 3a) suggested the fishery targeted large-sized specimens from about 13.5 cm, with the fishing mortality decreasing the survivors exponentially for larger specimens. Modelling of the data for exploitation levels, using relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) analysis based on knife edge selection (Figure 3b), suggested the exploitation rates for the population are 0.36 (E_{50}) and 0.72 (E_{\max}). The current exploitation rate (E) of 0.45 (Table 1) is larger than E_{50} , but smaller than the E_{\max} .

4 | DISCUSSION

Overexploitation is an emerging threat to the biodiversity of inland fisheries, and the ecosystem goods and services upon which thousands of people in mostly developing countries depend (Allan et al., 2005). Biological resource use (via inland capture fisheries), for example, is listed as the second greatest threat to the freshwater fishes of the Western Ghats (Smith et al., 2011), yet very little research has focused on their impacts to biodiversity or livelihoods. The “open-access” nature of the fisheries, frequent use of destructive fishing techniques and poor enforcement of existing laws (Raghavan et al. 2012) have made it extremely difficult to document and manage inland fisheries in the region.

Information on the demography (growth and mortality rates), status of populations (stock assessments) and number of fish harvested (exploitation levels and rates), and the intricate link between these items are required to better understand and effectively manage freshwater fisheries (Raghavan et al., 2013). Such information is currently biased towards the large-growing tropical cyprinids of the genus *Tor* (Bhat, Nautiyal, & Singh, 2000; Raghavan et al., 2011), with very little information available on other groups,

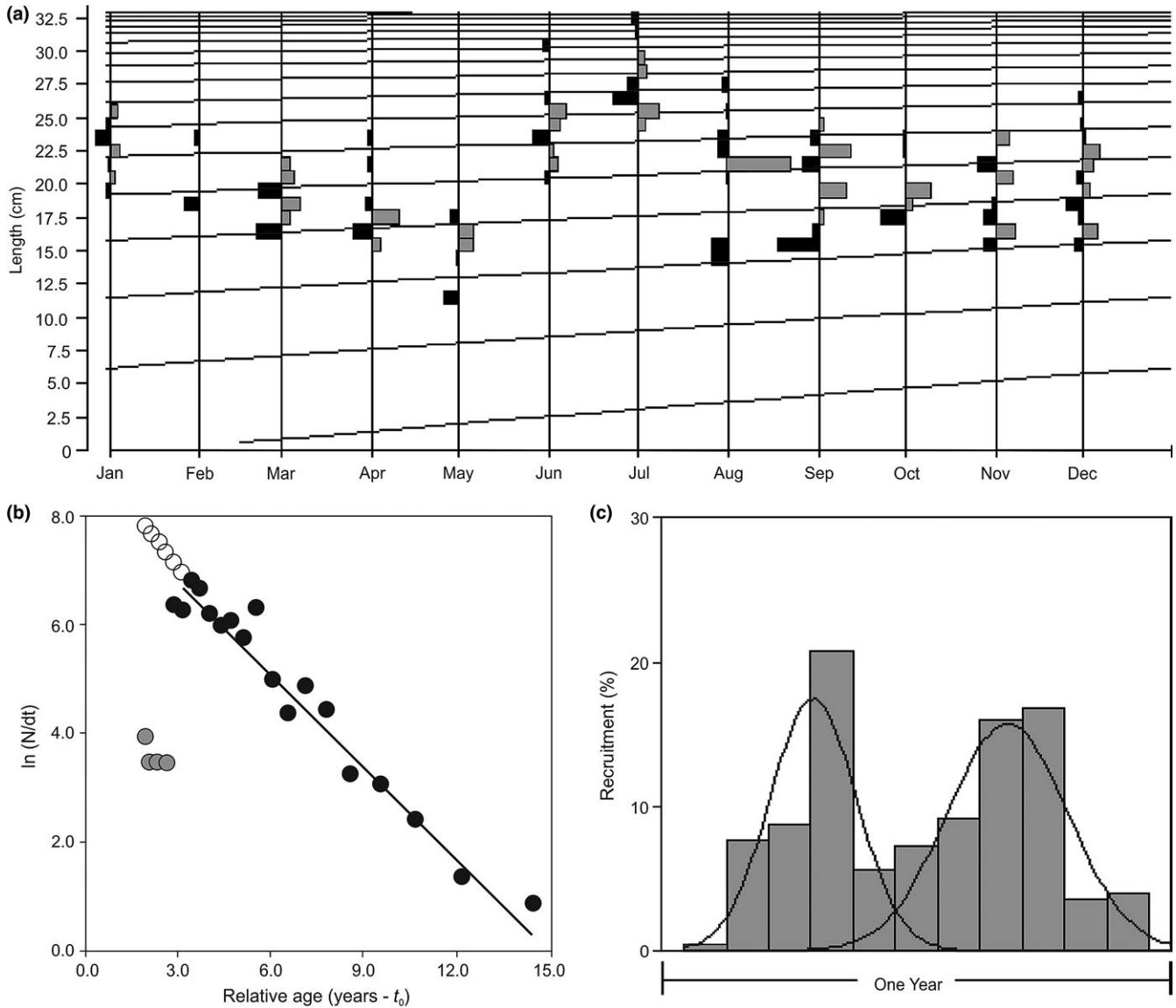


FIGURE 2 Growth and fishing dynamics of *Hypselobarbus kurali* from the Malampuzha Reservoir, India: (a) von Bertalanffy growth curve fitted to length-frequency data; (b) length-converted catch curve; (c) recruitment pattern

TABLE 1 Growth- and mortality-related parameters of *Hypselobarbus kurali* from Malampuzha Reservoir, India

Parameter	Value
Asymptotic length (L_{∞})	34.13 cm
VBGF growth constant (K)	0.21 year ⁻¹
Growth performance index (ϕ')	2.39
Potential longevity ($3/K$)	14.29 year
Length at first capture (L_c)	16.98 cm
Natural mortality (M)	0.32 year ⁻¹
Fishing mortality (F)	0.26 year ⁻¹
Total mortality (Z)	0.57 year ⁻¹
Exploitation rate (E)	0.45 year ⁻¹

including *Hypselobarbus* which comprise several threatened species (IUCN 2017) exploited for food security and livelihoods.

The largest *Hypselobarbus* recorded in the present study (32.0 cm) was smaller than the maximum known size of the species (35 cm; Menon, 1999). The observed length classes of exploited *H. kurali* (11.3–32.0 cm) in Malampuzha Reservoir are comparable to those caught in a gill-net fishery operating in River Kallada (9.8–27.0 cm) (Renjithkumar, Roshni, & Kurup, 2018), possibly attributable to the more or less similar mesh sizes employed at both locations. Comparable length-weight relationship “ b ” values were similarly observed in the present study (2.90, SE = 0.04) and by Renjithkumar et al. (2018) (2.93).

There are no previous studies on the population dynamics of *H. kurali*, making intraspecific comparisons impossible. The VBGF K value, and growth performance index (ϕ') for *H. kurali* (0.21 year⁻¹ and 2.39, respectively), however, is lower than in its congener, *H. carnaticus* (0.5–0.65 year⁻¹ and 5.08–5.22, respectively) (Manojkumar & Kurup, 2010). While the K value in *H. kurali* was comparable to other

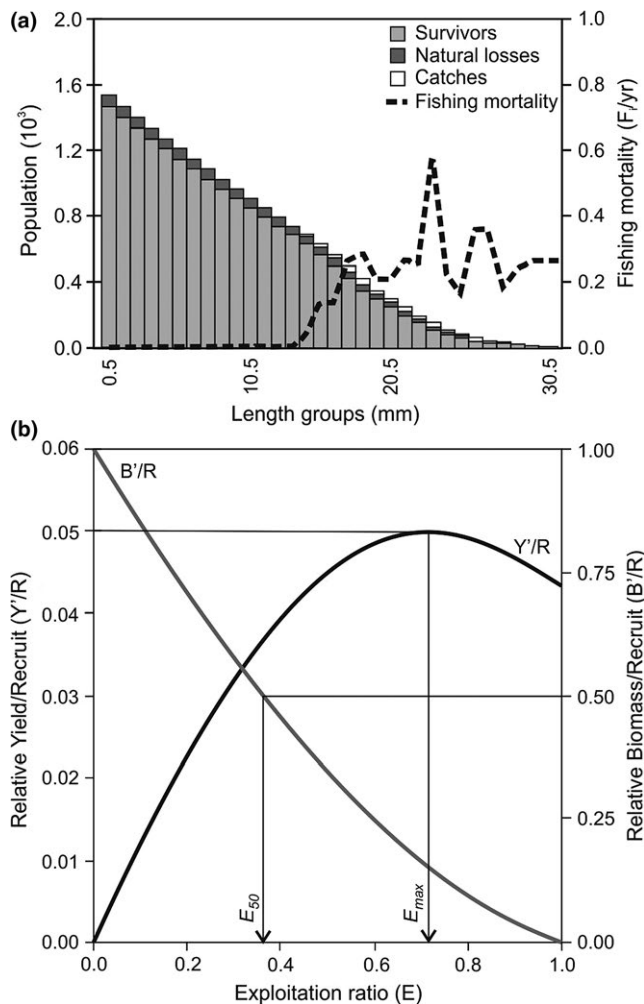


FIGURE 3 Growth and exploitation modelling for *Hypselobarbus kurali* from Malampuzha Reservoir, India: (a) virtual population dynamics; (b) relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) analysis

WG cyprinid fishes (0.12–0.23 year⁻¹ in *Tor khudree*), the ϕ was significantly lower (4.3–5.2) (Raghavan et al., 2011), suggesting *H. kurali* is comparatively slower growing than other large cyprinids of the region. Slow growth rates could prove disadvantageous for the species as it is being considered for aquaculture (Williams et al., 2016).

The length at first capture (L_c) for the population was estimated to be 16.98 cm. With no published information on any aspect of the reproductive biology, however, it is difficult to infer whether yet-to-be mature individuals are exploited. Virtual population analysis suggested a high natural mortality in the young size classes (till 13.5 cm), which could be attributed to either predation, diseases or environmental stressors (see Caveriviere & Toure, 1996). Although the current level of exploitation is not of great concern (62.5% of the E_{max}), there is nevertheless a need to develop and implement management plans to guide the future sustainability of the reservoir fishery of *H. kurali*, particularly given that many other species of *Hypselobarbus* are being extirpated from reservoirs of the Western Ghats due to unmanaged fisheries.

Effective management of freshwater fisheries is hindered by a lack of basic information on the ecology and population of many species, including those that are threatened (Cooke, Paukert, & Hogan, 2012). The present study on *H. kurali* has provided the first reference values on its growth, mortality and exploitation levels, which can serve as a baseline to set precautionary limits and management strategies, not only for this species, but also other poorly known, range-restricted and threatened congeners such as *H. dubius*, *H. periyarensis* and *H. micropogon* which are exploited through unmanaged fisheries and which are exhibiting declining populations.

ACKNOWLEDGEMENTS

The authors thank S. Solomon, S. Sukanya, S. Menon and B. Pereira for their support in the field, the Manager, St. Albert's College for facilities provided, local fishers in Malampuzha for their help during the field surveys, and two anonymous reviewers whose comments and suggestions greatly improved the manuscript.

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How to cite this article: Raghavan R, Ramprasanth MR, Ali A, Dahanukar N. Population dynamics of an endemic cyprinid (*Hypselobarbus kurali*): Insights from an exploited reservoir fishery in the Western Ghats of India. *Lakes & Reserv.* 2018;00:1–6. <https://doi.org/10.1111/lre.12233>