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NOTE

POPULATION DYNAMICS AND MANAGEMENT STRATEGIES FOR THE INVASIVE AFRICAN CATFISH *CLARIAS GARIEPINUS* (BURCHELL, 1822) IN THE WESTERN GHATS HOTSPOT

Kuttanelloor Roshni, Chelapurath Radhakrishnan Renjithkumar, Rajeev Raghavan, Neelesh Dahanukar & Kutty Ranjeet

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Population dynamics and management strategies for the invasive African Catfish *Clarias gariepinus* (Burchell, 1822) in the Western Ghats hotspot

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Freshwater biodiversity is in peril, threatened by a range of (often interacting) stressors including flow-regulation, pollution, invasive alien species, climate change, and overexploitation (Dudgeon et al. 2006; Strayer & Dudgeon 2010). Of these, biological invasion is one of the most widespread and damaging stressors on freshwater ecosystems (Strayer & Dudgeon 2010), responsible for the extinction of over 17 fish species, and the imperilment of over 450 threatened fish species worldwide (IUCN 2019).

The freshwater ecosystems of India's Western Ghats (WG) Hotspot harbour more than 300 fish species, of which 65% are endemic (Dahanukar et al. 2011). Though much of this endemism is concentrated in the southern region of the WG Hotspot, inside terrestrial protected areas, no management or monitoring plans are in place for freshwater taxa (Raghavan et al. 2016). For example, a threatened species of mountain catfish *Glyptothorax madraspatanus* was extirpated from Eravikulam National Park, a protected area in the WG

due to the invasion by the Rainbow Trout *Oncorhynchus mykiss* (Thomas et al. 1999). In a similar situation, four alien species compete for resources with eight point-endemics in the watershed of the Periyar National Park, one of WG's intensively-managed protected areas (Molur & Raghavan 2014).

The African Sharp-tooth Catfish, *Clarias gariepinus* (Burchell 1822) is one of the world's most successful aquatic invader (Booth et al. 2010), in view of its spread and impacts to native fauna in close to 30 countries (GISD 2020). Diverse life history traits including eurytopic nature, pseudo-lungs, trophic flexibility, predatory & piscivorous feeding habits, fast growth, and high mobility (Kadye & Booth 2012; Weyl et al. 2016) has facilitated their invasion across tropics; unmanaged aquaculture, and stock enhancement being the major reasons (Weyl et al. 2016). Although extensive information is available on the occurrence and distribution of invasive *C. gariepinus*, there has been very little focus on understanding the population dynamics of invasive populations (Booth et

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al. 2010). In the present paper, the demographics of invasive *C. gariepinus* in the watershed of the Periyar National Park, an Alliance for Zero Extinction (AZE) site, and one of the most critical habitats for freshwater fish conservation in southern Asia (Molur & Raghavan 2014) is determined, to inform management and conservation action.

The Periyar Lake-Stream system inside the Periyar National Park (9.160°N & 76.553°E) (an IUCN Category II protected area) is an AZE site known to harbour the only global population of three endangered cyprinids (*Hypselobarbus periyarensis*, *Tariqilabeo periyarensis* & *Lepidopygopsis typus*) (Molur & Raghavan 2014). This critical habitat is, however, threatened by four alien species, *Oreochromis mossambicus* (Peters, 1852), *Cyprinus carpio* (Linnaeus, 1758), *Poecilia reticulata* (Peters, 1859), and *Clarias gariepinus*. An organized small-scale fishery primarily focused on gillnets (32–110 mm) is carried out in the lake by local tribal fishers, and the resultant catch is sold at a nearby landing centre organized by the Kerala State Forest and Wildlife Department.

Clarias gariepinus samples (n=344) exploited using gill nets (40–110 mm mesh size) and sold at the local landing centre, were collected at monthly intervals from December 2018 to November 2019, measured for standard lengths (L_{TS} , to the nearest mm) and body weight (M_b , to the nearest g). A large share of the sample comprised of dead fish, and only a small number of individuals were alive at the time of collection. These were euthanized immediately by immersing in ice-slurry. The length data were grouped into 5cm class intervals with the smallest mid-length of 2.5cm. The length-mass relationship ($M_b = aL_T^b$) was determined following Pauly (1984) and the parameters (a, b) were estimated by least squares regression of log-log plot (Zar 1999). The null hypothesis that n=3 (i.e., individuals show isometric growth pattern; Froese 2006) was tested using two-tailed t-tests. The statistical analysis was performed in PAST 3.20 (Hammer et al. 2001).

The von Bertalanffy growth parameters, asymptotic length (L_∞) and growth coefficient (K) were estimated from length-frequency data using the electronic length frequency analysis I (ELEFAN I) incorporated in FAO-ICLARM Stock Assessment Tools II (FiSAT II) software (Gayanilo et al. 2005). Based on L_∞ and K values, growth performance index (ϕ) and potential longevity ($3/K$) were estimated (Pauly & Munro 1984). Instantaneous total mortality (Z) was estimated using length-converted catch curve (Pauly 1984); natural mortality (M) was determined by Pauly's empirical formula (Pauly 1980).

Table 1. Growth, mortality and exploitation parameters of *Clarias gariepinus* from Periyar Lake.

Demographics and exploitation parameters	Value
Asymptotic length (L_∞ ; cm)	91.88
Growth coefficient (K; year ⁻¹)	0.54
Growth performance index (ϕ)	3.66
Longevity ($3/K$; years)	5.56
Total mortality (Z; year ⁻¹)	1.34
Natural mortality (M; year ⁻¹) at 26°C	0.84
Fishing mortality (F; year ⁻¹)	0.50
Current exploitation rate (E)	0.37
Length at first capture (L_c ; cm)	29.90
$E_{0.1}$	0.46
$E_{0.5}$ (Optimum)	0.31
Exploitation rate producing maximum yield (E_{max})	0.54

$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.4634 T$ (T), where T is the annual mean temperature of the water in which the fish occurs (26°C for the study area); instantaneous rate of fishing mortality (F) was computed as $F = Z - M$ and exploitation rate (E) was as $E = F/Z$ (Gulland 1970). The E_{max} (maximum yield per recruit) and E_{50} (exploitation that retains 50% of the biomass) were predicted using relative yield per recruit (Y/R) and relative biomass per recruit (B/R) analysis using knife-edge selection method (Pauly 1984). From length-converted catch curve, the length at first capture (L_c) was analysed. Growth parameters were used to determine the reproductive pulses per year, and the relative strength of each pulse using recruitment analysis (Moreau & Cuende 1991). Growth and mortality parameters were used to perform virtual population analysis (VPA) (Hilborn & Walters 1992). Fishing mortality was considered as the terminal fishing mortality F_t . To understand how the population in different size classes might be affected by an increase in the fishing mortality, VPA was performed with different values of F_t . To develop an effective eradication plan for the local *C. gariepinus* population, the threshold value of E_{max} above which the population would be overexploited in Y/R analysis was plotted against L_c . To understand whether a change in the fishing regime, especially with respect to the length of first capture, can facilitate eradication of *C. gariepinus*, we performed Y/R analysis and plotted threshold value of E_{max} above which the population will collapse, against varying length at first capture (L_c).

Length and weight measurements of *C. gariepinus* collected from the Periyar Lake ranged 17.9–86.7 cm L_{TS} and 80–6,300 g. The LWRs was defined by the equation

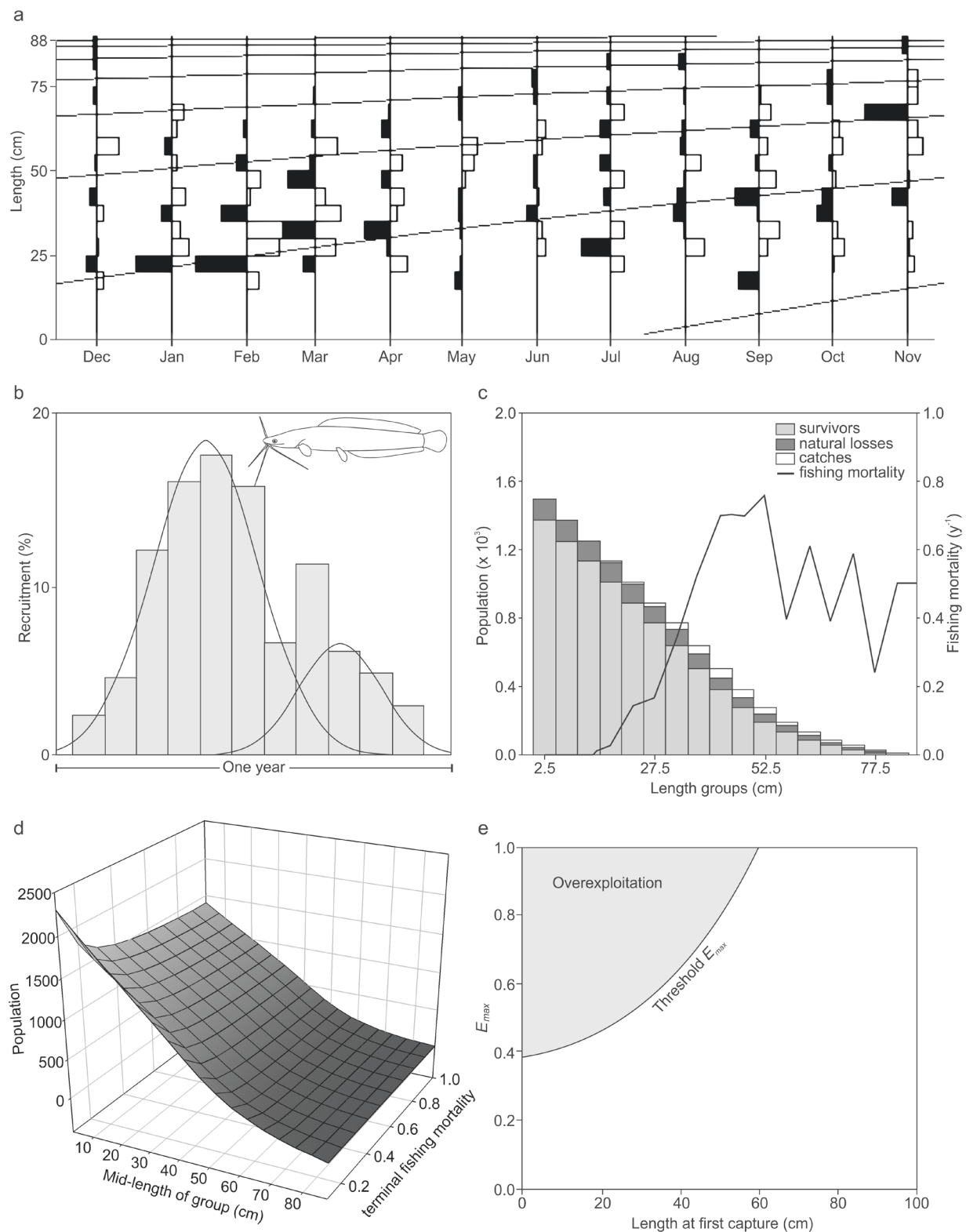


Figure 1. Growth and mortality modelling of *C. gariepinus* from Periyar Lake: a—von Bertalanffy growth curve drawn on a restricted length-frequency sample, where peaks or the positive points (black bars) and troughs or the negative points (white bars) are shown. The points were computed and used to plot the growth curve that passes through largest number of positive points by avoiding negative points | b—computed recruitment pattern suggests that the species has two spawning peaks in a year | c—length structure virtual population analysis suggests current fishing mortality can reduce population of larger individuals but not the smaller individuals | d—effect of terminal fishing mortality on the population in different size classes | e—effect of length at first capture on the maximum sustainable exploitation above which the population will be overexploited and subsequently collapse.

$W=0.0132 L^{2.8719}$, and the b value 2.8719 was significantly lower than the cubic value ($t=5.0092$, $P<0.0001$) expected under isometry, indicating that *C. gariepinus* shows a negative allometric growth pattern (A) in the Periyar Lake. The b value obtained in our study is similar to native *C. gariepinus* populations in Kenya (2.81; Macharia et al. 2017) and introduced populations in a reservoir in the WG (2.9; Pillai et al. 2016).

The occurrence of juveniles (17.9cm) as well as mature females (31.5cm) suggests that the species has successfully established and colonized the lake. The von Bertalanffy growth curve shows an asymptotic length of 91.88cm and a growth coefficient of 0.54 year^{-1} (Figure 1a; Table 1) which was greater than those observed for various native populations of *C. gariepinus*, i.e., L_{∞} : 80–124 cm, $K=0.06\text{--}0.49 \text{ year}^{-1}$ and $\phi=2.96\text{--}3.36$ (Clay 1984; Wudneh 1998; Okogwu 2011; Tesfaye & Wolff 2015; Macharia et al. 2017). The estimated growth performance index of 3.66 (Table 1) is also higher than that reported for *C. gariepinus* in its native range (Clay 1984; Wudneh 1998; Abdulkarim et al. 2009; Tesfaye & Wolf 2015). No estimates of growth parameters are available from any invasive populations of *C. gariepinus*.

The total mortality (Z) of *C. gariepinus* in Periyar Lake was estimated as 1.34 year^{-1} (Table 1). The natural mortality rate of 0.84 year^{-1} (Table 1) is comparable to an invasive population in South Africa (Booth et al. 2010), but lower than native populations in Nigeria (Abdulkarim et al. 2009), suggesting that *C. gariepinus* has no natural fish predators in its invasive habitat in the WG. The low fishing mortality and exploitation rate (Table 1), which is much below the optimum exploitation rate ($E_{\max}=0.68$) indicate minimal fishing pressure favouring population expansion. In addition, recruitment analysis suggested continuous recruitment throughout the year with two peaks (Figure 1b) similar to populations in Western Africa (Kwarfo-Apegyah & Ofori-Danson 2010).

The VPA (Figure 1c) suggests a high survival rate due to low natural mortality and fishing pressure. A simulation of VPA for increasing fishing mortality (Figure 1d) revealed that greater fishing pressure could exponentially reduce the juvenile population but will not result in population eradication. Further, adult individuals may not be significantly affected, probably because of high survival rate due to low fishing mortality and predation. Our analysis further suggests that using this experimental fishing regime will not result in eradication of the local *C. gariepinus* population. Analysis to understand the changes in the fishing regime suggests that the threshold value of E_{\max} required to overexploit the species decreases exponentially with

decrease in L_c (Figure 1e). The length at first capture in our experimental fishing was 29.90cm (Figure 1c), i.e. 32.54% of the asymptotic length. Reducing this value to below 10cm, comprising mainly of immature individuals (see Hossain et al. 2016 for size at first maturity values), will no doubt be the best management strategy for eradication. This may be achieved through mesh size selectivity, and specifically targeting spawning grounds to capture young, immature individuals.

Understanding the population biology of an invasive species is important for its long-term management (Booth et al. 2010). Rapid growth, high growth performance index, low fishing mortality and year-round recruitment significantly contribute to the successful invasion of *C. gariepinus* in Periyar Lake, and possibly throughout its invasive range. Though it might be difficult to eradicate *C. gariepinus* from the lake, where they have already established a strong population, effective management and control can be achieved by targeting fish smaller than 10cm. Further studies to understand the reproductive biology and ecology, and its links to the demographics of *C. gariepinus* will help inform improved management measures for this invasive species in a critical freshwater AZE Site.

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