Fishery, Demographics and Exploitation of Two Sympatric Snakeheads (*Channa striata* and *Channa pseudomarulius*) in Small-scale Fisheries of the Western Ghats, India: Implications for Conservation

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ABSTRACT

Sympatric snakeheads (*Channa striata* and *C. pseudomarulius*) are high-valued food fishes that constitute a major portion of wild-caught snakeheads in tropical Asia. This study assessed the fishery, demographics, and exploitation parameters of *C. striata* and *C. pseudomarulius* in a small-scale subsistence fishery in the Chalakudy River, a biodiversity hotspot in the Western Ghats of Southern Peninsular India. The estimated landings in this study were 3.26 t for *C. striata* and 2.46 t for *C. pseudomarulius*. *Channa pseudomarulius* exhibited a higher asymptotic length (L_∞) of 89.25 cm compared to 63 cm for *C. striata*. However, *C. pseudomarulius* had a higher growth constant (K = 0.90 $year^{-1}$) than *C. striata* (K = 0.46 $year^{-1}$), indicating a faster growth rate. Fishing mortality (F = 1.71 $year^{-1}$) and natural mortality (M = 0.66 $year^{-1}$) were also higher for *C. pseudomarulius* compared to *C. striata* (F = 0.79 $year^{-1}$, M = 0.47 $year^{-1}$). The current exploitation rates (E) of *C. striata* (0.63) and *C. pseudomarulius* (0.72) indicate unsustainable fishing pressure, placing these species in the Western Ghats River at imminent risk of collapse. Overexploitation of mature individuals threatens population size in view of their continuous breeding, stable recruitment and fast growth. The present investigation provides initial insights into the demography of these snakehead species, supporting the development of management strategies and awareness programmes in the Western Ghats, as well as in similar tropical habitats.

Keywords: Growth, Management, Mortality, Overexploitation, Western Ghats

INTRODUCTION

Small-scale fisheries play a crucial role in enhancing nutrition, ensuring food security, and improving the livelihoods of fishers and allied fish workers worldwide (Kanthiah, 2010). More than 50% of the global fish catch comes from the small-scale sector, with approximately 95% of this being consumed by locally (FAO, 2020). The majority of inland fisherfolk work in the small-scale sector, which ranges from family-based artisanal fishing to commercial operations using motorized boats (Welcomme *et al.*, 2010). Inland small scale fisheries support the livelihoods of more than 820 million people around the world (Silvano and Kurien, 2023). These fish are primarily traded in local inland fish markets, with most of the catch consumed by rural residents (Welcomme *et al.*, 2010). Many large freshwater species are harvested through small-scale fisheries, serving both food security and medicinal purposes (Belton and Thilsted, 2014). However, increasing demand for these larger fish has led to over exploitation, causing population declines. To assess the impact of such exploitation, information on population status, mortality, exploitation rates, and recruitment levels is essential.

The family Channidae consists of air-breathing carnivorous freshwater fish native to tropical Asia and Africa, commonly known as

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snakeheads. To date, 47 valid species have been recorded (Rainboth, 1996; Li *et al*., 2006; Vishwanath and Geetakumari, 2009). The family includes three genera, *Aenigmachanna* (1 species), *Channa* (43 species), and *Parachanna* (3 species) (Rüber *et al*., 2019; Britz *et al*., 2020). Snakehead, or murrels, vary in size from small to large, ranging from 17 cm to 180 cm in length. The Asian snakehead, *Channa striata* (Bloch, 1793), is a tropical freshwater species found in rivers, reservoirs, ponds, and lakes across Southeast Asia, the Middle East, and Africa (Chaudhry *et al*., 2019). Due to its high nutritional value and minimal intramuscular bones, *C. striata* commands a high market price, ranging from 5 to 7 USD per kilogram (Jhingran, 1982; Michelle *et al*., 2004; Sahu *et al*., 2012a; 2012b; Kumar *et al*., 2021). In India, this species is not only economically important food fish but is widely used for medicinal and pharmaceutical applications (Zakaria *et al*., 2007; Mustafa *et al*., 2012).

Channa pseudomarulius (Hamilton 1822) commonly known as the orange-spotted snakehead, has a very limited geographical distribution, primarily in the Western Ghats region of India (Britz *et al*., 2017). It hold significant fishery importance due to its widespread distribution, natural abundance, and high market value. However, limited information is available on the biological characteristics of these sympatric snakehead species, including length-weight relationships, dietary habits, and reproductive biology (Weliange and Amarasinghe, 2007; Djumanto *et al*., 2020; Roshni and Renjithkumar, 2020). Furthermore, no studies have comprehensively examined the demographics and stock status of these species across their entire range.

Given this knowledge gap, the present study aims to assess the fishery status, demographics, and exploitation levels of *C. striata* and *C. pseudomarulius* in a small-scale fishery in the Western Ghats of southern peninsular India. There is currently a lack of information on key biological aspects such as maturation, fecundity, growth, exploitation rates, and recruitment percentages of tropical snakeheads. This study provides essential demographic data on these two freshwater snakehead species and offers insights for developing sustainable exploitation and conservation strategies.

MATERIALS AND METHODS

Study site

The Western Ghats biodiversity hotspot in Southern peninsular India is recognized as distinct biogeographic region due to its exceptional rich aquatic diversity (Dahanukar *et al*., 2011). The Chalakudy River, originating from the Anamalai hills of the Southern Western Ghats (SWGs), is the fifth longest among 44 rivers of Kerala and is a home to 98 fish species (Raghavan *et al*., 2008b).

Data collection

Samples were collected at monthly from June 2018 to May 2019 at fish landing sites along the Chalakudy River, Southern Western Ghats of India. *C. striata* and *C. pseudomarulius* were captured by artisanal fishers using gillnets, seine nets, and occasionally, hook and lines, then sold in local markets. Monthly data on the snakehead fishery were collected from the Annamanada, Mampra, and Kanakkankadavu fish landing centres. No experimental fishing was conducted for this study.

Length-frequency data were randomly collected from well-mixed catches on each sampling day to minimize size-based bias in population assessment. The total length of each fish was measured to the nearest millimetre (mm), while total weight was measured to the nearest grams (g). A total of 808 individuals, including 356 *C. striata* (16–44 cm) and 452 *C. pseudomarulius* (23.9–61.2 cm), were used for length-weight relationships and demographic studies.

Data analysis

Fishery

The daily landings from each gear type were estimated using the formula established by Kurup *et al*. (1993):

$$W = (w/n) \times N,$$

where W represents the total weight of snakeheads, w denotes the total weight of the species in the sampled gear, n is the number of gears sampled, and N is the total number of similar gear type operated in the sampling area. The monthly catch was calculated by multiplying the daily catch by the total number of fishing days in the study area (25 days per month). The total exploited fishery was estimated by summing the monthly landings over the study period.

Length- weight relationships

The length-weight relationship was calculated using the equation:

$$W = aL_b,$$

and logarithmically transformed into:

$$\log W = \log a + b \log L,$$

where W is the whole-body weight (g), L is the total length (cm), and a and b are regression parameters (Le Cren, 1951; Froese, 2006). The values of a and b were estimated using least-square regression (Zar, 1999), with 95% confidence limits calculated. A Student's t-test was conducted to determine whether the b value significantly deviated from the isometric growth prediction ($b = 3$). A statistically significant difference from 3 ($p<0.05$) indicated allometric growth (positive or negative), while isometric growth was assigned when b was not statistically different from 3 ($p>0.05$) (Yilmaz *et al*., 2012).

Growth, mortality, and exploitation

Growth, mortality, and exploitation of *C. striata* and *C. pseudomarulius* were analysed using length-frequency data, which were grouped into 25–mm class intervals. Growth parameters, including asymptotic length (L_∞) and growth rate (K), were estimated using the von Bertalanffy Growth Function (VBGF). The ELEFAN-1 (Electronic Length Frequency Analysis) software tool incorporated in FiSAT-II (FAO-ICLARM Stock Assessment Tools) (Gayanilo *et al*., 2005) was used to calculate L_∞ and K. The von Bertalanffy growth equation (VBGF) was applied as follow:

$$L_t = L_\infty [1- \exp (-K (t-t_0)],$$

where L_t is the length at age t, L_∞ is the asymptotic length, K is the growth coefficient, t is the fish age, t_0 is the theoretical age when TL is zero. The theoretical age at zero length (t_0) was estimated using the equation of Pauly (1980):

$$\text{Log}_{10}(-t_0) = -0.392-0.275 \text{ Log}_{10}L_\infty-1.038\text{Log}_{10}K.$$

Potential longevity (t_{max}) was estimated using the following equation:

$$t_{max} = (3/K)+t_0.$$

Based on L_∞ and K values, the growth performance index (ϕ') was calculated (Munro and Pauly, 1983):

$$\phi' = \log K+2 \log L_\infty.$$

The total mortality rate (Z) was computed using the length-converted catch curve method (Pauly, 1984). Natural mortality rate (M) was estimated using Pauly's empirical formula (Pauly, 1980):

$$\ln M = -0.0152-0.279 \ln L_\infty+0.6543 \ln K+0.463 \ln T$$

where, L_∞ is the asymptotic length (cm), K is the growth constant (year^{-1}), and T is the annual mean temperature (29 °C) in the study area. Fishing mortality (F) was estimated as:

$$F = Z-M.$$

The exploitation rate (E) was estimated by (Pauly, 1984):

$$E = F/Z$$

The length at first capture (L_c or L_{50}) was estimated using Pauly's ogive selection (Pauly, 1984). Length-structured virtual population analysis (VPA) was performed to estimate survivors, natural mortality (M), and fishing mortality (F) for each length group. Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) analyses were used to estimate E_{max} (maximum yield per recruit) and E_{50} (exploitation rate retaining 50% of biomass) (Beverton and Holt, 1966). The recruitment patterns of *C. striata* and *C. pseudomarulius* populations were analyzed using FiSAT routine (Gayanilo *et al*., 2005).

RESULTS

Fishery of murrels

The annual exploited fishery of *C. striata* and *C. pseudomarulius* from the river was estimated at 3.26 t and 2.46 t, respectively. Catches were dominated by *C. striata* individuals in the 20–34.9 cm length group, while *C. pseudomarulius* individuals in the 25–54.9 cm length group predominated the catches. Gill nets, seine nets, and hook and lines were the primary fishing gears used in the Chalakudy River for harvesting snakeheads, with the number of gears at each landing centre ranging from 3 to 6. Snakeheads were mainly caught at the Annamanada, Mampra, and Kanakkankadavu fish landing centres. Seasonal variations were noticed in the catch, with landings of *C. striata* peaking from September to December and *C. pseudomarulius* landings peaking in September to November. The highest landing of *C. striata* was observed in October (0.6 t), whereas the highest landing of *C. pseudomarulius* was recorded in September (0.4 t) (Figure 1).

Length-weight relationships

The measured minimum and maximum lengths and weights of the sampled *C. striata* and *C. pseudomarulius* were 12.2–62 cm and 15.5–86.1 cm, and 31–1,200 g and 48–2,870 g respectively. The length-weight relationships of *C. striata* and *C. pseudomarulius* were described by the equations $W = 0.014\ L^{2.684}$ ($r^2 = 0.988$) and $W = 0.014\ L^{2.657}$ ($r^2 = 0.980$), respectively. Both species showed negative allometric growth ($b<3$, t-test, $p<0.05$) which suggests that the fish become relatively thinner or more elongated as they grow rather than gaining mass at the same rate as their length increases.

Growth and mortality

The von Bertalanffy growth equation fitted for both species (Figure 2) indicated a higher asymptotic length for *C. pseudomarulius* (89.25 cm) compared to *C. striata* (63 cm) (Table 1). *C. pseudomarulius* exhibited a higher growth rate (0.90 $year^{-1}$) compared to *C. striata* (0.46 $year^{-1}$), indicating that *C. pseudomarulius* reaches its L_∞ more rapidly (Figure 3). This observation was further supported by the shorter lifespan of *C. pseudomarulius* (3.33 year) compared to *C. striata* (6.52 year). *C. pseudomarulius* also exhibited a slightly higher growth performance index (5.85). Between two species, *C. pseudomarulius* had a higher natural mortality (M) (0.66 $year^{-1}$) compared to *C. striata* (0.47 $year^{-1}$). Higher fishing mortality were also observed in *C. pseudomarulius* (1.71 $year^{-1}$) compared to its sympatric congener, *C. striata* (0.79 $year^{-1}$).

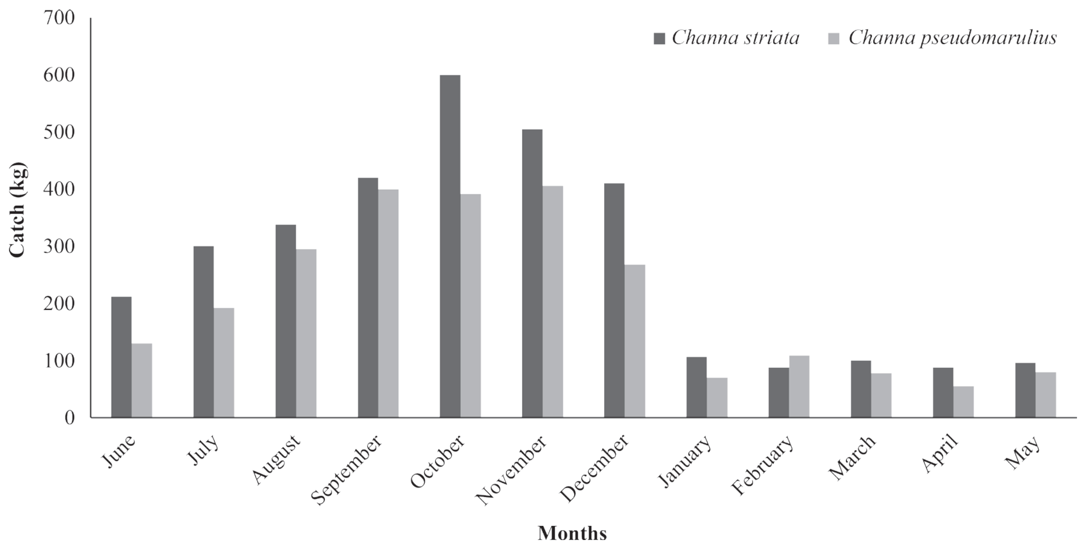

Figure 1. Monthly variation in the catch of *Channa striata* and *Channa pseudomarulius* in the Chalakudy River, India.

Table 1. Growth, mortality and exploitation parameters of *Channa striata* and *Channa pseudomarulius* in the Chalakudy River, India.

Population parameter	*C. striata*	*C. pseudomarulius*
Asymptotic length (L_∞, cm)	63	89.25
Growth coefficient (K; year^{-1})	0.46	0.90
Growth performance index (ϕ)	5.27	5.85
Longevity (3/K; years)	6.52	3.33
Annual total mortality rate (Z, year^{-1})	1.26	2.37
Annual natural mortality rate (M, year^{-1})	0.47	0.66
Annual fishing mortality rate (F, year^{-1})	0.79	1.71
Length at first capture (L_c; cm)	16.59	30.89
Annual exploitation (E)	0.63	0.72
E_{10} (exploitation that retains 10% of the biomass)	0.418	0.458
E_{50} (exploitation that retains 50% of the biomass)	0.311	0.342
E_{max} (exploitation rate producing maximum yield)	0.500	0.556

Note: L_∞ = asymptotic length (cm); K = growth coefficient (year^{-1}); ϕ = growth performance index; Z = total mortality (year^{-1}); M = natural mortality (year^{-1}); F = fishing mortality (year^{-1}); E = current exploitation rate; E_{10} = exploitation that retains 10% of the biomass; E_{50} = exploitation rate where stock is reduced to half its virgin biomass; L_c = length at first capture (cm)

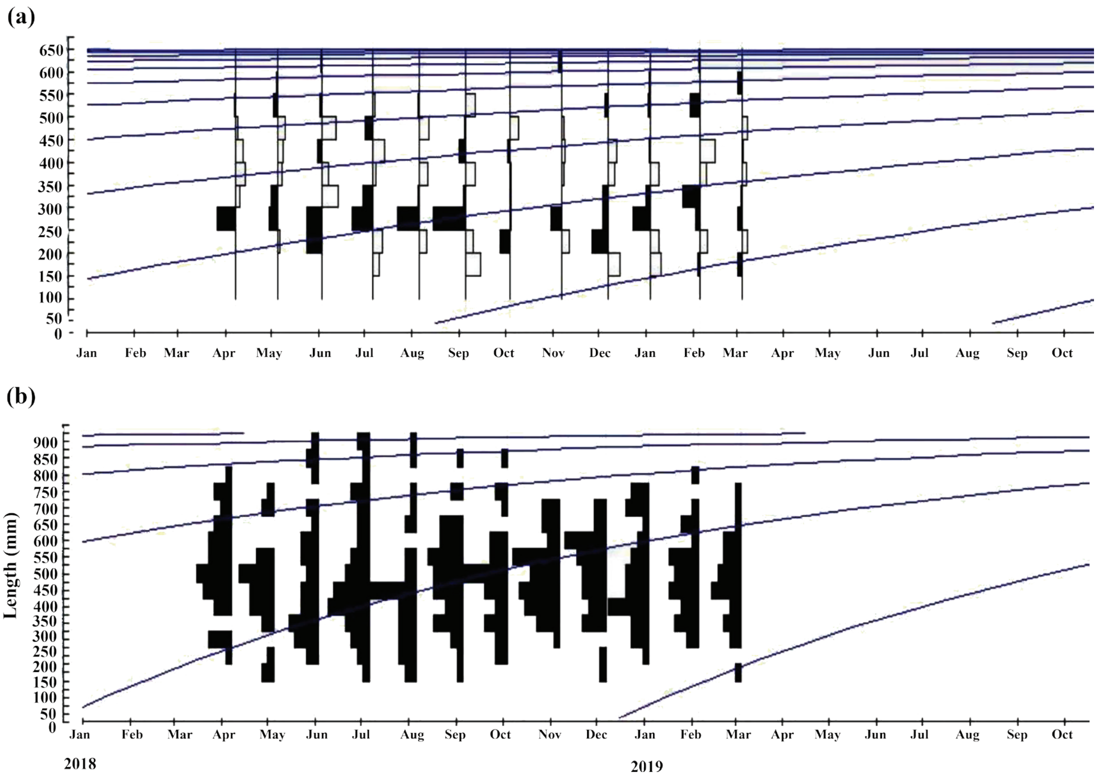

Figure 2. von Bertalanffy growth curves (VBGR) for *Channa striata* (a) and *Channa pseudomarulius* (b) in the Chalakudy River, India.

Exploitation and recruitment

The estimated length at first capture (L_c) was 16.59 cm for *C. striata* and 30.89 cm for *C. pseudomarulius*, representing 26.3% and 34.61% of their respective asymptotic lengths. The L_{25} and L_{75} capture probabilities were 15.53 cm and 17.65 cm for *C. striata*, and 25.05 cm and 36.73 cm for *C. pseudomarulius*. Virtual Population Analysis (VPA) indicates that fishing primarily targets *C. pseudomarulius* at 30–50 cm (F = 0.8–1.84 year^{-1}) and *C. striata* at 15–30 cm (F = 0.36–0.91 year^{-1}), with population declines occurring beyond 50 cm and 25 cm, respectively (Figure 5). VPA revealed three peaks in fishing mortality for *C. striata* and two for *C. pseudomarulius*, with greater fishing pressure on *C. pseudomarulius*. The estimated $E_{0.1}$ (exploitation retaining 10% of biomass), $E_{0.5}$ (exploitation retaining 50%) and E_{max} (maximum yield exploitation rate) were 0.42, 0.31, and 0.50 for *C. striata*, and 0.46, 0.34, and 0.56 for *C. pseudomarulius* (Figure 4). The current exploitation rate (E) for *C. pseudomarulius* (0.72) exceeded both E_{max} (0.54) and E_{50} (0.34), indicating severe overfishing. Similarly, *C. striata* faced high fishing pressure, with its exploitation rate (0.63) surpassing E_{max} (0.50).

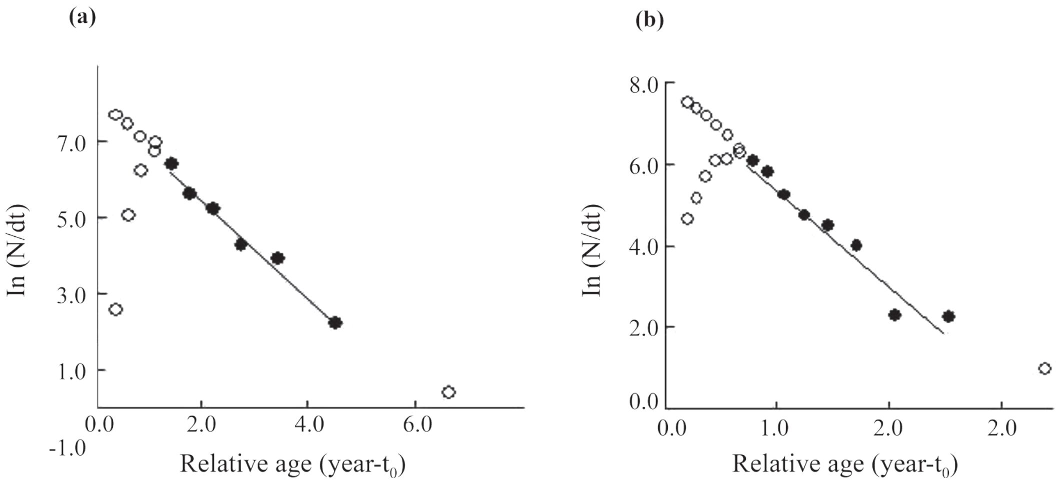

Figure 3. Length-converted catch curves for *Channa striata* (a) and *Channa pseudomarulius* (b) in the Chalakudy River, India.

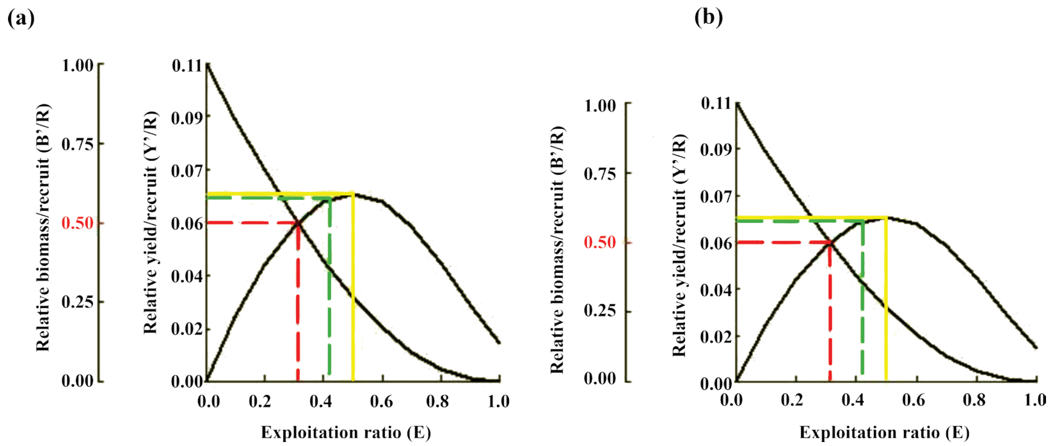

Figure 4. Relative yield-per- recruit (Y/R) and relative biomass- per-recruit (B/R) analysis using knife-edge method *Channa striata* (a) and *Channa pseudomarulius* (b) from the Chalakudy River, India.

Recruitment analysis revealed two peaks for *C. pseudomarulius* and one for *C. striata*, indicating differences in their spawning seasons (Figure 6). Recruitment fluctuated throughout the year, with *C. pseudomarulius*, with peaking in July (25.19%) and reaching its lowest in April (1.93 %), while *C. striata* peaked in February (22.33%) and was lowest in July (1.03%).

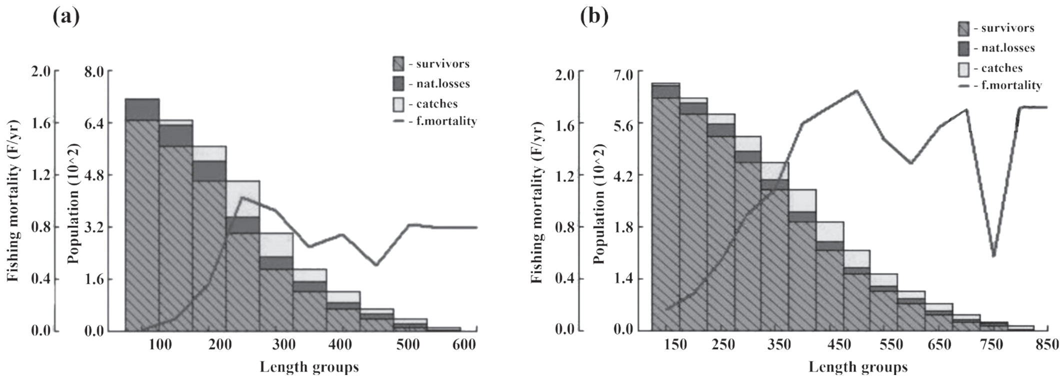

Figure 5. Length converted virtual population analysis (VPA) *Channa striata* (a) and *Channa pseudomarulius* (b) from the Chalakudy River, India.

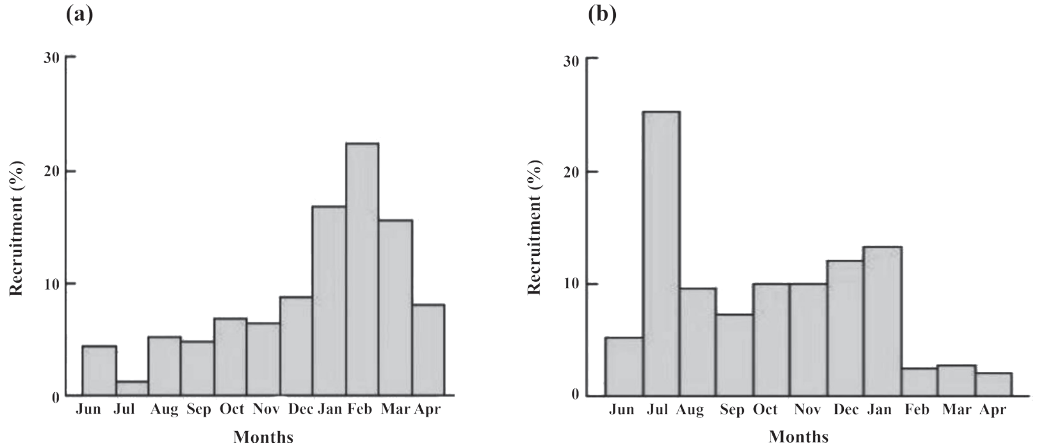

Figure 6. Recruitment pattern of *Channa striata* (a) and *Channa pseudomarulius* (b) from the Chalakudy River, India.

DISCUSSION

In many regions across Asia, inland fisheries lack scientific management due to a lack of awareness among scientists and fishery managers about the capability of stock assessment models, particularly in data-deficient riverine fisheries (Bandara *et al*., 2020; Charernnate *et al*., 2021). The Western Ghats ecoregion of Southern India harbours more than 320 freshwater fish species, nearly 90 of which are exploited through small-scale fisheries (Dahanukar and Raghavan, 2013). This region has witnessed the overexploitation of large-sized food fishes, leading to population declines. Many snakehead species are classified as threatened on the IUCN Red List (Abraham, 2011). The conservation of fish populations harvested through small-scale fisheries presents significant social and biological challenges, especially in riverine ecosystems (Mace and Reynolds, 2001). There is only limited research on the fishery, growth, mortality, and exploitation of coexisting fish species harvested by artisanal fisheries in the Western Ghats regions of India (Shanmughan *et al*., 2022; Roshni and

Renjithkumar, 2023). Snakeheads are an important livelihood source for local fishermen around the rivers of the Western Ghats, contributing 122.46 t to the fish landings from major rivers in Central Kerala Rivers (Renjithkumar, 2015). *C. striata* and *C. pseudomarulius* occur sympatrically, with *C. striata* contributed 67.37 t to the total murrel landings in the riverine system of Kerala (Renjithkumar *et al*., 2011; 2016; 2021a; Renjithkumar, 2015). Fishery catch data from medium-sized rivers in Kerala (Bharathapuzha, Muvatupuzha and Pampa) indicate that the annual exploitation of *C. striata* ranges from 4.60 t and 36.34 t for length groups of 14.4–43.9 cm (Renjithkumar *et al*., 2011; 2016; 2020). Snakehead populations in many rivers of Kerala have declined significantly due to over exploitation, habitat degradation, and disease outbreaks (Kurup, 2000; Renjithkumar *et al*., 2011). The catch data of *C. striata* (3.23 t) in the present study is significantly lower than in other rivers of Kerala (4.60–36.34 t) (Renjithkumar *et al*., 2011; 2016; 2020). Raghavan *et al*. (2008a) reported multiple threats to fish populations in the Chalakudy River, including habitat alteration, unregulated exploitation, water quality deterioration, and the invasion of alien fish species. Although the percentage share of catches between *C. striata* and *C. striata* was not substantially different (57% versus 43%), *C. striata* rarely reaches its reported maximum length of 100 cm (Davidson, 1975) or even its common length of 61 cm (Yamamoto and Tagawa, 2000). In the present study, the largest *C. striata* specimens captured (62 cm) exceeded the recent record of 42.1 cm from the same river (Renjithkumar *et al*., 2021b). The maximum length of a species plays a crucial role in determining its asymptotic length and growth coefficient (Hossain, 2010). The present findings extend the maximum length of *C. pseudomarulius* to 86.1 cm, surpassing the previous record of 57.8 cm from Vembanad Lake, India (Roshni and Renjithkumar, 2020). Length-weight relationships are vital fish stock assessments and population management (Le Cren, 1951; Renjithkumar *et al.*, 2021b). The *b* parameters for *C. striata* and *C. pseudomarulius* were within the acceptable range (2.5–3.5) (Froese, 2006), suggesting negative allometric growth. The ‘b’ value of *C. striata* (2.66) in the Chalakudy River is slightly lower than that of a similar species reported from the riverine stretches of Lake Vembanad (2.73) (Ali *et al*., 2013) and the wetlands of West Bengal, India (3.104 and 3.060) (Chakraborty *et al*., 2017). Roshni and Renjithkumar (2020) reported a b value of 2.90 for *C. pseudomarulius* from Lake Vembanad, which differs from the value obtained in the present study (2.66). Variations in the *b* value can result from differences in habitat, season, specimen number, sex, gonadal maturation, diet, stomach fullness, growth phase, fishing gear and mesh size, fishing methodology and sampling frequency (Froese, 2006; Renjithkumar *et al*., 2021b). The r^2 value of *C. striata* and *C. pseudomarulius* fall within the expected range (>0.90), indicating that the model accurately represents their growth and health status (Hanif *et al*., 2017).

The calculated asymptotic length (L_∞) and growth coefficient (K) of *C. pseudomarulius* were higher than those of *C. striata*, indicating that *C. pseudomarulius* grows faster (Table 1). Slow-growing species are particularly vulnerable to collapse due to climatic variability and harvesting pressure (Pinsky and Byler, 2015). The asymptotic length (L_∞) of *C. striata* is comparable to that of same populations in River Sutlej, Punjab (L_∞ = 63 cm) (Shikha *et al*., 2023). Fahmi *et al*. (2013) reported a high asymptotic length (72.98 cm) and a low *K* value (0.36 $year^{-1}$) for *C. striata* in Lubuk Lampam floodplains, South Sumetra. The overall growth performance index (ϕ) is used to calculate and exhibit minimal variance compared to other alternative parameters (e.g., K, L_∞) (Pauly and Munro, 1984). High growth performance index (ϕ) values the recorded for *C. striata* (5.27) and *C. pseudomarulius* (5.85). The ϕ value for *C. striata* in the present study was higher than that reported for the Sutlej River (3.488) (Shikha *et al*., 2023), possibly due to the species' ability to utilize a wide range of food resources available in the river.

Fish populations decline is driven by natural mortality (M) and fishing mortality (F). In this study, total mortality (Z), natural mortality, and fishing mortality for *C. striata* were 1.26 $year^{-1}$, 0.47 $year^{-1}$, and 0.79 $year^{-1}$, respectively, while for *C. pseudomarulius*, they were 2.37 $year^{-1}$, 0.66 $year^{-1}$, and 1.71 $year^{-1}$, respectively. The exploitation rates (E) were 0.63 for *C. striata* and 0.72 for *C. pseudomarulius*. The higher fishing mortality compared to the natural mortality in *C. striata* and *C. pseudomarulius* suggests that the species are experiencing a significant fishing pressure. Managing mortality rates is crucial for sustainable fisheries. High fishing mortality (1.27 $year^{-1}$) and natural mortality (1.25 $year^{-1}$) for *C. striata* were reported in the Sutlej River (Shikha *et al*., 2023). Fahmi *et al*. (2013) recorded natural and fishing mortalities for *C. striata* in the Lubuk Lampam flood plains at 0.73, and 0.58 $year^{-1}$, while Sofarini *et al*. (2018) observed average natural and fishing mortalities for *C. striata* in Danau Panggang swamp Indonesia as 0.43, and 0.69 per year, respectively, which is close to the present study. A Z/K ratio above 1.0 indicates mortality-dominated populations, while values below 1.0 suggest growth predominance (Etim *et al*., 1999). A Z/K value near 2 suggests light exploitation. The Z/K value in this study (2.73 for *C. striata*, 2.63 for *C. pseudomaruilus*) suggest overfishing, which may lead to recruitment failure and population decline (Raghavan *et al*., 2018). Ideally, fishing mortality should match natural mortality, for an exploitation rate (E) of 0.5 $year^{-1}$ (Gulland, 1970).

The exploitation rate exceeded $E_{0.5}$ and E_{max}, indicating unsustainable exploitation. As a precautionary measure, exploitation should be reduced to the point where the marginal increase in Y/R reaches 1/10 of the marginal increase calculated at a very low exploitation level ($E_{0.1}$). This reference value–0.42 for *C. striata* and 0.46 for *C. pseudomarulius*–serves as a relatively safe target reference point (TRP) for sustainable fishery management. The E value (0.63 and 0.72) for both species exceed $E_{0.1}$ (0.42 and 0.46), indicating that they are experiencing higher exploitation levels than what is sustainable for retaining 10% of their biomass. Therefore, it is imperative to implement management measures to reduce fishing pressure and ensure resource sustainability.

Hasan *et al*. (2021) reported that *C. striata* attains maturity at 21.1 cm in the Pearl River, China; 23.0 cm in Pampanga River, the Philippines; 27.7 cm in the Chi River, Thailand; 29.34 cm in the North Kerian rice agroecosystem, Malaysia. In the present study, the length at first capture (L_c) for *C. striata* was 16.59 cm, indicating the indiscriminate exploitation of immature individuals, which negatively impacts spawning biomass. Capturing immature fish can significantly affect population stability and recruitment (Gwinn *et al*., 2015). To ensure sustainable catches with minimal stock impact, it is advisable to target fish at L_{opt} = 25 cm.

Currently, limited data on the spawning characteristics of *C. striata* and *C. pseudomarulius* in the river hinders the development of effective regulatory frameworks for their management.

Conservation and Management plans

The estimated length at first capture for *C. striata* in the Chalakudy River is 16.59 cm, significantly below its estimated size at first maturity. Additionally, the average annual mean length recorded in the fishery is lower than the optimum length required for sustainable exploitation, indicating a fishery targeting juveniles. The high susceptibility of juvenile to gill net and seine fishing, along with indiscriminate harvesting through dynamiting and electric fishing, poses a serious threat to future yield.

Reducing the current fishing effort and enforcing strict penalties, including bans and imprisonment for unethical fishing practices, would promote sustainable harvesting. Murrels spawn naturally during the southwest monsoon (June-September) (per. ober), making a four-month fishing ban essential during this period.

The fragmented nature of riverine fisheries and the direct household consumption of fish by inland fishers present major challenges to sustainable management of fisheries in the Western Ghats region (Shanmughan *et al*., 2022). Effective management strategies should include limiting the number of fishers entering the fishery and implementing quotas regulation.

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