Assessment of population dynamics of *T. putitora* (Ham, 1822) in the Nayar river basin

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Abstract

The present study analyzed the population characteristics of *Tor putitora* in their breeding and nursery grounds in the Nayar river basin. The growth parameters such as asymptotic length, growth rate and growth performance index were estimated as 80.01 cm, 0.810 per year and 3.71 per year while the potential longevity was estimated as 4.6 years. The mortality parameters such as total, natural and fishing mortality were estimated as 2.88 /year, 1.05/ year and 1.83 / year respectively. The length at 25 %, 50% and 75% susceptibility to capture was estimated as 40.87 cm, 38.11 cm and 35.34 cm respectively. The fishing mortality and exploitation beyond optimum level and maximum sustainable exploitation ratio (Emax) indicate the overly exploitation of Mahseer resources in their breeding and nursery grounds. Currently, the breeding grounds are facing intense growth and recruitment overfishing which may result in stock collapse in the forthcoming years.

Keyword: Mahseer, growth rate, mortality, exploitation, recruitment, overfishing.

Introduction

The *Tor putitora* (Hamilton), commonly known as the Himalayan or Golden Mahseer, is a stenothermal and rheophilic fish species that primarily inhabits cold-water regions within the Himalayan Range. It is an endemic species to this region and has garnered considerable popularity due to its sporty behavior, which has been observed and admired by individuals around the world. It is also considered among one the largest freshwater cyprinids.

The Himalayan Mahseer undergoes a tri-phased migration as a means of sustaining their life-history characteristics, which include food resource management, overwintering/learning

imprints, and spawning. (Nautiyal et al., 2001). This migratory phase is the major concern for the mahseer population as most of them get caught during their journey (Shreshta, 1997). Beside this, the other factors such as blockage of migratory path due to dam and reservoirs, regulated water flow, habitat destruction, pollution are the other major factor that are contributing toward population decline of Mahseer, which is already categorized as endangered species (Jha et al., 2018).

Therefore, in the context of current exploitation and man-made hinderance toward the mahseer population, it is imperative to implement a continuous assessment and monitoring program to ensure the sustainable management of Mahseer resources. In this regard, the present study was conducted to determine the fundamental population parameters and current exploitation status of *T. putitora*. This study aims to provide the necessary information for the sustainable management of Mahseer population in the breeding and nursery grounds of Himalayan Mahseer.

Study Area

The Nayar, which is a tributary of the Ganga that is fed by springs and located approximately 10 kilometers downstream of Devprayag, functions as a breeding and nursery ground for T. putitora stock. The Nayar originates from the Dudhatoli peaks of Pauri Garhwal district in Uttarakhand, where it takes the form of Eastern and Western Nayar (as illustrated in Figure I). Ultimately, these two rivers converge at Batkul ka Sain, thereby forming the primary channel of the Nayar, which eventually merges with the Ganga at Vyasghat. The life cycle of the Himalayan Mahseer is intricately linked with the interdependent tributaries of the Ganga, namely Alaknanda, Bhagirathi, Song, and Nayar, as espoused by Nautiyal et al., (2001). However, it is only the Song and Nayar rivers that are situated close to the Gangetic Mahseer population, which serves as a breeding ground (Nautiyal, 2002) and nurtures juveniles as nurseries through the provision of a bountiful food supply (Nautiyal, 2013). As per the 2013 CPCB report, the Song River is currently encountering an alarming rate of sewage and pollutant load. In contrast, situated approximately 40 kilometers upstream of the foothill Ganga, the Nayar serves as a crucial breeding ground for the Mahseer population, benefiting from comparatively lesser human interventions.

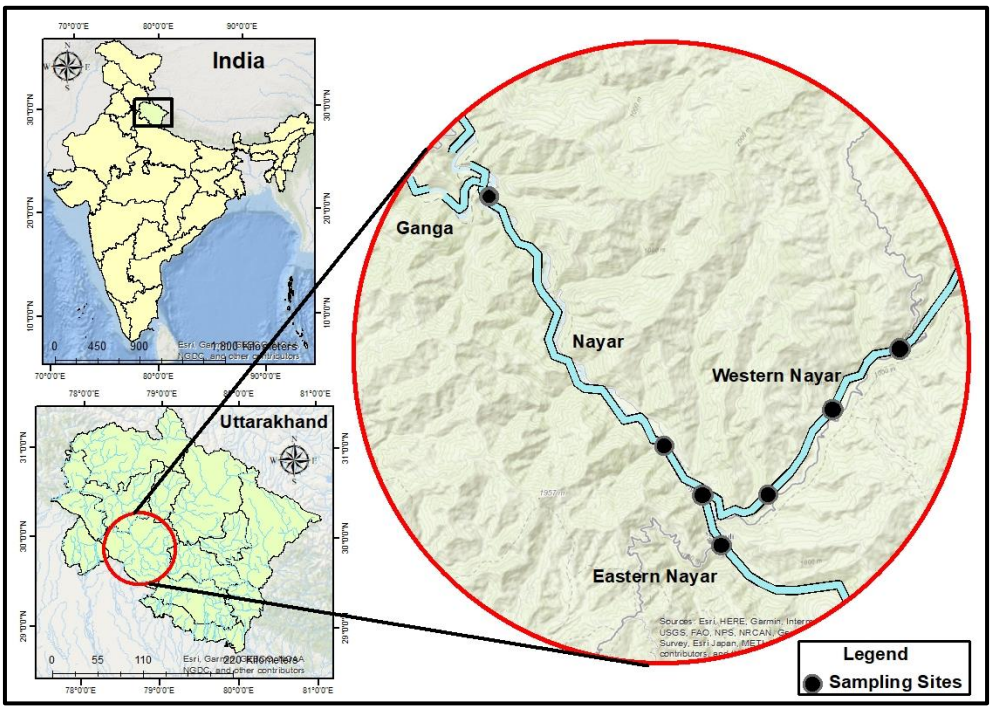

Figure 1. Study area and sampling locations.

Method

The current investigation was implemented over a period of 4 months spanning from July 2022 to October 2022. A careful selection of sampling sites within the Nayar was made, from which fish samples were collected on a weekly basis via local fishermen (Fig I). All T. putitora specimens were thoroughly cleansed utilizing a cotton cloth. Upon retrieval, the total length was measured to the nearest 0.1 cm and the total weight was gauged to the nearest 0.1 gm with the aid of measuring tape and electronic digital balance, correspondingly. The weight of the more sizable specimens was determined utilizing a digital hanging scale with an accuracy of 5 gm.

Size-composition

For the study period, a total of 400 specimens of T. putitora were sampled. The length-frequency data were subsequently grouped into size classes of 10 cm interval. Notably, the examined size classes had the smallest mid-length of 6.2 cm.

Growth and mortality parameters

The present study examines the growth and mortality parameters of T. putitora by analyzing the length frequency data through diverse models in FiSAT II software (FAO-ICLARM stock assessment tool) version 1.2.2. Specifically, the von-Bertalanffy growth parameters (VBGF), comprising of asymptotic length ($L\infty$) and growth rate (K), have been evaluated using ELEFAN II method. The asymptotic length ($L\infty$) represents a theoretical or predicted value that is derived through the predicted growth rate and potential longevity (t_{max}) of the fish within the stock. Theoretical age at zero length (t0) and growth performance index (φ) has been evaluated using the following equations (Pauly, 1984);

$$\text{Log10}\,(-t_0) = -0.392 - 0.275\text{Log10}\,L_\infty - 1.03\text{Log10}K$$

$$\varphi' = \text{Log10}\,K + 2\text{Log10}\,L_\infty$$

While the value of potential longevity (t_{max}) has been calculated using,

$$t_{max} = 3/K + t_0$$

Subsequently, the utilization of FiSAT II software facilitated the execution of the VBGF graph, recruitment patterns, and virtual population analysis. The length-converted catch curve model provided by FiSAT II software was utilized to compute total mortality (Z), natural mortality (M), and fishing mortality (F). The average annual temperature of the designated stretch was recorded at 21.9°C. Annual mortality (A) was calculated using the equation (Ricker, 1975);

$$A = 1 - S, \text{ where, } S = \text{survival rate, } S = e{-}z$$

Probability of capture

The probability of capture for fish susceptible to fishing gears (mostly cast nets) at different lengths was estimated at 25%, 50%, and 75% (i.e., L25, L50, L75). The ascending left component of the length-converted catch curve was used to assess the probability of capture of the fish (Gayanilo et al., 2005).

Exploitation

The exploitation ratio (E) and rate of exploitation (U) of the given stock was calculated using the formula (Pauly, 1984);

$$E = F/Z \text{ and } U = E * A.$$

The exploitation ratio helps to assess whether the stock is under-exploited (E< 0.5) or over-exploited (E> 0.5) in the selected stretch. The exploitation rate is considered optimum when fishing mortality is 40% of the natural mortality i.e., $Fopt = 0.4 * M$ (Pauly, 1984). Relative yield per recruit and relative biomass per recruit were also analyzed using the Knife edge selection of the Beverton and Holt model in the FiSAT II software.

Recruitment pattern

The recruitment stock refers to either the number of fish that enter into the fishing stock or the size of the stock that is being utilized for fishing purposes (Gulland, 1965). The length at first recruitment (Lr) of the observed stock was calculated using the midpoint of the lowest class interval among observed length-frequency samples (Gheshalgi et al. 2012). The annual major and minor recruitment pulses along with their strength were calculated using FiSAT II software.

Results and Discussion

The dimensions of *T. putitora* specimens exhibited a range from 6.2 to 79.8 cm, comprising both resident stock, which measures less than 25 cm (present throughout the year), and seasonal stock of migratory adults and brooders, which measure greater than 25 cm. The majority of individuals constituted the size group ranging from 10-15 cm, succeeded by those in the size groups of 5-10 cm and 15-20 cm, as indicated in Figure II. The size group exceeding 25 cm constituted a relatively lower proportion of the entire cohort since the large-sized brooders migrate for spawning during the initiation of the monsoon season, as stated by Nautiyal et al. (2001).

Growth parameters

The asymptotic length (L_∞) was estimated as 80.01 cm with the growth rate (k) of 0.810 per year while growth performance index (Φ) was calculated as 3.710 per year. The estimated age of the

hatchling (t_0) was calculated as -0.82 per year while potential life-span was calculated as 4.6 years.

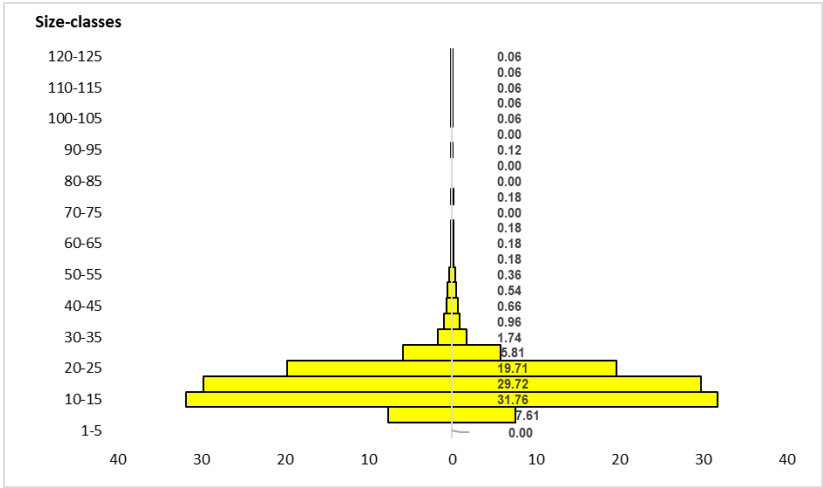

Figure 2 Size composition of *T. putitora* in the Nayar river.

A slow growth rate against the increasing mean length of *T. putitora* has been recorded for the present cohort (Fig. 3). However, continuous growth was observed throughout the year as seasonal growth oscillations were found to be significant and strong (C < 1) indicating influence of seasonality on the growth of the species. The growth of the juveniles was seen continuous throughout the year while during May growth gets reduced but still continuous and reaches to its maximum in November.

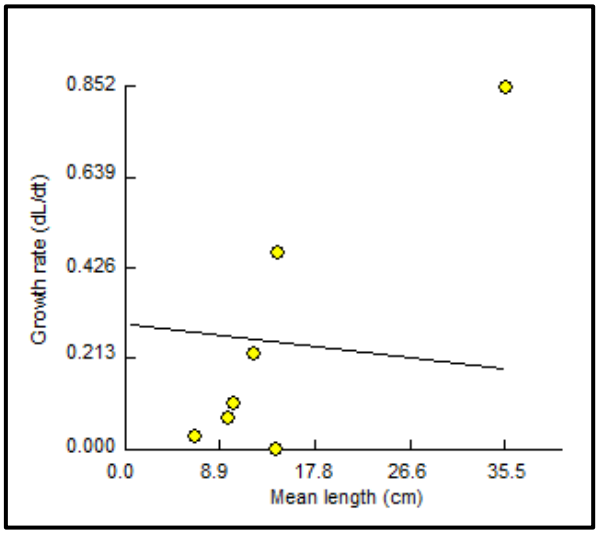

Figure 3. Gulland and Holland plot for growth rate determination against the mean length**.**

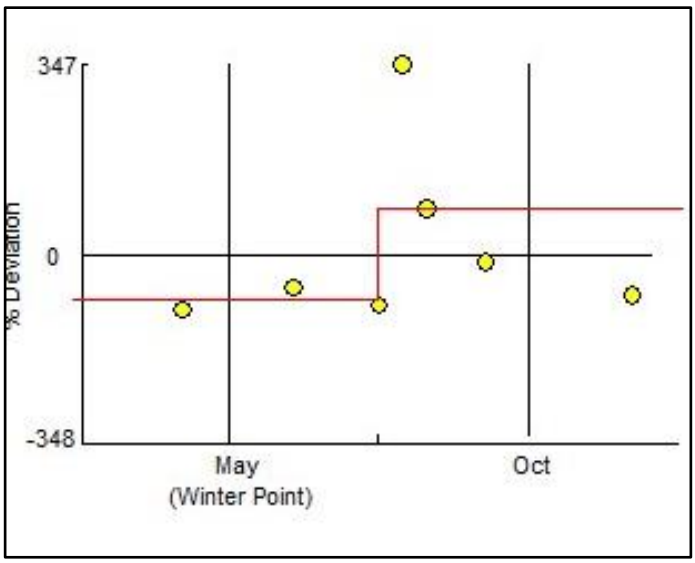

Figure 4. Seasonal growth oscillations of *T. putitora*.

Mortality parameters

The total mortality (Z) was estimated as 2.88 where, natural mortality accounted about 1.05 and that for fishing mortality was 1.83 (Fig. 5). The survival rate (S) was estimated as 0.05 while that of annual mortality (A) was estimated as 0.94. Here, the optimum fishing mortality was estimated at 0.42 while exploitation ratio was estimated as 0.64. Therefore, the exploitation ratio and fishing mortality has surpassed the optimum level.

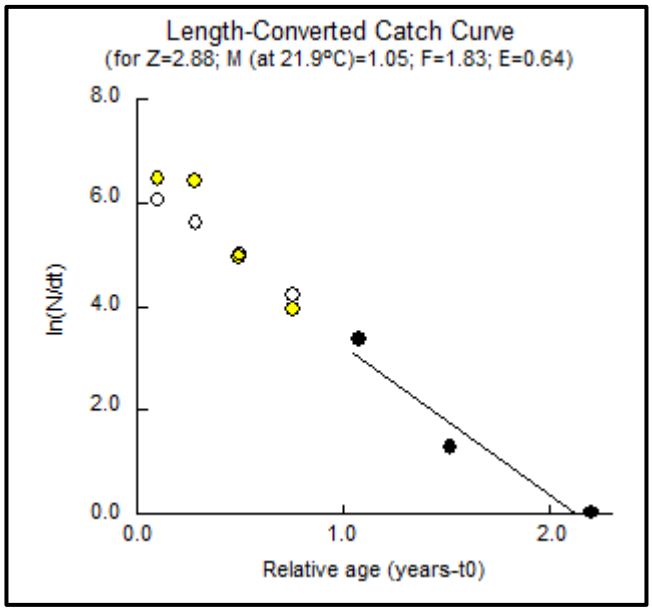

Figure 5. Mortality parameters of *T. putitora*.

Probability of capture

The probability of capture extrapolated curve depicts that fishes measuring less than 16.20 cm are highly susceptible to being captured, as shown in Figure 6. However, in the current cohort, fishes measuring 10-15 cm constituted 30.98 5 % of the total catch, whereas those measuring 15-20 cm constituted 27. 98 %. Therefore, the fishes measuring below 20 cm formed about 65.4 % of the total catch.

The graph of probability of capture estimated L_{25}, L_{50} and L_{75} as 40.87 cm, 38.11 cm and 35.34 cm respectively (Fig. 6). However, half of the mahseer population attain maturity at the length of 52 cm while at 88 cm the whole population become mature (Nautiyal, 1985). This indicate that the most of the individuals of Mahseer get caught even before attaining the sexual maturity.

The virtual population analysis of have shown high fishing mortality of juveniles measuring between 16.2 to 26.1cm. However, another peak was observed in the size group measuring above 66.2 cm. This larger size group mainly form the spawning biomass in the Nayar river as they migrate toward their breeding grounds solely for the purpose of spawning. However, the act of fishing of juveniles (sexually mature) and adults (brooders) is essentially governing the phenomenon of “growth and recruitment overfishing”.

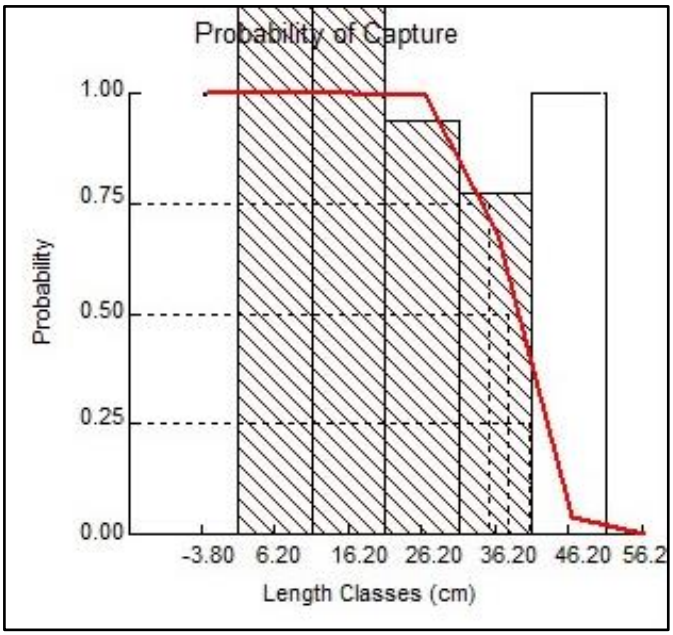

Figure 6. Probability of capture at different 25%, 50% and 75% susceptibility level.

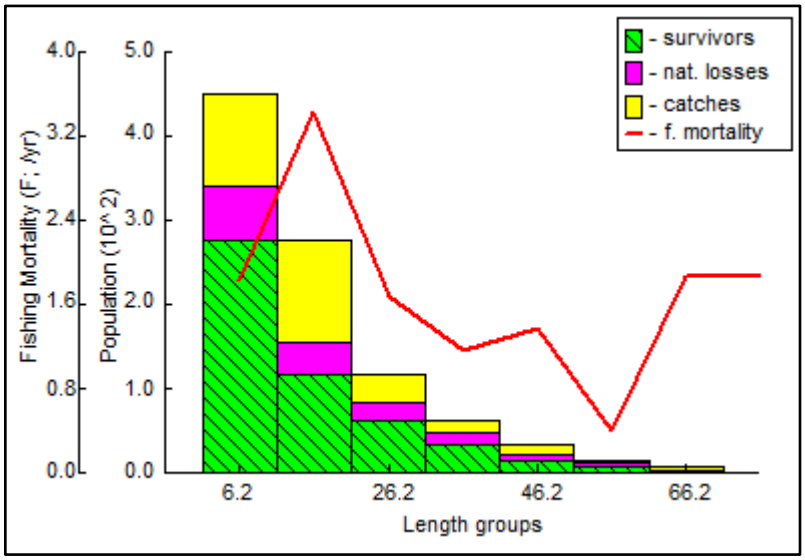

Figure 7. Virtual population analysis (VPA) of *T. putitora.*

Exploitation

The depletion of juvenile and migratory cohorts, including those with potential for breeding, is a significant contributor to the reduction of the Mahseer population in the Indian subcontinent (Bhatt and Pandit, 2016). In addition to *T. putitora*, other species of Tor, such as *T. tor*, *T. duronensis*, and *T. tambroides*, are also at high risk of overexploitation (Ngguyen et al., 2007). In order to achieve optimal exploitation of the fish cohort, fishing mortality rates should not exceed 40% of natural mortality (i.e., F_{opt} = 0.4M), which would result in an optimal exploitation rate of 0.5/year.

The graph of relative yield or biomass per recruit has estimated E_{10}, E_{50} and E_{max}. as 0.355, 0.278 and 0.421 respectively. The predicted Emax therefore, found below the current exploitation ration which further indicate the overexploitation of *T. putitora* stock.

The relationship between the relative yield per recruit and biomass per recruit with exploitation ratio for both studied years is depicted by the Beverton and Holt plot. The input parameters, namely Lc / L∞ and M/K ratio, were estimated as 0.47, 1.2 respectively. As the Lc / L∞ ratio is less than 0.5, it signifies that juveniles constitute the major portion of the fishing cohort (Pauly and Munro, 1984), which is also reflected in the virtual population analysis.

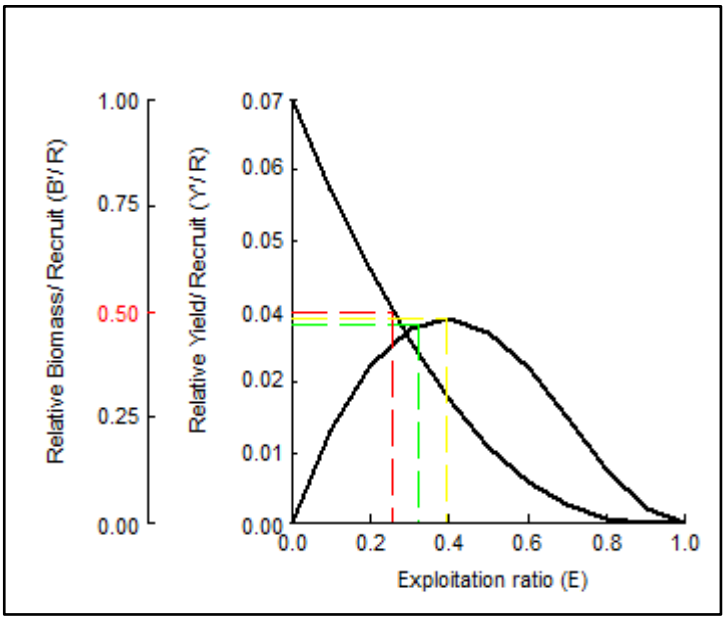

Figure 8. Relative yield or biomass per recruit analysis of *T. putitora*.

Recruitment

The initial recruitment length Himalayan Mahseer was determined as 11.15 cm. This indicates an increase in the minimum length of the fish being exploited for fishing purposes. The recruitment process was observed to occur consistently throughout the year, demonstrating an efficient and effective recruitment cycle (Amponsah et al., 2016). The graph of recruitment has shown major recruitment pulses in January with 24.23% followed by February with 22.39 % (Fig. 8).

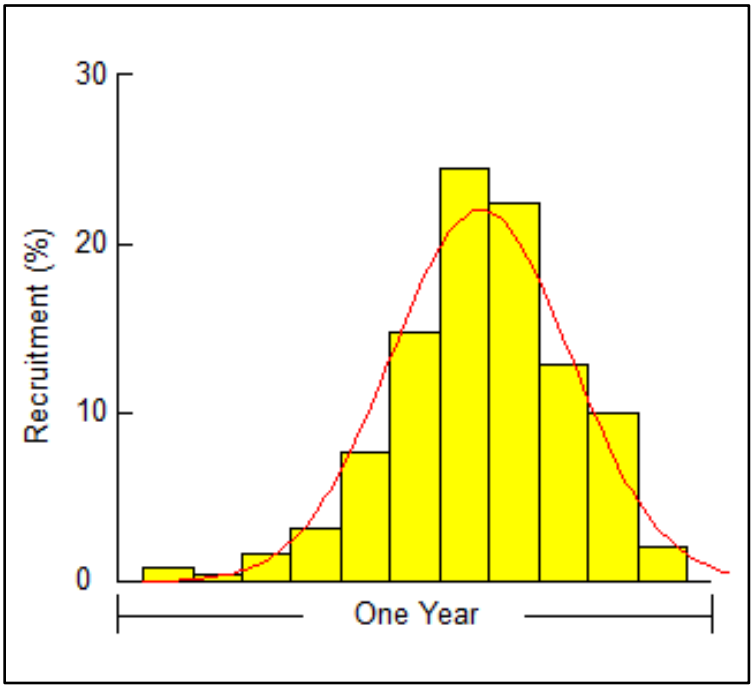

Figure 9. Recruitment pattern of *T. putitora* in the Nayar.

Conclusion

The current classification of the Himalayan Mahseer as endangered by IUCN (2018) is a result of increasing habitat degradation owing to river management, hydro project construction, mining and quarrying activities, the discharge of pollutants, and rampant poaching. Consequently, the objective of the research was to comprehend the evolving growth parameters of the Himalayan Mahseer in the Nayar's breeding and nursery grounds. The fundamental aim of managing fisheries is to ensure sustainable production over an extended period of time, primarily through regulatory and enhancement measures. The current study provides comprehensive information on the status of the Himalayan Mahseer, *T. putitora* in the Nayar river valley basin. The overexploitation of juveniles before attaining sexual maturity is a major concern for the dwindling population of endangered Himalayan Mahseer. Other than reducing the population size, the overexploitation could also affect the reproductive potential of the mahseer by intensive growth and recruitment overfishing. Therefore, In order to enhance the current stock status and maintain the stock of *T. putitora* in the breeding and nursery grounds of the Nayar, it is recommended that fishing effort be reduced and trawl cod end mesh size be increased.

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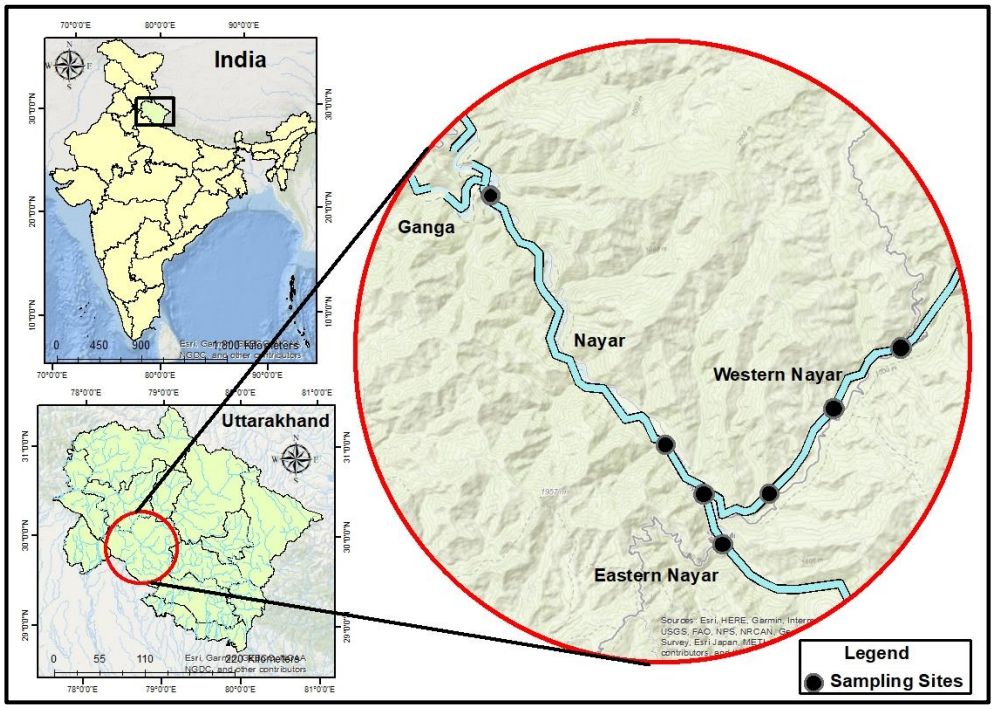

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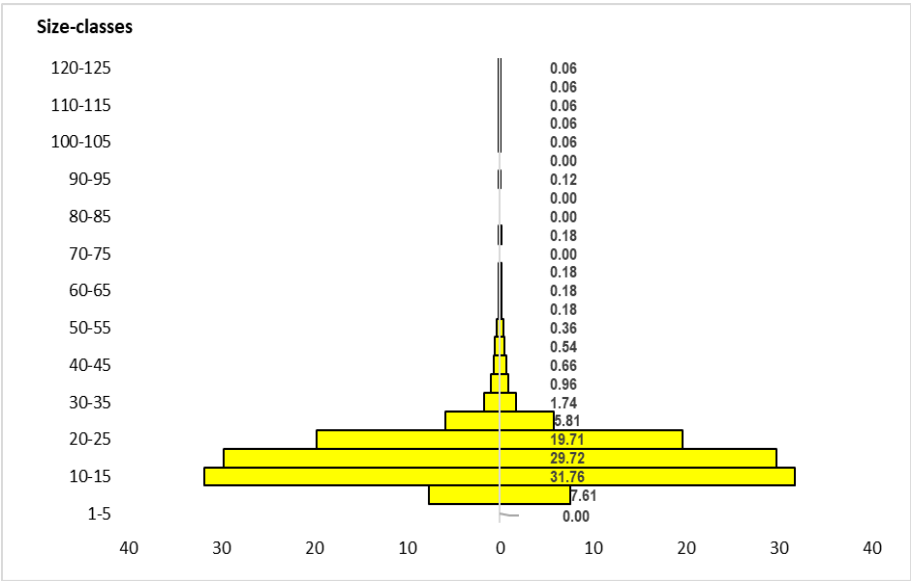

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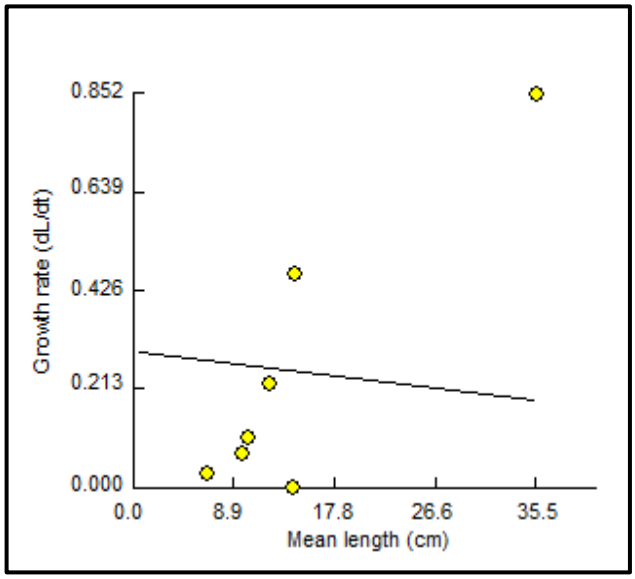

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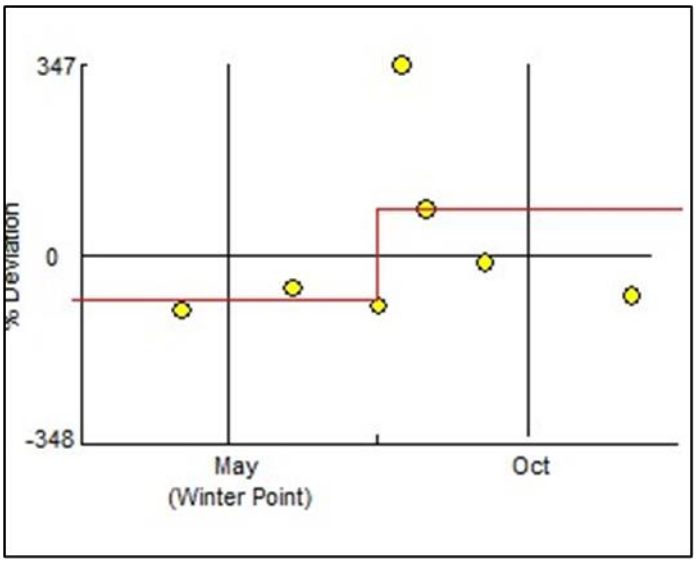

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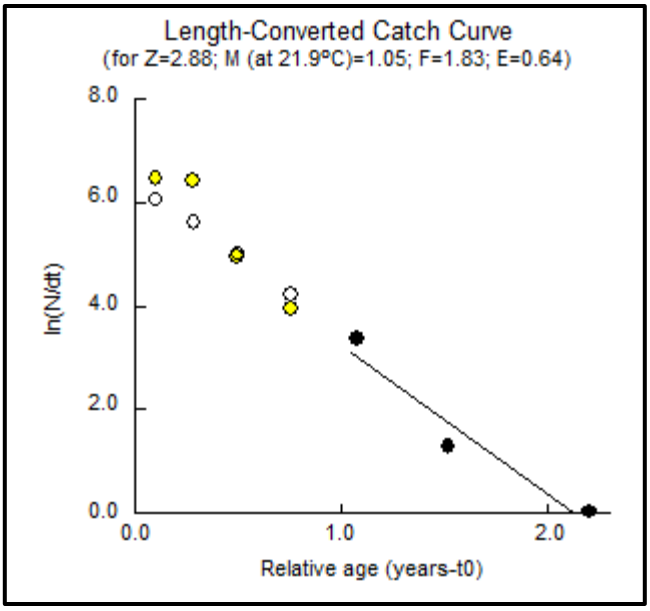

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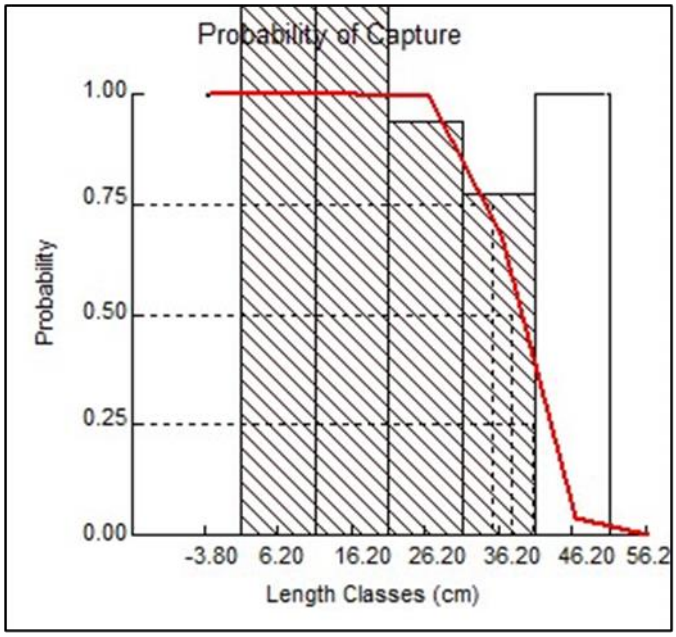

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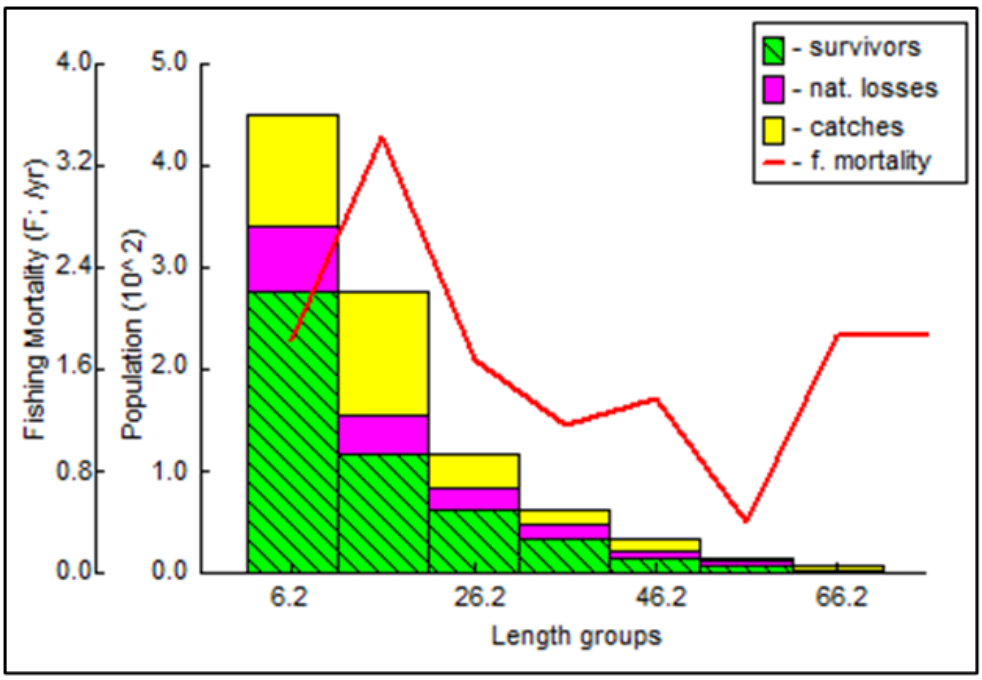

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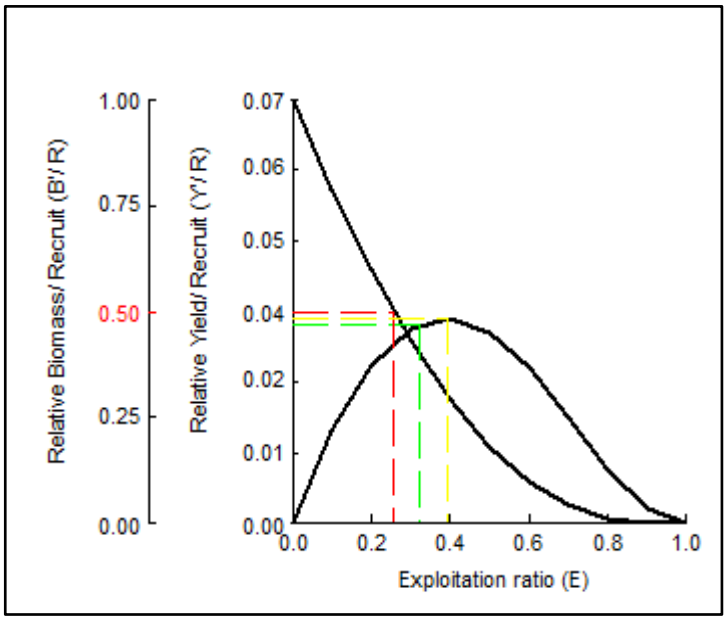

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