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Original Article

Stock assessment of rosy barb, *Pethia conchonius* (Hamilton, 1822) in Dal Lake of Kashmir Himalayas

Sinan Nissar[1] • Yahya Bakhtiyar[1] • Tabasum Yousuf[1] • Abrar Ahmad Bhat[1] • Sofi Mohammad Zuber[2]

[1] *Fish Biology and Limnology Research Laboratory, Department of Zoology, University of Kashmir, Srinagar 190006, Jammu and Kashmir, India*
[2] *Department of Zoology, Govt. Degree College Bijbehara, Anantnag 192124, Jammu and Kashmir, India*

Correspondence
Yahya Bakhtiyar; Fish Biology and Limnology Research Laboratory, Department of Zoology, University of Kashmir, Srinagar 190006, Jammu and Kashmir, India
yahya.bakhtiyar@gmail.com

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Abstract
For management of fish stocks, assessing the various parameters of population dynamics are regarded as being extremely important. Under this backdrop the population dynamics parameters *viz*. growth, mortality and recruitment of *Pethia conchonius*, inhabiting the Dal Lake of Kashmir Himalayas were analysed using FiSAT II software. The analysed specimens were collected from five different sites within the lake and exhibited a total weight range of 0.3 to 6.4 g and a total length range of 3.1 to 7.8 cm. The relative condition factor for the fish was reported to be 1.11. The growth parameter *i.e.,* asymptotic length, age at zero length, growth performance index and growth constant were reported to be 10.0 cm, –0.75 years, 1.48 and 0.30 year^{-1} respectively. The total mortality of 1.49 year^{-1}, consisting of natural mortality of 0.88 year^{-1} and fishing mortality of 0.61 year^{-1} was reported. An exploitation rate of 0.41 is suggestive of a less exploited state of the fish. The length at first maturity was found to be higher than the length at first capture, a condition that can disturb the stock, as such the utility of a net with relatively larger mesh size is advisable. The current research on the population dynamics of *P. conchonius* can be used as the baseline data for its management practices.

Keywords: condition factor; Dal Lake, FiSAT-II; length-weight relationship; LWR

1 | INTRODUCTION

Pethia conchonius (Hamilton, 1822), commonly known as rosy barb and locally known as Bloz in Kashmir, is a freshwater fish of Cyprinidae family and is deemed as one of the hardiest barbs (Froese and Pauly 2024). The fish has a silver body with a characteristic black dot on the caudal part. Albeit sexual dimorphism is not prominent, however, a dramatic change in colour during the breeding season occurs when the male portrays a claret abdominal portion and the scales of the female possess an enhanced sheen. *Cyprinus carpio* (Common carp) was introduced in Kashmir around 1955 – 1956 and it is likely that *P. conchonius* may have been accidentally introduced at the same time (Kullander *et al.* 1999). The fish has been reported from multiple water bodies of Kashmir, including the world-famous Dal Lake.

Dal lake, the second-largest lake of the Kashmir valley and widely regarded as the most pristine location on earth, is one of the most valued Himalayan water features (Lawrence 1895). The ecological alterations taking place within the lake (shrinkage of the area from 75 km^2 to 10.5 km^2) (Jeelani and Shah 2006; Qadri and Yousuf 2008; Khan *et al.* 2012; Rashid *et al.* 2017) complemented with the intensive exploitation of the fish fauna, have collec-

tively altered the population of various fish species inhabiting the lake. This has led to plummeting catches from the lake which mandates a timely assessment of the fish fauna of the lake to provide status on the exploitation intensity of fish stocks so that appropriate measures can be taken for sustainable management of the stock and to avoid over-exploitation.

Pethia conchonius is primarily considered a non-food fish, often captured for its utility as bait to ensnare larger fish, which has consequently led to a dearth of research on this species. Nonetheless, its potential in the ornamental fish industry has garnered some scholarly attention, primarily focusing on morphometric studies, length-weight relationship and condition factor analysis (Mir and Mir 2012; Shafi and Yousuf 2012; Saroniya *et al.* 2013; Bhat *et al.* 2022; Yousuf *et al.* 2023). However, comprehensive data on the various aspects of the population dynamics of *P. conchonius* remain notably scarce, with only a solitary study by Mitra *et al.* (2011) on the river Ganga providing a complete account.

Population dynamics studies facilitate the assessment of a fish stock by analysing three main parameters of a population *i.e.*, growth, recruitment and mortality (Vivekanandan 2005; Kilduf 2009). The utility of hard parts for growth assessment faces multiple constraints (especially the sophistication of equipment and time consumption) making length frequency analysis methods a widely used approach to assess age and growth in fishes (Pauly 1984; Kindong *et al.* 2018). This has eventually led to the development of various computer programs like the one developed by Fournier *et al.* (1990) *i.e.*, the MULTIFAN and the other developed by Gayanilo Jr and Pauly (1997) *i.e.*, the FiSAT, both utilizing the length frequency data to assess various population parameters of a fish stock.

Given the scarcity of research on this species, particularly concerning studies on population dynamics, the present study was initiated to assess the growth, recruitment, exploitation, and mortality rates of *P. conchonius* from Dal Lake.

2 | METHODOLOGY

2.1 Study area and location of study sites

The Dal Lake is an urban lake located in the Hazratbal area of Srinagar within the geographical coordinates of 34°04′ – 34°11′N, 74°48′ – 74°53′E (Figure 1). The lake is the second largest lake of the valley with an open water area of 10.5 km^2 that offers remunerative fishery resources and livelihood to thousands of households living in its vicinity. The major food fishes of the lake are: *Cyprinus carpio*, *Schizothorax* sp., *Carassius carassius* and the major forage fishes of the lake are: *Gambusia holbrooki*, *Pethia conchonius* and *Crossocheilus diplochilus* (Bhat *et al.* 2022).

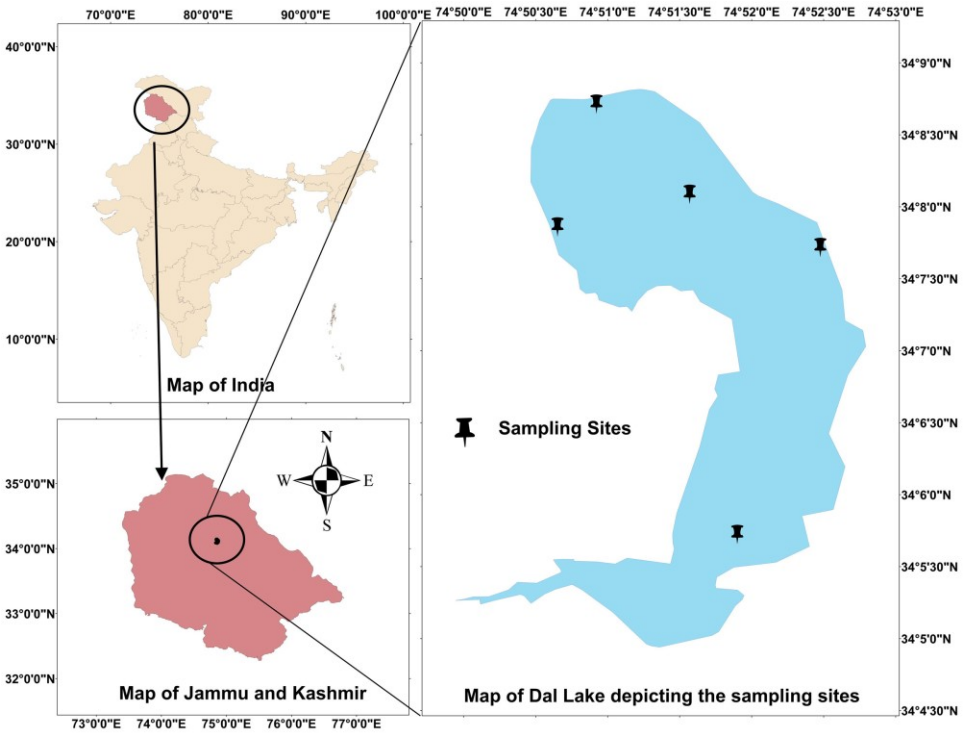

FIGURE 1 Map of Dal Lake in Jammu and Kashmir of India showing the sampling sites.

2.2 Sampling Setup

During the present study, a total of 530 fish specimens were collected using local fishermen. The fish sampling was carried out for a period of 2 years (October 2021 to September 2023) during morning hours (08:00 am to 11:00 am) from five different locations within the lake.

The use of smaller mesh-sized cast nets (locally known as Guran Zaal), with a mesh size of 10 mm, facilitated the capture of smaller-sized fishes (forage fishes and younger ones of food fishes). The fishes were kept alive, bought to the laboratory and sorted based on the keys provided by Kullander *et al.* (1999). The biometric analysis was carried out using Vernier caliper, Aero Space, China for length measurement to the nearest 0.1 cm and Sartorius GM 312 for weight measurement to the nearest 0.01 g.

2.3 Analysing the biometric data

2.3.1 Length-weight relationship (LWR)

The equation provided by Le Cren (1951) was used to assess the LWRs of the fish

$$W = aL^b$$

Where W denotes the total weight of the fish, L denotes the total length of the fish, *b* represents the slope and *a* represents the intercept of the length vs weight graph.

2.3.2 Relative condition factor (K_n)

In order to avoid some drawback of the Fulton condition factor, the relative condition factor was introduced by Le Cren (1951). It is the ratio of observed weight to that of calculated weight and is provided below

$$K_n = \frac{W}{aL^b}$$

2.3.3 Growth parameters and mortality

The two major growth parameters *i.e.*, asymptotic length (L_∞) and growth constant (K) were computed using the FiSAT II software (ELEFAN-I module) (Gayanilo *et al.* 1995), utilizing the equation given below

$$L_t = L_\infty [1\text{-}e^{-K(t-t_0)}]$$

The value of the age at zero length (t_0) was determined utilizing the equation provided by Pauly (1979), *i.e.*,

$$\text{Log}(-t_0) = -0.392 - 0.275\text{Log}L_\infty - 1.038\text{LogK}$$

The growth performance index (Ø) was determined using the equation given by Pauly and Munro (1984), *i.e.*,

$$Ø = \text{Log K} + 2\text{Log}L_\infty$$

The natural mortality (M) was calculated using FiSAT II, utilizing the equation given by Pauly (1980), *i.e.*,

$$\text{Log M} = -0.0152 - 0.279\text{log}\, L_\infty + 0.6543 \log \text{K} + 0.463 \log \text{T}$$

Where K represents the growth constant, L_∞ is the asymptotic length and T is the mean temperature of the water body.

The length-converted catch curve was used to determine the fishing mortality (F) and total mortality (Z) as per Pauly (1983). The exploitation ratio (E) was computed using the equation provided by Beverton and Holt (1957) and Ricker (1975) *i.e.*,

$$E = F / Z$$

2.3.4 Recruitment pattern, virtual population analysis, Beverton and Holt analysis

The monthly recruitment pattern of the fish was computed using the FiSAT II software as per Dadzie *et al.* (2007). Using the growth coefficients of the LWR equation, growth and mortality parameters, the virtual population analysis (VPA) was carried out as per Gayanilo *et al.* (2005). The knife edge module of FiSAT II was used for the Beverton and Holt analysis to plot the yield and biomass/recruit against the rate of exploitation (Beverton and Holt 1966; Pauly and Soriano 1986).

2.3.5 Length at first maturity

The length at first maturity (L_m) describes the length at which 50% population attains reproductive maturity. In order to determine L_m, the frequencies of occurrence of adult mature specimens were plotted against length class and fitted to a logistic function.

3 | RESULTS

3.1 Length-weight relationship and condition factor

During the study period, *P. conchonius* showed a minimum length of 3.1 cm and a maximum length of 7.8 cm. The total weight fluctuated between a minimum of 0.3 g and a maximum of 6.4 g. The fishes within the length group of 4.5 to 7.0 cm were found to be most abundant in the catch. The value of "a" (intercept) and "b" (slope) of the length-weight relationship equation were reported to be 0.0053 and 3.5 respectively (Figure 2). The relative condition factor (K_n) was reported to be 1.11.

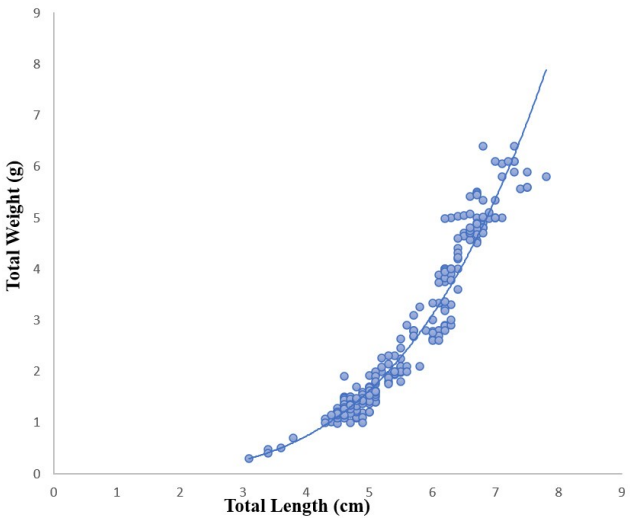

FIGURE 2 Scatter diagram of length-weight relationship of *Pethia conchonius* from Dal Lake of India.

3.2 Growth parameters

The growth constant (K) was reported to be 0.30 year^{-1} and the asymptotic length (L_∞) was reported to be 10.0 cm. The von Bertalanffy growth curve and the length-frequency histograms are presented in Figure 3. The growth performance index of the *P. conchonius* was reported to be 1.48 and the age at zero length (t_0) was reported to be -0.75 years.

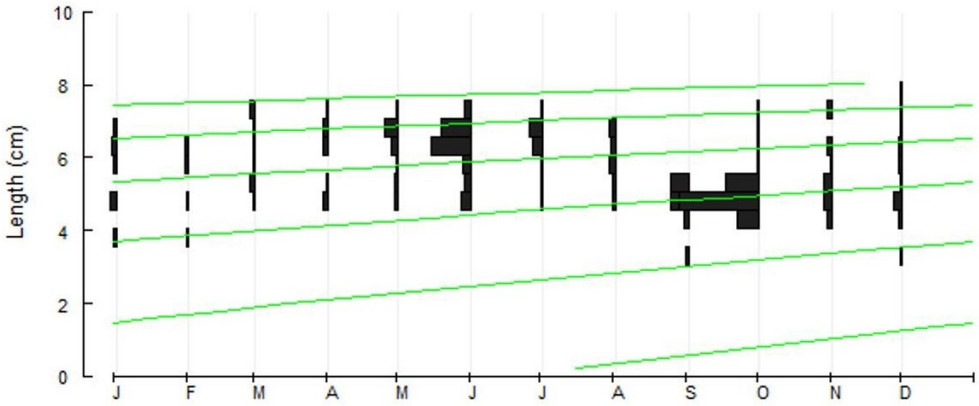

FIGURE 3 von Bertalanffy growth curve of *Pethia conchonius* from Dal Lake of India.

3.3 Mortality and rate of exploitation

The mortality parameters *i.e.*, the total mortality, the fishing mortality, the natural mortality and the exploitation ratio for *P. conchonius* were reported to be 1.49 year^{-1}, 0.61 year^{-1}, 0.88 year^{-1} and 0.41 respectively (Figure 4).

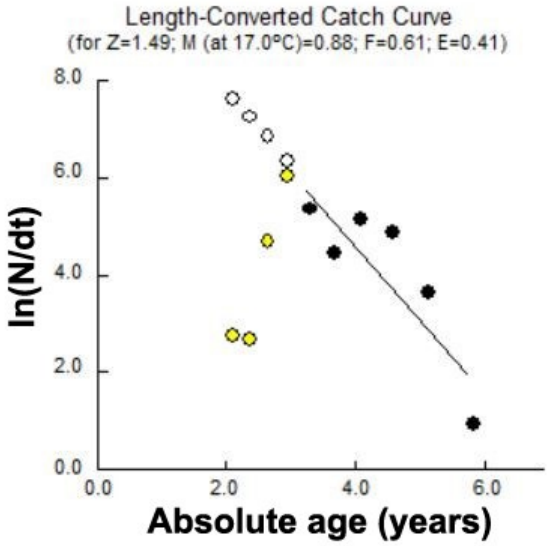

FIGURE 4 Length-converted catch curve of *Pethia conchonius* from Dal Lake in India.

3.4 Recruitment, virtual population analysis, Beverton and Holt analysis

Pethia conchonius from Dal Lake shows recruitment peaks for spring and summer month (April to July), contributing approximately 80% to the total recruitment (Figure 5). The fishing mortality shows a drastic increase beyond the 5.6 cm length as revealed by VPA (Figure 6). The yield per recruit plot of Beverton and Holt estimated the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit ($E_{0.5}$) value of 0.37, exploitation rate producing maximum yield (E_{max}) to be 0.90 and exploitation rate at which the marginal increase in relative yield per recruit is 10% ($E_{0.1}$) to be 0.76 (Figure 7). For *P. conchonius*, the length at first capture (L_C) was reported to be 4.69 cm.

3.5 Length at first maturity

The frequency of occurrence of adult female specimens was plotted against length class and fitted to a logistic function to determine the mean fish length at first sexual maturity (L_m). In case of *P. conchonius* the length at first sexual maturity was reported to be 6.2 cm for females (Figure 8). The various biometric and population parameters of *P. conchonius* are depicted in Figure 9.

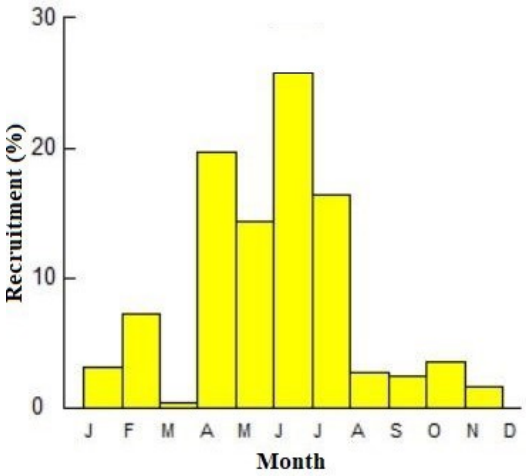

FIGURE 5 Recruitment patterns of *Pethia conchonius* from Dal Lake in India.

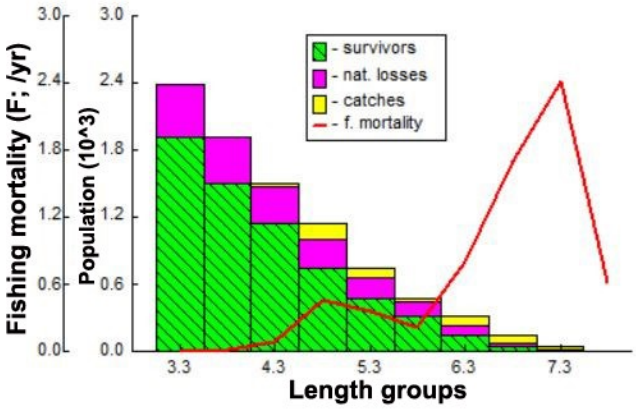

FIGURE 6 Virtual population analysis of *Pethia conchonius* from Dal Lake in India.

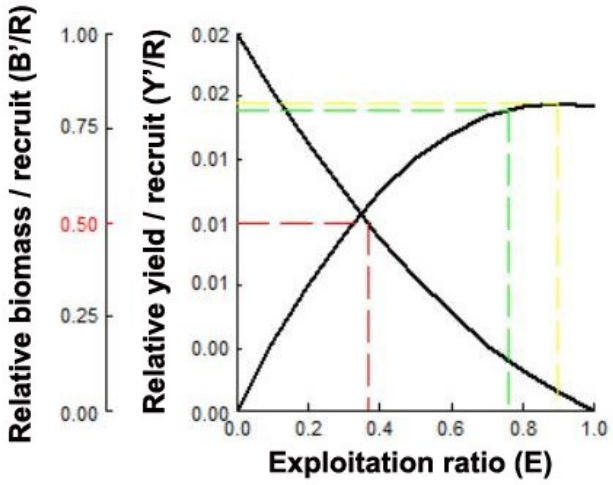

FIGURE 7 Beverton and Holt analysis curve for *Pethia conchonius* from Dal Lake in India.

4 | DISCUSSION

The growth pattern of a fish population, exploitation intensity, recruitment potential, and mortality happen to be the most vital factors in fish population dynamics. Utilising the length-frequency data, the current study provides inferences on the population of *P. conchonius* in Dal Lake. The species, albeit not having the status of a food fish shows strong potential as an ornamental fish as such the study of the various aspects of its population tends to be imperative, which forms the backdrop for the current research problem.

4.1 Length-weight relationship and condition factor

Length-weight relationship (LWR) is a fundamental concept in fish population studies that facilitates the estimation of the weight of a species using its length data and vice versa. This vital bioecological tool yields data on the general condition of a fish population and has practical applications in fisheries management and assessment of stocks (Ricker 1975; Arafat and Bakhtiyar 2022). Analysing the length and weight data of *P. conchonius* from Dal Lake revealed that the fish exhibited a length range of 3.1 to 7.8 cm and a weight range of 0.3 to 6.4 g. The value of LWR growth coefficient "b" was found to be 3.5 indicating positive allometric growth.

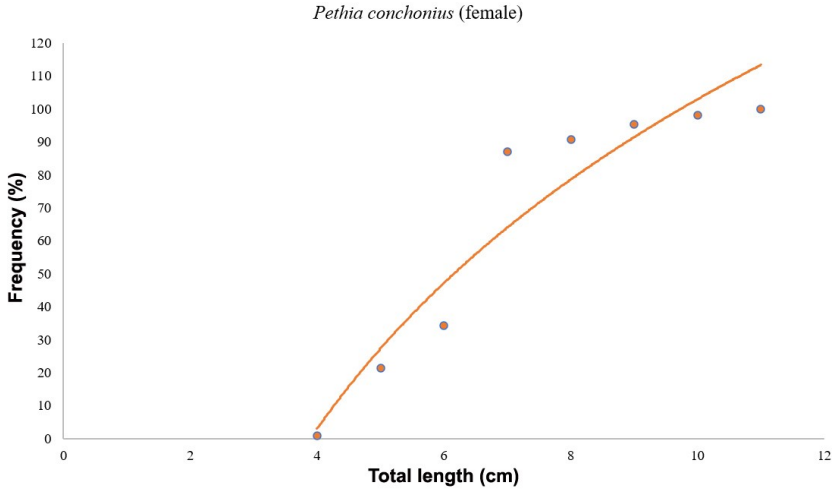

FIGURE 8 Graph showing length at first maturity in *Pethia conchonius* from Dal Lake in India.

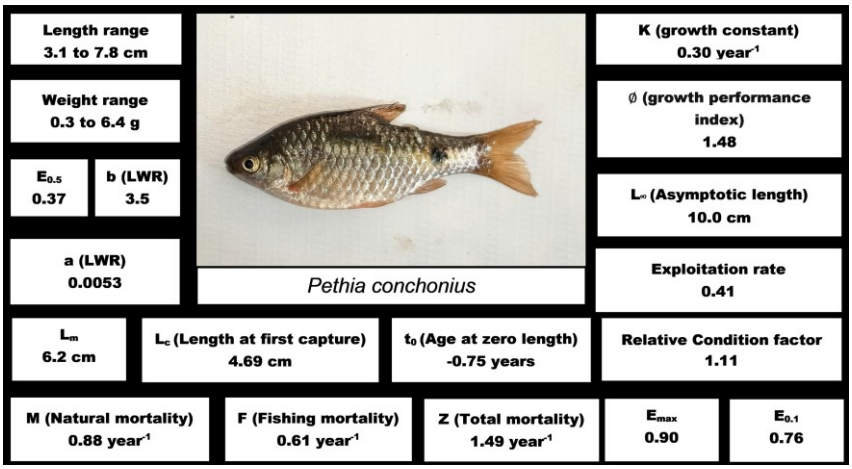

FIGURE 9 Population parameters of *Pethia conchonius* from Dal Lake in India.

The relative condition factor reported during the current study was 1.11. Fishes showing good growth condition show a relative condition factor ≥ 1 whereas the fishes with a poor growth condition show relative condition factor <1. Similar results were reported by Bhat *et al.* (2022) while studying the LWRs of fish species of Dal Lake, reporting a length range of 3.5 to 7.0 cm, a weight range of 0.6 to 6.2 g, *b* value of 3.55 and a Fulton condition factor of 1.64 ± 0.34 in *P. conchonius* from Dal Lake. Shafi and Yousuf (2012) reported a length range of 3.8 to 8.4 cm, a weight range of 1.42 to 10.7 g, *b* value of 2.94 and a Fulton condition factor range of 1.49 to 1.96 in the *P. conchonius* of Dal Lake. Saroniya *et al.* (2013) while studying the morphometric characteristics of *P. conchonius* of Pahuj River, Madhya Pradesh, reported a length range of 5.6 to 10.0 cm. Yousuf *et al.* (2023) reported *P. conchonius* from Manasbal Lake exhibiting a length of 5.54 ± 0.14 cm, a weight of 3.45 ± 0.33 g, *b* value of 3.07 and Fulton condition factor of 1.63 ± 0.03. Mir and Mir (2012) studied the LWRs of *P. conchonius* from River Jhelum and reported a length range of 1.55 to 11.65 cm, *b* value of 2.56 to 2.86 and a Fulton condition factor of 0.57 to 0.98. Morphometric analysis serves as a valuable tool for researchers to investigate how fish body shape develops across various ecosystems. By measuring size and shape quantitatively, morphometric characters can distinguish between different fish populations. These variations may arise from diverse influences, such as habitat type, gene flow, sampling approach, ecological and environmental factors (Baker and Foster 2002; Mullen *et al.* 2009; Chikwana *et al.* 2023; Nissar *et al.* 2024).

4.2 Growth parameters

The asymptotic length was reported to be 10.0 cm and happens to be a vital factor for demarcating the mesh size limits of fishing gears (Gebremedhin *et al.* 2021). The von Bertalanffy curvature parameter (growth constant) for *P. conchonius* of Dal Lake was reported to be 0.30 year^{-1}, indicative of a moderate growth rate as per Sparre and Venema (1998). The size distribution of a fish stock can be altered by various external factors, especially the fishing technique and the ambient temperature (Tu *et al.* 2018). These factors alongside the data models utilized can eventually alter the growth rates and asymptotic lengths of a stock (Etim *et al.* 1998). Mitra *et al.* (2011) analysed the population status of *P. conchonius* from Ganga River basin and reported a faster rate of growth (K = 0.71 year^{-1}) than the current study, attributed to tropical condition of River Ganga. Fish growth in temperate waters is often constrained by lower temperatures. Consequently, it's not surprising that species capable of thriving in both temperate and tropical waters exhibit the highest growth rates in the warmer tropical regions (Lowe-McConnell 1987; Henderson 2005).

4.3 Mortality and rate of exploitation

The natural mortality was found to be higher than the fishing mortality for *P. conchonius* in Dal Lake, indicative of less exploitation of the fish from the lake, since it is not a food fish and the exploitation ratio of 0.41 is indicative of the same. The value of K is associated with the longevity of a fish species which in turn is related to mortality (Beverton and Holt 1959; Saville 1977). If the natural mortality of a slow-growing fish species is high, it could go extinct (Sparre and Venema 1998). Mortality and growth rates are connected, with natural mortality showing direct dependence on K and an inverse dependence on asymptotic length (Sparre and Venema 1998), besides the growth rates also influence the susceptibility of a fish to fishing or predation (Pauly 1984; Allen and Hightower 2010). Mitra *et al.* (2011) reported similar fishing mortality in *P. conchonius* from River Ganga primarily due to non-food utility of the fish within both the water bodies. However, the higher total and natural mortality of *P. conchonius* in River Ganga as compared to Dal Lake is attributable to the higher competition (more diversity in Ganga than Dal Lake) and higher pollution load in the former (Bhat *et al.* 2022; Das *et al.* 2023).

4.4 Recruitment, virtual population analysis, Beverton and Holt analysis

The addition of new individuals to a harvestable stock is denoted by recruitment and happens to be a strong driver of the fish population (Camp *et al.* 2020). *Pethia conchonius* showed recruitment peaks during spring and summer months (April to July), contributing approximately 80% to the total recruitment and coinciding with an increase in the temperature whereas winter months showed the lowest recruitment given a decrease in the temperature (Kindong *et al*. 2018). The availability of food and favourable weather conditions are the primary factors that could influence recruitment in fish (Shoji *et al.* 2011; Okamoto *et al.* 2012; Tableau *et al.* 2015; Gebrekiros 2016; Kripa 2017).

Virtual population analysis gives insight into the survivor proportion and the losses incurred due to natural mortality and fishing by plotting various length groups against fishing mortality. During the current research work the number of survivors and natural losses decreased with increasing size, the mortality due to fishing escalated beyond the length of 5.6 cm and the fish catch was highest in the length groups of 4.6 to 5.5 and 6.1 to 7.0 cm. Similar results have been obtained by Mohamed (2022) for *Tenualosa Ilisha*, wherein the catches were highest in the mid-length groups.

The yield per recruit plot of Beverton and Holt estimated E_{max} and $E_{0.1}$ value of 0.90 and 0.76 respectively which is higher than the exploitation ratio of 0.41, indicating an underexploited state of *P. conchonius* in Dal Lake.

The underexploited state of the fishery is due to the non-food utility of the *P. conchonius*. Similar results have been reported by Kumar *et al.* (2021) in case of *Puntius sophore* and by Zan-Bi *et al.* (2022) for *Brachydeuterus auratus*. These values are primarily influenced by fishing pressure, feeding variability, ecological and physiological conditions (Biswas 1993; Zan-Bi *et al.* 2022).

4.5 Length at first maturity

Besides refraining from fishing during the spawning period, targeting only mature specimens is crucial for sustainable fishing practices. The length at first maturity (L_m) is a significant phase in a fish's life cycle. At this point, resources that were previously allocated for growth and survival are redirected towards reproduction (Wootton 1998). Although L_m is a trait specific to each species, it can be influenced by factors such as resource availability, fishing pressure, environmental conditions, and biotic interactions (Lappalainen *et al.* 2016; Souza *et al.* 2019). In case of *P. conchonius* the length at first sexual maturity was reported to be 6.2 cm for females. Despite extensive literature review, no studies have been identified that offer data on the length at first maturity for *P. conchonius*. FishBase, one of the authentic data repositories of fishes, also indicates a deficiency of data concerning this parameter for *P. conchonius* (Froese and Pauly 2024). Almeida *et al.* (2018) emphasized that the first sexual maturation is a critical milestone in an animal's life history, which must be taken into account for effective fish management. During the current study the length at first maturity was found to be 6.2 cm whereas length at first capture was found to be 4.69 cm, indicating that $L_m > L_c$, which can disturb the stability of the stock and render the stock vulnerable to capture by the currently available fishing net prior to them attaining maturity. Similar results depicting $L_m > L_c$ were reported by Wehye *et al.* (2017) and Rudi *et al.* (2018). In case where $L_m < L_c$, the individuals would at least breed in their lifetime, enabling stock renewal to ensure sustainability (Udoh and Ukpatu 2017; Panda *et al.* 2018; Mohamed 2022).

5 | CONCLUSIONS

The present study on the population dynamics of *P. conchonius* from Dal Lake was carried out to establish the baseline data on the growth, mortality, exploitation and recruitment pattern of the fish. During the current study, LWR reflected a positive allometric growth of the fish. The condition factor of the fish indicated good growth of the fish in the water body, primarily due to the hardiness of the rosy barb. The fish has a moderate growth rate, high natural mortality but a low exploitation rate. $L_m > L_c$ is indicative of a condition that can disturb the stock, as such the utility of a net with relatively larger mesh size is advisable for fishing *P. conchonius* within this lake. *Pethia conchonius* is a vital forage fish of Dal Lake and tends to be a vital food source for aquatic birds besides having good potential for the ornamental industry making it a valuable fauna of the lake. This study shall aid in devising better culture and management protocols for *P. conchonius*.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare, that are relevant to the content of this article.

AUTHORS' CONTRIBUTION

S Nissar: study design, field sampling, sample analysis, data analysis and manuscript preparation; Y Bakhtiyar: Research supervision, data analysis, manuscript preparation and editing; T Yousuf: sample analysis and manuscript preparation; AA Bhat: field sampling and sample analysis; SM Zuber: manuscript preparation and editing.

DATA AVAILABILITY STATEMENT

The data collected during the current study will be available from the corresponding author on reasonable request.

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S Nissar http://orcid.org/0000-0003-0549-7653
Y Bakhtiyar http://orcid.org/0000-0002-1162-0040
T Yousuf http://orcid.org/0000-0002-7164-7966
AA Bhat http://orcid.org/0000-0002-4209-7926
SM Zuber http://orcid.org/0000-0003-0114-2740