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Original Article

Analyzing population dynamics and growth patterns of *Cyprinus carpio* and *Carassius carassius* in Anchar Lake, Kashmir

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Abstract
The present study examines the population dynamics of *Cyprinus carpio* (common carp) and *Carassius carassius* (crucian carp) in Anchar Lake, Kashmir, through the analysis of length- weight relationships (LWR), growth patterns, mortality rates, exploitation rates, and recruitment dynamics. The length-weight relationships for both species exhibited negative allometric growth, with *C. carpio* showing a regression equation of log W = 2.80 log L – 1.56 and *C. carassius* showing log W = 1.52 log L + 0.01. Growth parameters were estimated using the von Bertalanffy growth function (VBGF) yielding asymptotic lengths (L_∞) of 31.60 cm for *C. carpio* and 30.00 cm for *C. carassius*, with respective growth coefficients (K) of 0.44 year^{-1} and 0.38 year^{-1}. The total mortality rates were 1.26 year^{-1} for *C. carpio* and 1.54 year^{-1} for *C. carassius*, with fishing mortality rates of 0.44 year^{-1} and 0.79 year^{-1} respectively, indicating that *C. carpio* is subject to moderate exploitation (E=0.35) while *C. carassius* is overexploited (E=0.51). Recruitment patterns for both species were highest in spring and early summer, with *C. carpio* showing optimal recruitment between April and May. Virtual population analysis (VPA) and yield-per-recruit analysis revealed that *C. carpio* is currently harvested sustainably, while *C. carassius* faces overfishing risks. The study highlights the need for adaptive management strategies, including stricter fishing regulations and seasonal closures, to ensure the long-term sustainability of these fish populations in Anchar Lake.

Keywords: lake; LWR; management strategies; recruitment patterns; VBGF; VPA

1 | INTRODUCTION

Population dynamics, which represent a subset of potential population characteristics, are the mechanisms that give rise to variations in a population's biomass or abundance over time. The current status of a population and its potential future changes can be inferred from estimates of population dynamics (Pope *et al*. 2010; Forsyth *et al*. 2013; Andrabi *et al*. 2024). Three dynamic rate functions-growth, recruitment, and mortality generally characterise the specific processes that affect fish biomass and abundance. A cohort's (year-class) biomass is increased by growth and recruitment, whereas a cohort's overall biomass and fish population decrease as a result of mortality (Allen and Hightower 2010). Dynamic mathematical models, such as the Beverton-Holt model (Beverton and Holt 1957, 1966) are valuable tools for forecasting future yields and stock biomass under various fishing strategies, thereby playing a significant role in shaping management approaches (Dadzie 2007). The present study was conducted to assess the key population parameters of *Cyprinus carpio* and *Carassius carassius* in Anchar Lake. The primary aim is to develop an effective management and conservation policy for the fishery based on the findings.

Cyprinus carpio (common carp) is classified within the order Cypriniformes and the family Cyprinidae, which is recognized as the largest family of freshwater fish. This species predominantly inhabits freshwater ecosystems, particularly in lentic environments such as ponds and lakes, as well as lotic systems like rivers (Barus *et al*. 2001). It exhibits a broad geographic distribution, found in nearly all countries globally. It is particularly prevalent and culturally significant in Asia and certain European nations, where it is often cultivated in aquaculture and valued for its economic and nutritional contributions (Weber and Brown 2011). This widespread distribution and regional popularity reflect its adaptability to diverse aquatic environments and its importance in local fisheries and culinary traditions (Manjappa *et al*. 2011; Rahman 2015). Common carp ranks as the third most extensively cultivated and commercially significant freshwater fish species globally (FAO 2013). The introduction of common carp (*Cyprinus carpio*) to Dal Lake in 1956 was intended to augment fish production in the Kashmir region. Since that time, this species has proliferated across nearly all aquatic habitats in Kashmir, with its population experiencing substantial growth. This expansion can be attributed to the inherent hardiness of the carp, coupled with its remarkable adaptability, allowing it to thrive even in compromised or degraded environments (Fotedar 1974; Balon 1995).

Carassius carassius, commonly referred to as the crucian carp, is a freshwater fish belonging to the family Cyprinidae. This species is distinguished by its deep, laterally compressed body, small head, and short, rounded fins. Native to the freshwater systems of Europe and Asia, *C. carassius* has shown remarkable adaptability to a variety of aquatic habitats, including lakes, ponds, and slow-moving rivers. Notably, its capacity to thrive in low-oxygen environments enhances its resilience to fluctuations in water quality, enabling it to establish viable populations across diverse ecosystems (Shafi 2012). In Kashmir, *C. carassius* is considered an exotic species, locally known as “Gang gaad”. It was inadvertently introduced into Dal Lake between 1956 and 1958 alongside common carp. Since this introduction, the crucian carp has successfully acclimatized to the varying environmental conditions of the lake, contributing to the local aquatic biodiversity (Nagell and Brittain 1977; Holopainen and Hyvarinen 1985).

The importance of this study is underscored by the fact that there has been no prior research specifically focusing on the demographic aspects of fish populations in Anchar Lake. By investigating the population dynamics of *C. carpio* and *C. carassius*, this research not only fills a critical knowledge gap but also provides essential insights for effective management and conservation strategies. Understanding these demographic factors is crucial for addressing ecological challenges and ensuring the sustainability of the lake’s aquatic ecosystems.

The present study investigates the growth parameters, mortality rates, recruitment patterns, and exploitation levels of *C. carpio* and *C. carassius* in Anchar Lake. Utilizing length-frequency data, this analysis employs the ELEFAN-I (Electronic Length-Frequency Analysis) method, facilitated by the FiSAT II software (Gayanilo *et al*. 2005). This approach allows for a comprehensive assessment of the population dynamics of both species, contributing valuable insights into their ecological status and management needs.

2 | METHODOLOGY

2.1 Study area

Anchar Lake is a shallow basin lake located approximately 12 kilometres northwest of the Srinagar district in the scenic Kashmir Valley (Figure 1). The lake is situated at 34°20′N 74°82′E, with an average elevation of 1,584 meters above sea level (Tahseen *et al*. 2018). Anchar Lake has an average depth of around 4 meters (Lone *et al*. 2020). However, its water level fluctuates significantly over the year because of changes in inflow from the Sindh River, variations in rainfall, sediment accumulation, and anthropogenic influences (Showqi *et al*. 2018). The lake basin hosts an open drainage-type water body, receiving water from a network of channels that includes local catchment areas, open springs, and the Sindh River (Ganie *et al*. 2015). Dal Lake flows into Anchar Lake at its southern end via a small inflow channel known as Nallah Amir Khan. Water exits the lake through the Shallabugh wetland and flows into the Jhelum River (Showqi *et al*. 2018). In recent decades, the lake has experienced significant shrinkage primarily due to human activities. Currently, the lake spans approximately 6.8 km², with about 1.69 km² of open water, while the rest has turned into marshland due to on-going human impact on the lake's ecosystem (Gulzar and Abubakr 2019).

2.2 Sampling design

In the present study, a total of 580 specimens of *C. carpio* and 308 specimens of *C. carassius* were collected from three sampling sites. Sampling was carried out monthly over a two-year period (May 2022 to April 2024), with consistent effort during each session, and was conducted in the morning hours (9:00–11:00 am) to standardize environmental conditions and ensure uniformity throughout the study. Local fishermen assisted in the capture of these specimens using lift nets (locally known as Khurizal) with a mesh size of 30 mm. Captured samples were subsequently transported to the Fish Biology and Limnology Research Laboratory at the Department of Zoology, University of Kashmir, for further analysis. To perform biometric studies, length measurements were taken using a digital Vernier calliper (Aerospace, China) and recorded to the nearest 0.1 cm and total weight was measured using a digital balance (Sartorius GM 312) with an accuracy of 0.1 g.

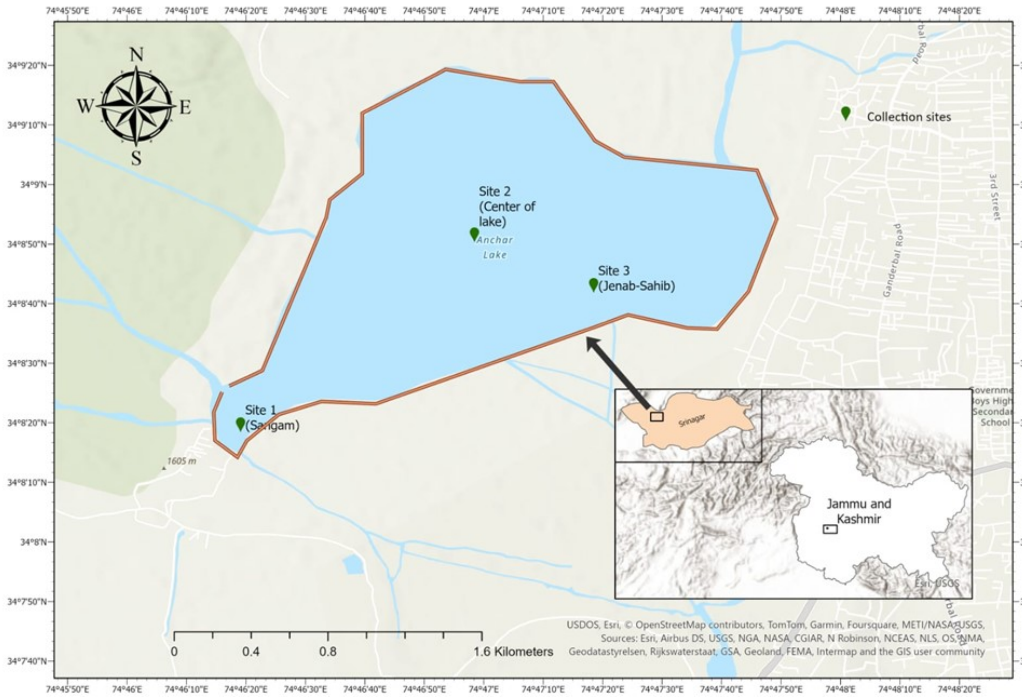

FIGURE 1 Map depicting location of study area and study sites.

2.3 Data analysis

Data analysis and graphical representations were carried out using Microsoft Excel 2016. Length-weight relationships were estimated using log-transformed linear regression. Analysis of key growth parameters, mortality rates, exploitation rates, recruitment patterns, virtual population dynamics, and yield-per-recruit were performed using the FiSAT II software.

2.4 Parameters calculation

2.4.1 Length-weight relationship (LWR): In evaluating the length-weight relationships (LWRs) of the fish, the equation proposed by Le Cren (1951) is expressed as:

$$W = aL^b$$

The logarithmic form of which is given by Ricker (1975) as:

$$\text{Log } W = b \log L + \log a$$

Where W represents the total weight (in grams), L denotes the total length (in centimetres), a is the intercept of the regression curve, and b is the growth coefficient. The relative condition factor, often denoted as K_n, is a metric used to assess the health and wellbeing of fish populations and is defined as the ratio of the observed weight of a fish to its expected weight. It is calculated using the following formula as given by Le Cren (1951):

$$K_n = W/aL^b$$

2.4.2 von Bertalanffy growth function: The von Bertalanffy growth function was evaluated using FiSAT II (FAO-ICLARM Stock Assessment Tools II). The growth parameters were determined through the ELEFAN-I method, which provided values for the asymptotic length (L_∞) and the growth coefficient (K). The values of L_∞ and K were utilized to estimate the length at age (L_t) using the equation provided by (Gayanilo *et al*. 2005), which is expressed as follows:

$$L_t = L_\infty (1 - e^{-K(t-t0)})$$

The theoretical age at fish length 0, denoted as (t_0), was calculated using the formula proposed by (Pauly 1984):

$$\log(-t_0) = -0.3952 - 0.2752 \log(L_\infty) - 1.038 \log K$$

The growth performance index (ϕ) was calculated to assess the growth performance of the fish population, using the formula established by (Pauly and Munro 1984):

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

2.5 Mortality rates

2.5.1 Total mortality rate (Z): The Z was calculated using FiSAT II, employing the Length-converted catch curve method.

2.5.2 Natural mortality rate (M): The M was estimated according to (Pauly 1980) using the formula:

$$\log(M) = -0.0152 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

Where L_∞ is the asymptotic length, K is the growth coefficient, and *T* is the average temperature of the habitat.

2.5.3 Fishing mortality rate (*F*): The *F* was calculated based on the relationship:

$F = Z - M$

Where *Z* represents the total mortality rate, and *M* is the natural mortality rate.

2.5.4 Exploitation rate (*E*): The *E* was determined using the formula provided by (Sparre and Venema 1992):

$E = F/Z$

Where *E* is the exploitation rate, *F* is the fishing mortality rate, and *Z* is the total mortality rate.

2.6 Virtual population analysis, relative yield-per-recruit and biomass-per-recruit

The estimation of length-structured virtual population analysis (VPA) was conducted following the procedures outlined in FiSAT II, as described by (Fry 1949). The relative yield-per-recruit (*Y/R*) and relative biomass-per-recruit (*B/R*) were estimated using the knife-edge analysis method originally proposed by (Beverton and Holt 1966) and subsequently modified by (Pauly and Soriano 1986). This analysis was performed using the FiSAT software, allowing for an effective assessment of the fishery's productivity and sustainability.

3 | RESULTS

3.1 Length- weight relationship and condition factor

The estimated length–weight equations and relative condition factors for for *C. carpio* was log W= 2.80 log L−1.56, r = 0.94, b= 2.81 and K_n = 1.02 and it was for *C. carassius* was log W = 1.52 log L + 0.01, r = 0.67, b = 1.52 and K_n = 1.05 (Figure 2 and 3). The results of the study suggest that both the fish species exhibit negative allometric growth.

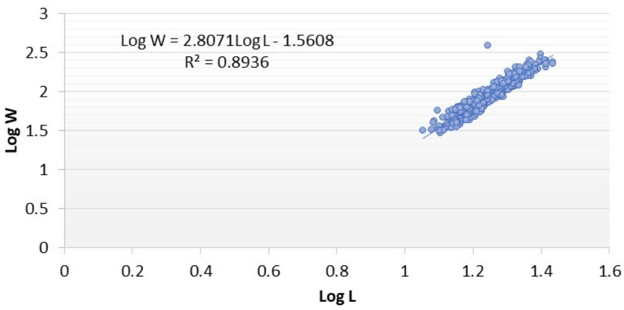

FIGURE 2 Length–weight relationship of *Cyprinus carpio* from Anchar Lake.

3.2 Growth parameters

The growth parameters for *C. carpio* were estimated using the von Bertalanffy growth formula (VBGF) and the length-frequency distribution is presented in Figure 4. The parameters obtained were: asymptotic Length (L_∞): 31.60 cm; growth coefficient (K): 0.44 year^{-1}; growth performance index (ϕ): 2.64; age at zero length (t_0): –0.36 years and Length at first capture (L_c): 11.84 cm.

Based on these parameters, the VBGF equation for *C. carpio* can be expressed as: L_t=31.60(1−e$^{-0.44(t+0.36)}$)

For *C. carassius*, the length-frequency distribution is presented in Figure 5 and the parameters estimated from VBGF were: asymptotic length (L_∞): 30.00 cm; growth coefficient (K): 0.38 year^{-1}; growth performance index (ϕ): 2.53; age at zero length (t_0): – 0.43 years and Length at first capture (L_c): 9.72 cm. Based on these parameters, the VBGF equation for *C. carassius* can be expressed as: L_t= 30 (1−e$^{-0.38(t+0.43)}$)

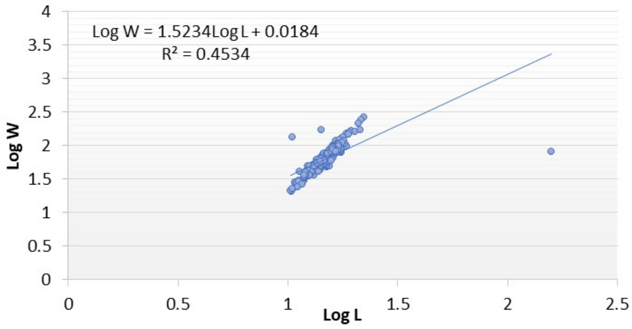

FIGURE 3 Length–weight relationship of *Carassius carassius* from Anchar Lake.

3.3 Mortality rates and exploitation ratio

For *C. carpio*, the total mortality (*Z*), the fishing mortality (*F*), the natural mortality (*M*) and the exploitation ratio (*E*) were reported to be 1.26 year^{-1}, 0.44 year^{-1}, 0.82 year^{-1} and 0.35 respectively (Figure 6). For *C. carassius*, the reported values for total mortality (*Z*), fishing mortality (*F*), natural mortality (*M*), and exploitation ratio (*E*) were 1.54 year^{-1}, 0.79 year^{-1}, 0.75 year^{-1}, and 0.51 respectively (Figure 7).

3.4 Recruitment patterns

For *C. carpio*, the highest recruitment appears in April, followed by May, with percentages nearing or exceeding 15%. This suggests that the recruitment of *C. carpio* is most successful in late spring (Figure 8). For *C. carassius*, the highest number of recruits appear in the spring months and lowest in the late summer and early fall (Figure 9).

3.5 Virtual population analysis, relative yield-per-recruit and biomass-per-recruit

From the length-structured virtual population analysis (VPA) conducted for *C. carpio* (Figure 10), it was observed that the length group between 17 and 20 cm exhibited the highest vulnerability to the fishing gears employed in the lake, reflecting increased fishing mortality. The graph also shows that the survival rate was highest in the smaller size group, particularly between 11 and 14 cm. For *C. carassius* (Figure 11), the length classes most susceptible to fishing mortality were 14 – 15 cm, while the highest survival rate was observed in the 10 – 12 cm size group. Using the knife-edge selection approach, the relative yield-per-recruit (*Y/R*) and biomass-per-recruit (*B/R*) were calculated as functions of *M/K* and L_c/L_∞, respectively. The *M/K* and L_c/L_∞ values for *C. carpio communis* were reported to be 0.37 and 1.86, and 1.97 and 0.32 for *C. carassius* respectively. The ogive curve showed that the maximum sustainable yield (E_{max}) for *C. carpio communis* was 0.596 with E_{10}=0.507 and E_{50}=0.324, and for *C. carassius*, it was 0.553 with E_{10}=0.464 and E_{50}=0.309 (Figure 12 and 13). Table 1 summarizes the key population dynamics parameters for *C. carpio* and *C. carassius* in Anchar Lake.

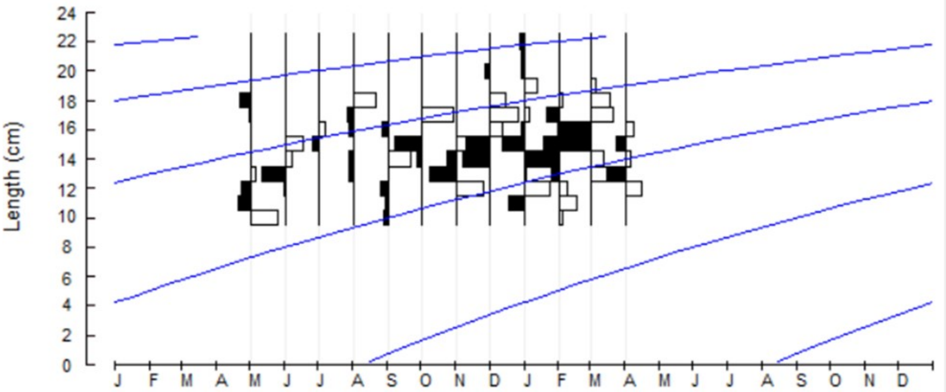

FIGURE 4 Length- frequency distribution output obtained from FiSAT II for *Cyprinus carpio* from Anchar Lake.

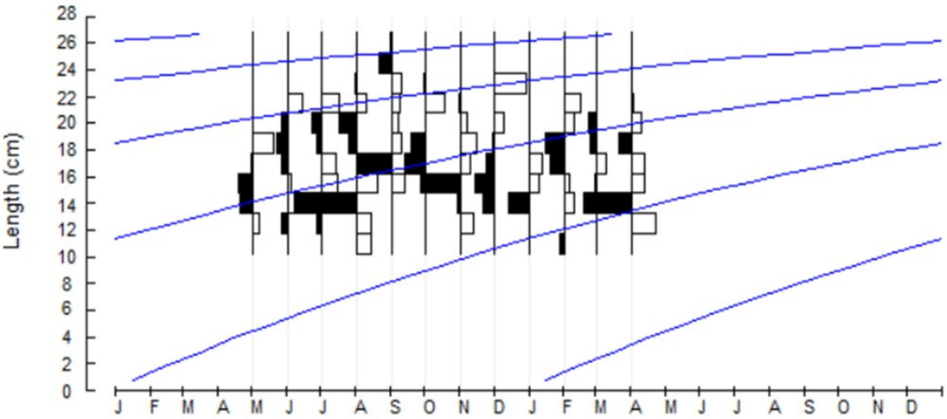

FIGURE 5 Length- frequency distribution output obtained from FiSAT II for *Carassius carassius* from Anchar Lake.

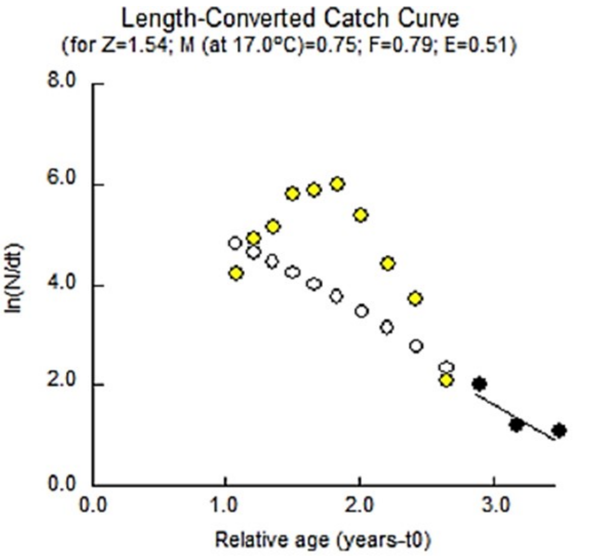

FIGURE 6 Length- converted catch curve obtained from FiSAT II for *Cyprinus carpio* from Anchar Lake.

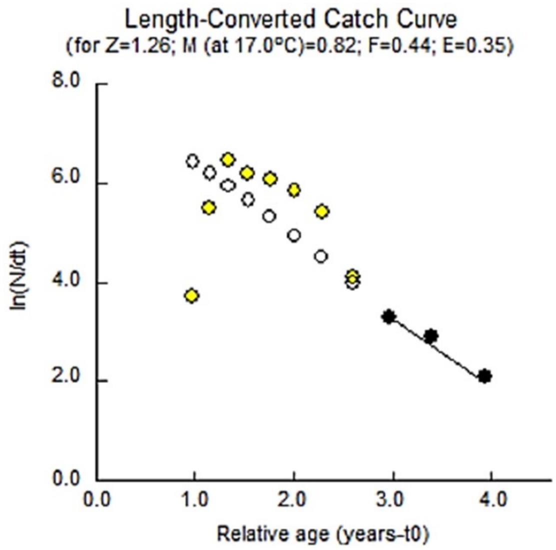

FIGURE 7 Length-converted catch curve obtained from FiSAT II for *Carassius carassius* from Anchar Lake.

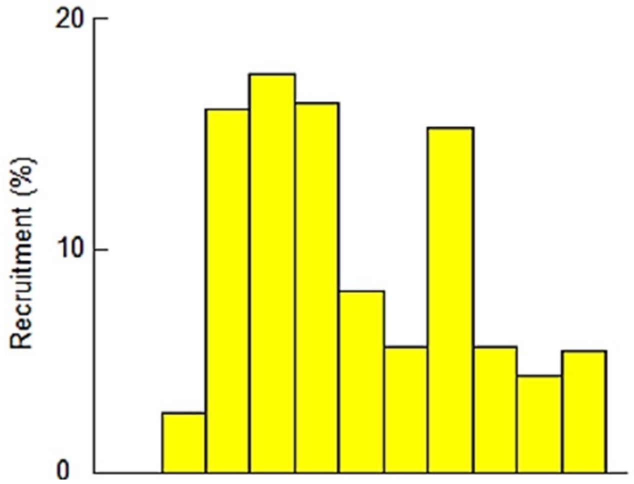

FIGURE 8 Recruitment pattern obtained from FiSAT II for *Cyprinus carpio* from Anchar Lake.

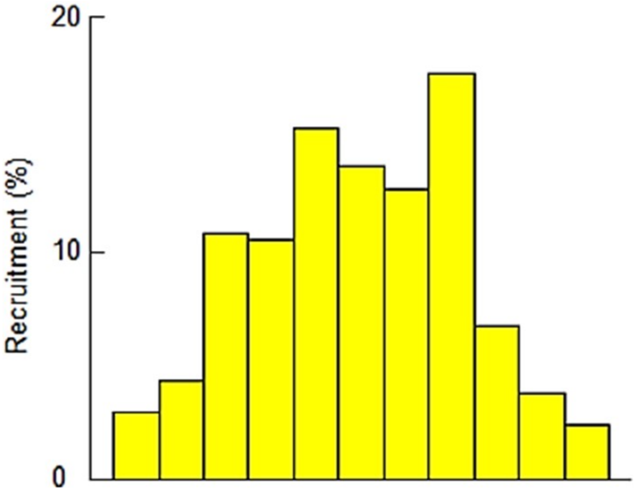

FIGURE 9 Recruitment pattern obtained from FiSAT II for *Carassius carassius* from Anchar Lake.

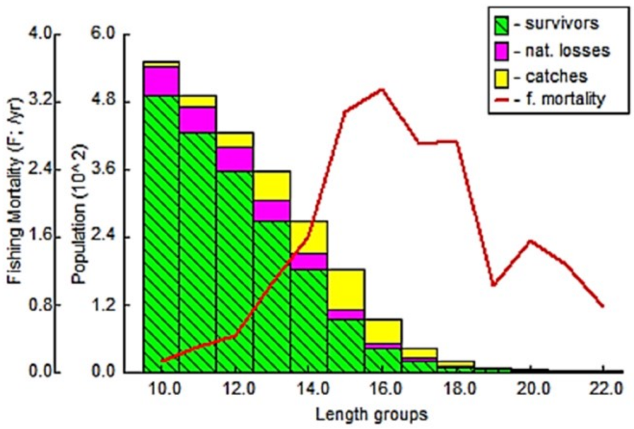

FIGURE 10 Length structured VPA output for *Cyprinus carpio* from Anchar Lake.

4 | DISCUSSION

Fish population dynamics is largely dependent on the growth pattern of fish populations as well as recruitment potential, mortality rates, and the degree of exploitation. These factors significantly impact the sustainability and health of aquatic ecosystems. This research examines two economically important species, *C. carpio* and *C. carassius*, utilizing length-frequency data to infer their population dynamics in Anchar Lake. A thorough understanding of these dynamics is crucial for formulating strategies that promote sustainable fisheries management.

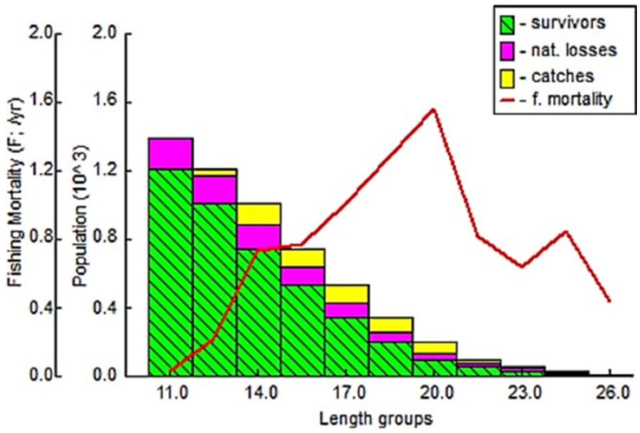

FIGURE 11 Length structured VPA output for *Carassius carassius* from Anchar Lake.

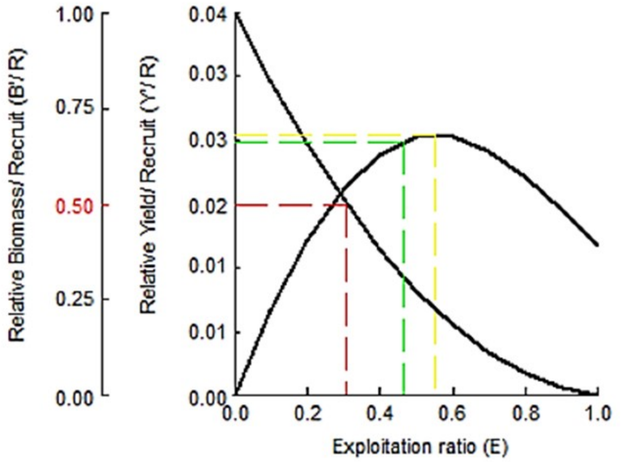

FIGURE 12 Beverton and Holt analysis curve for *Cyprinus carpio* from Anchar Lake.

4.1 Length-weight relationship and relative condition factor

Length-weight relationships are highly valuable in fisheries research as they facilitate the transformation of growth-in-length equations into growth-in-weight metrics, enabling biomass estimation, and provide insights into fish condition and the variations in life histories among different species (Moutopoulos and Stergiou 2002; Zargar *et al*. 2012). The exponent '*b*' indicates the growth pattern of fish species. The optimal value for the exponent *b* is determined to be 3, which indicates isometric growth. Values of *b* less than 3 signify negative allometric growth, while values greater than 3 indicate positive allometric growth (Wani *et al*. 2020; Nissar *et al*. 2024a).

Hile (1936) proposed that the value of *b* can vary from 2.5 to 4.0. According to (Allen 1938), the ideal value for the regression coefficient *b* in fish should be near 3.0. Growth coefficient (*b*) values for *C. carpio* and *C. carassius* were found to be 2.81 and 1.52, respectively, showing negative allometric growth for both fish species in Anchar Lake.

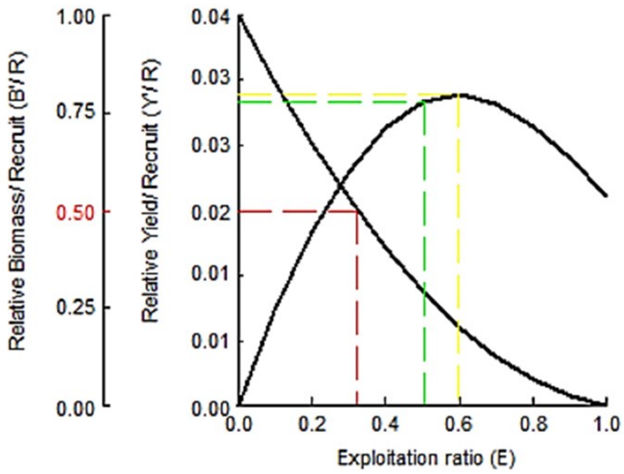

FIGURE 13 Beverton and Holt analysis curve for *Carassius carassius* from Anchar Lake.

The relative condition factor (K_n) serves as an important indicator of the overall well-being of fish (Le Cren 1951; Gulland 1983; George *et al*. 1985). A K_n value greater than one indicates favourable health and condition, while a value below one suggests that the fish is in poor condition. The relative condition factor (K_n) in the present study was found to be greater than 1 for both *C. carpio* and *C. carassius* in Anchar Lake. This suggests that both species are in good health and exhibit favourable overall condition, indicating a supportive environmental habitat. The findings of the present study are supported by the results of (Shafi *et al*. 2012; Zargar *et al*. 2012; Das *et al*. 2019; Syed *et al*. 2020; Wani *et al*. 2020; Andrabi *et al*. 2021; Andrabi *et al*. 2024; Nissar *et al*. 2024b).

4.2 Growth parameters

Cyprinus carpio and *C. carassius* were found to have asymptotic lengths (L_∞) of 31.60 cm and 30.00 cm, respectively, based on the K-scan method of ELEFAN- I. The estimates of L_∞ vary significantly among studies. Andrabi *et al*. (2024) reported an L_∞ value of 38.85 cm for *C. carpio* from Manasbal Lake, while Talet and Talet (2019) found an L_∞ value of 36.7 cm from Abed Dam in Algeria. (Mirza *et al*. 2012) reported a substantially higher L_∞ value of 80.33 cm for *C. carpio* in Mangla Reservoir. The observed dissimilarity in growth parameters of the same species across different geographic locations may be due to several factors including variations in environmental conditions, availability and diversity of food resources, reproductive activity, and the sizes of fish populations (Sparre and Venema 1998; Wootton 2011).

TABLE 1 Population dynamics parameters for *Cyprinus carpio* and *Carassius carassius* in Anchar Lake, Kashmir, India.

Parameters	*Cyprinus carpio*	*Carassius carassius*
Length–weight equation	log W= 2.80 log L−1.56	log W=1.52 log L+0.01
Relative condition factor (K_n)	1.02	1.05
Correlation coefficient (r)	0.94	0.67
Asymptotic length (L_∞) cm	31.60	30.00
Growth constant (K) year^{-1}	0.44	0.38
Growth performance index (ϕ)	2.64	2.53
Age at zero length (t_0) year	-0.368	-0.434
Length at first capture (L_c) cm	11.84	9.72
Total mortality (Z) year^{-1}	1.26	1.54
Natural mortality (M) year^{-1}	0.82	0.75
Fishing mortality (F) year^{-1}	0.44	0.79
Exploitation rate (E)	0.35	0.51
Emax	0.596	0.553
E_{10}	0.507	0.464
E_{50}	0.324	0.309
L_c/L_∞	0.374	0.324
M/K	1.86	1.970

An important metric for assessing the possibility that fish populations may have been overexploited is the annual coefficient of growth (*K*), which appears to be correlated with the longevity and mortality rates of a fish population (Beverton and Holt 1957). The growth constants (*K*) obtained in this study for *C. carpio* (0.44 year^{-1}) and *C. carassius* (0.38 year^{-1}) indicate that both species exhibit moderate growth rates based on the range provided by (Sparre and Venema 1998). Thus, the current study confirms that *C. carpio* and *C. carassius* in Anchar Lake are moderate-growing fish species, with *C. carassius* exhibiting a slightly lower growth rate than *C. carpio*.

4.3 Mortality rates and Exploitation ratio

The computation of overall mortality is an essential component of the evaluation of the demographic stock, as it provides insights into the potential percentage of individuals that may be removed from the population (Pope *et al*. 2010). Beverton and Holt (1959) stated that the natural mortality of a fish is positively associated with the growth constant, while it is inversely related to the asymptotic length. In the current study, the total mortality for *C. carpio* was 1.26 year^{-1}, with natural mortality at 0.82 year^{-1} and fishing mortality at 0.44 year^{-1}.

In contrast, *C. carassius* exhibited higher total mortality at 1.54 year^{-1}, with natural mortality at 0.75 year^{-1} and fishing mortality at 0.79 year^{-1}. These findings indicate that although both species display moderate growth rates, *C. carpio* has a more balanced mortality distribution, with a significant portion attributed to fishing activities. In contrast, *C. carassius* shows a higher total mortality rate, which may suggest increased vulnerability to fishing pressures or environmental factors.

Our results are similar to those reported by (Balik *et al*. 2006; Saba 2016; Hashemi *et al*. 2019) who studied *C. carpio* in Lake Karamik, *C. auratus* in Shadegan Wetland, and *Schizothorax niger* in Nigeen Lake, respectively. These variations in mortality rates for the same species across different habitats can be attributed to factors such as the pace of growth, the abundance of prey, and the level of fishing effort in those environments (Rahman *et al*. 2016).

4.4 Recruitment

The recruitment pattern of *C. carpio* in Anchar Lake showed clear seasonality, with higher recruitment during spring and early summer and a noticeable decline in winter. These seasonal peaks may be influenced by favourable water temperatures, increased primary productivity, and greater food availability, although these factors were not measured directly in the present study. A similar pattern was observed for *C. carassius*, with recruitment highest from April to June and declining from July to September. Recruitment during the colder months (November to February) decreased markedly, which is consistent with reduced reproductive activity and lower metabolic rates typically reported for temperate freshwater fishes. The recruitment of fish populations is generally shaped by the interplay between accessible food resources and suitable environmental conditions, particularly temperature regimes (Tableau *et al*. 2015; Kripa 2017). Furthermore, extensive ecological studies indicate that recruitment peaks commonly coincide with periods offering optimal thermal conditions and adequate food supply, supporting successful spawning and larval survival (Laiz *et al*. 2025).

4.5 Virtual population analysis, yield-per-recruit and biomass-per-recruit

Virtual population analysis (VPA) is an essential tool in fish stock assessment, commonly used to estimate the population dynamics of fish species by integrating historical data, such as catch and effort records, along with biological parameters. By reconstructing the age or size composition of the population over time, VPA provides valuable insights into the past, current, and future status of fish populations, helping fishery managers predict trends in stock abundance and guide sustainable harvest practices (Abdallah and El-Haweet 2000). The relative yield-per-recruit (*Y/R*) and biomass-per-recruit (*B/R*) in this study were evaluated based on the ratios of L_c/L_∞ and M/K, respectively. The values calculated for L_c/L_∞ and M/K were 0.374 and 1.86 for *C. carpio*, and 0.324 and 1.970 for *C. carassius*, respectively. These ratios suggest that both species are being harvested at a size that is a significant portion of their potential maximum size, which could influence their future productivity and overall fishery yield. The exploitation rate was found to be lower than the predicted E_{max} for *C. carpio*, with E = 0.35 and E_{max} = 0.421. This suggests that the fishing pressure on *C. carpio* is currently sustainable and below the threshold that would lead to overfishing. In contrast, the exploitation rate for *C. carassius* (E = 0.51) was higher than its E_{max} (0.421), indicating that the fishing pressure on this species is too high and may result in overfishing if not managed properly.

5 | CONCLUSIONS

This study examined the population dynamics of *C. carpio* and *C. carassius* in Anchar Lake, revealing key insights into their growth, mortality, and exploitation rates. Both species exhibit negative allometric growth, with *C. carpio* showing a moderate growth rate (K = 0.44 year^{-1}) and *C. carassius* growing more slowly (K = 0.38 year^{-1}). While *C. carpio* is currently harvested at sustainable levels (E = 0.35), *C. carassius* is overexploited (E = 0.51), indicating a need for immediate management action. To ensure the long-term sustainability of fish populations in Anchar Lake, it is recommended to implement measures to reduce fishing pressure on *C. carassius*. This can be achieved through the establishment of stricter catch limits, the enforcement of size limits, and the implementation of seasonal fishing closures, particularly during peak recruitment periods. For *C. carpio*, maintaining current harvesting practices that align with sustainable exploitation rates will help preserve population stability and prevent overfishing. Additionally, continued monitoring of fish stocks, coupled with adaptive management strategies, is essential for maintaining the health of these populations and ensuring the long-term viability of the Anchar Lake fishery.

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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

SJ: Field work, Lab work, Drafting, Statistical Analysis. SN: Lab work, Statistical Analysis, Reviewing manuscript. TY: Field work, Statistical Analysis. YB: Supervision, Drafting, Reviewing manuscript

DATA AVAILABILITY STATEMENT

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

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