

Stock Assessment and Population Dynamics of Common Carp (*Cyprinus carpio* Linnaeus, 1758) from Ottu Reservoir, Haryana, India

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ABSTRACT

The present study assessed the population parameters and stock status of common carp (*Cyprinus carpio*) from the Ottu reservoir, Haryana, India using length-frequency data of 716 fish samples analysed through the FISAT-II software package. The asymptotic length (L_{∞}) and growth coefficient (K) were 369.43 mm and 0.72 year⁻¹, respectively with a growth performance index (ϕ') of 4.99 indicating moderate growth. Natural mortality (M), fishing mortality (F), and total mortality (Z) rates were 1.1 year⁻¹, 1.73 year⁻¹ and 1.84 year⁻¹ respectively. Recruitment pattern indicates a single annual recruitment with a major peak during August-September. It was observed that the likelihood of capture at L25, L50, and L75 was 271.26, 296.15 and 307.71 mm, respectively with length at first capture (L_c) estimated at 296.15 mm. The relative yield per recruit (Y'/R) and biomass per recruit (B'/R) were 0.80 and 1.01, respectively. The exploitation (E) rate was estimated at 0.63, which indicated the fish was overexploited ($E > 0.50$) in the Ottu reservoir. These results indicate that in order to effectively utilization of *C. carpio* in Ottu reservoir, suitable fisheries management methods like limiting fishing effort and mesh size regulation are required.



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1. Introduction

Small-scale fisheries provide food and livelihood benefits for millions of people especially in low-income

groups (FAO, 2014). Many of these, fisheries are operated by poor rural households, mostly for small-scale economic security and subsistence. For people who are unable to obtain other nutritious sources, the industry is crucial in treating essential deficiencies like as protein, omega-3 fatty acids and vitamins. The inland fish resources were overfished, and the populations have been diminishing [32]. Thus, one of a nation's most significant sources of income is its fishing industry. In terms of human nutrition, it is also a significant food sector. It emphasizes how aquaculture is increasingly helping to maintain carp production and reduce the impact of fishing on natural populations. Thus, the growth of carp farming is an essential part of sustainable fisheries management, guaranteeing freshwater ecosystems, socioeconomic resilience and resource protection [12].

In order to develop scientific methods for the conservation, management and protection of fish species as well as to achieve a sustainable yield, it is crucial to study their population dynamics. Fish population dynamics is the variation in a population's size brought on by a number of factors, including recruitment, growth, mortality and reproduction, which causes a particular population to increase or decrease [21]. Management and planning of aquatic resources require an understanding of many population factors such as the asymptotic length and growth coefficient, the rate of natural and fishing mortality and the degree of exploitation [6]. An investigation is necessary to enable improved management due to a lack of understanding concerning population structure and aquatic utilization of resources.

Estimating population parameters, such as growth, the lifespan, mortality, length at first capture, abundance, recruitment pattern and exploitation rate is a primary challenge in the study of population changes. The biomass status and size of the fish population are assessed using these measures [3]. Fish size and age data serve as a basis for growth estimation. Fish growth is an important aspect of many fisheries stock assessments and a significant aspect of fish biology [23]. Some studies have examined the population structure, development and stock status of *Cyprinus carpio* in the southern Caspian Sea, despite the species' great commercial significance and extensive distribution. A wide range of the research that is currently available focuses on factors like growth parameters, mortality or genetic variation. However, thorough long-term analyses of population dynamics and patterns of exploitation are still few. For efficient fisheries management and sustainable exploitation of common carp species, initial information on size and age structure, growth, mortality and stock assessment are crucial [19], [13].

Due to many natural and man-made factors, Haryana's freshwater fisheries catch is currently declining regularly, making it unable to fulfil the increasing fish demand. Therefore, the only way to solve the current problem will be to explore, exploit and cultivate water resources. The understanding of the biology, ecology and population size of freshwater fishes is crucial for fulfilment of this aim.

The freshwater fish *Cyprinus carpio* (Linnaeus, 1758), a species of the Cyprinidae family, is tolerant of a variety of conditions but typically prefers large bodies of water with soft sediments and slow-moving or stationary water [14]. In Haryana, India, the *Cyprinus carpio* (common carp) is found in many freshwater systems. One of the most prevalent and economically significant species in Haryana is the common carp. Three of the six strains/varieties (such as scale carp, mirror carp, leather carp, golden carp, etc.) that are found in the ponds, rivers and reservoirs are essential to state traditional aquaculture sector [22].

The objective of this study is to evaluate the temporal variation in population structure, growth and mortality of common carp in the Ottu reservoir during January 2025- December 2025 to support sustainable management. Validated population models and standard fisheries assessment techniques such as length-based studies and the von Bertalanffy growth model is used to estimate quantitative markers of growth, mortality

and exploitation.

By focusing on these metrics, the study aims to offer a thorough analysis of population dynamics and assess how sustainable the present fishing demands are. This involves analysing how natural growth and mortality rates interact, as well as the effects of fishing and other human activity and how they affect stock resilience. The study aims to add to the collection of knowledge supporting conservation efforts and adaptive management techniques for the common carp fishery by integrating these biological and fisheries variables.

2. Materials and methodology

2.1 Study area and sampling design

The present study was conducted at Ottu reservoir, located near the Sirsa district in Haryana, India. The study was carried out over a period of 12 months from January 2025 to December 2025 in order to evaluate the biological parameters of fish population with special emphasis on *Cyprinus carpio*. In order to understand the seasonal variations in environmental conditions and fish population dynamics, sampling was carried out at monthly intervals from various fishing zones within the reservoir. Figure 1 presents a map of the sampling points in the Ottu Reservoir and shows the geographic distribution of the sampling locations throughout the reservoir.

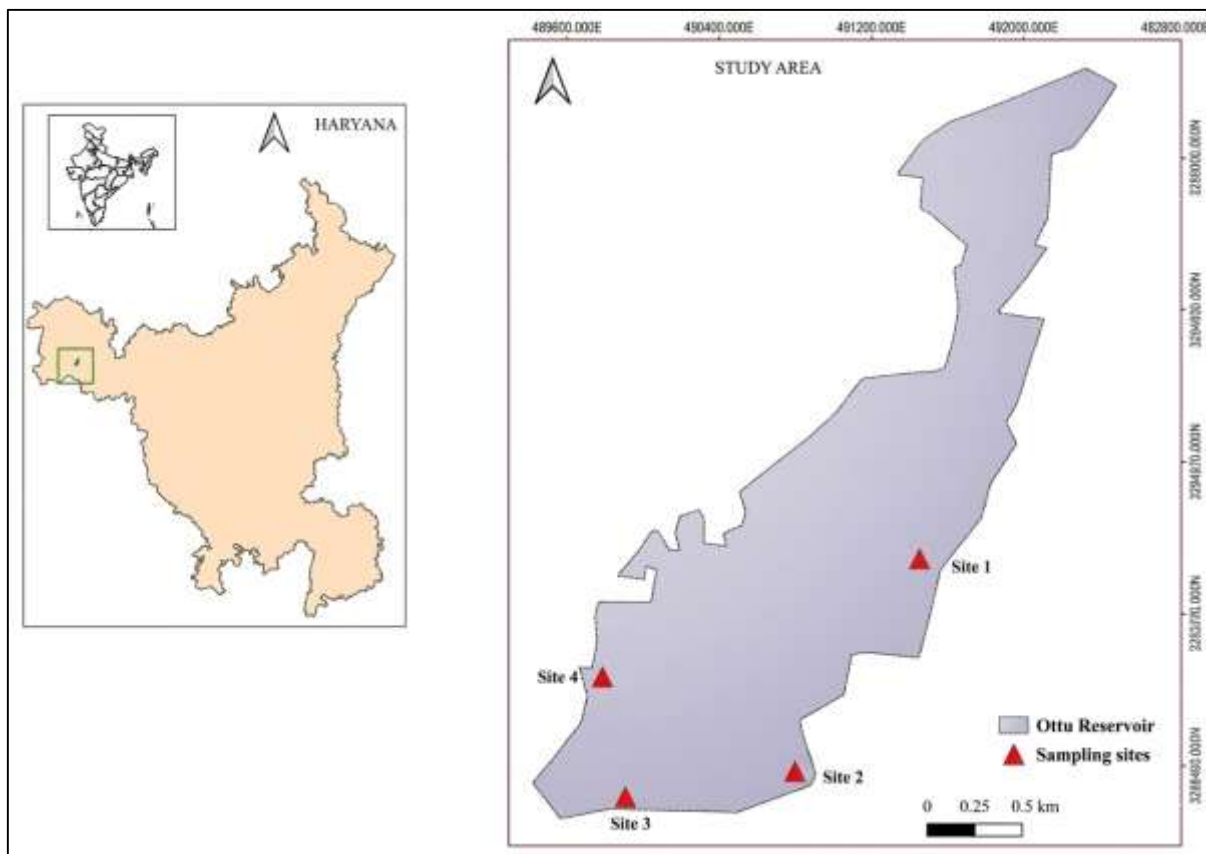


Fig. 1: Map of sampling stations in the Ottu reservoir

2.2 Data collection and analysis

During the study period, 716 fish specimens were collected from four specific sampling points in the Ottu Reservoir. Multi-filament gill nets with varied mesh sizes (6, 8, 10, and 12 cm), cast net and drag net were used for collection in order to catch fish of various sizes. After collection, each specimen's total length was

measured using a measuring board to the nearest 0.1 cm and an electronic balance was used to record its body weight to the nearest 0.01 g. In order to assess the growth patterns and population characteristics of the common carp under study, statistical analyses were performed using the biometric measurements obtained.

2.3 Population Parameters Estimation Using FiSAT II

Computer based FiSAT II program [15] were used to estimate the population parameters such as asymptotic length (L_{∞}), growth co-efficient (K), natural mortality (M), Fishing mortality (F), total mortality (Z), exploitation rate (E), recruitment pattern, relative yield-per-recruit and biomass-per-recruit. Length-frequency data were then analyzed using the ELEFAN (electronic length frequency analysis) using the correct routines in FiSAT II package [28], [26], [27], [30], [15].

2.4 Growth Parameters Estimation

2.4.1 Von Bertalanffy Growth Function (VBGF)

The growth parameters, asymptotic length (L_{∞}) and growth co-efficient (K) were estimated following the Von Bertalanffy growth equation [37]:

$$L_t = L_{\infty}(1 - \exp^{-K(t-t_0)})$$

Where, L_t is the length at age t , L_{∞} the asymptotic length, K the growth co-efficient and t_0 is theoretical age at which fish length is zero. Parameters of L_{∞} and K were computed from the ELEFAN I.

2.4.2 Growth Performance Index

The growth performance index (ϕ') for common carp was computed following the equation [29].

$$\phi' = \log_{10}K + 2\log_{10}L_{\infty}$$

2.5 Mortality and Exploitation Rate Estimation

2.5.1 Total Mortality (Z)

The total mortality (Z) was estimated using the length converted catch curve analysis in FiSAT II Program using the input parameters L_{∞} , K and t_0 [29]. The theoretical equation used in this analysis is,

$$\ln \left(\frac{N_i}{\Delta t_i} \right) = a + b \times t_i$$

where N_i =the number of fish in length class i ; Δt_i = the time required for the fish to grow through length class i , t_i =the age corresponding to the mid length of class i and b = slope of regression (estimate of Z with sign changed).

2.5.2 Natural Mortality (M)

The natural mortality (M) has been estimated using the empirical relationship derived by [29].

$$\ln M = -0.0152 - 0.279 \ln L_{\infty} + 0.06543 \ln K + 0.463 \ln T$$

where, M is the natural mortality, L_{∞} is asymptotic length in cm, K is growth coefficient and T is mean annual temperature ($^{\circ}$ C).

2.5.3 Exploitation Rate (E)

The E (exploitation rate) was calculated using:

$$E = \frac{F}{Z} = \frac{F}{F + M}$$

2.6 Probability of Capture and Length at First Capture

2.6.1 Probability of Capture

Probability of capture was estimated by backward projection assumes no gear selectivity, using the following relationship:

$$N_{i-1} = N'_i \times \text{Exp}(Z\Delta t_i)$$

Where N_i =Terminal population, N'_i =Number of fish under the length groups that not recruited under gear, Δt_i =the time needed for the fish to grows through length class i , $Z=(Z_i+Z_{i+1})/2$, $Z_i=M+F_i$, $F_{i-1}=F_i-X$, $=F/(\text{No. of classes below } P_{i+1})$ and P_i =the first length group with a probability of capture equal to 1.0 and whose lower limit is an estimate of L' .

2.6.2 Length at First Capture

The length at first capture (L_c or L_{50}) was calculated following [29]. The ratio of the length-converted catch curve's ascending and descending arms was used to calculate the probabilities of capture by length.

2.7 Recruitment Pattern

The recruitment pattern was estimated using the procedure incorporated in FiSAT II software following [15].

2.8 Yield-per-Recruit and Biomass-per-Recruit Analysis

Relative yield-per-recruit (Y'/R) and Biomass-per-recruit (B'/R) were estimated growth parameters and probabilities of capture [30].

$$U = 1 - \frac{L_c}{L_\infty}$$

Where, L_c is length at first capture and L_∞ = asymptotic length

The Beverton and Holt model, a part of the FiSAT II package was used to compute the expected Y'/R values [9- 11].

3. Results and Discussion

3.1 Growth parameters

The growth parameters, asymptotic length (L_∞) and growth coefficient (K) of von Bertalanffy growth model were estimated for *Cyprinus carpio* as 369.43 mm and 0.72 year⁻¹, respectively. The calculated correlation co-efficient (R^2) (ESP/ASP) through ELEFAN I was 0.118. Fig. 2 shows the computed growth curves for *Cyprinus carpio* using these parameters and over the restructured length-frequency distribution. The growth performance index (ϕ') of *Cyprinus carpio* in the Ottu reservoir was estimated to be 4.99, indicating a moderate growth performance of the species in the study area.

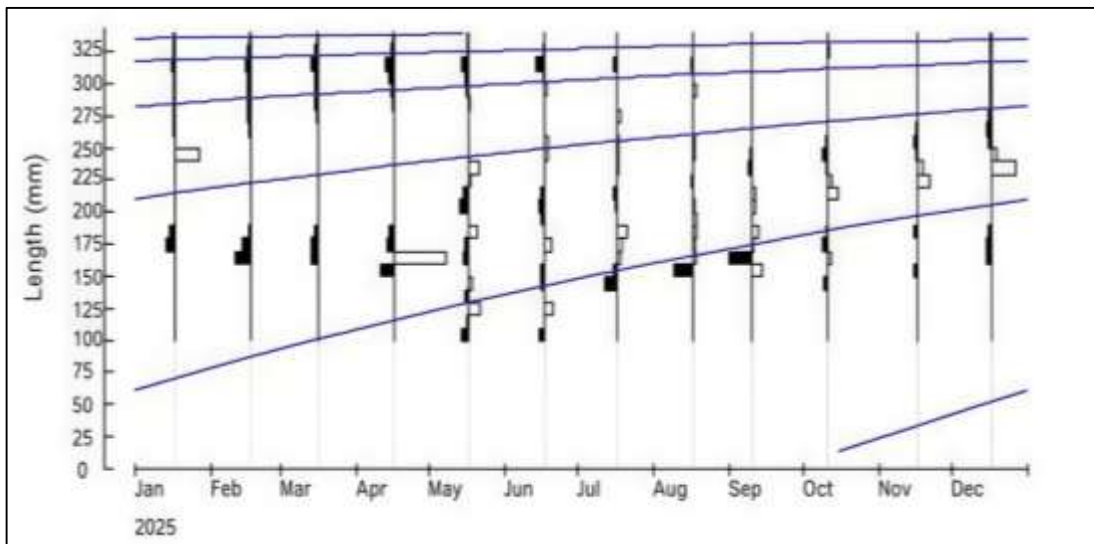


Fig. 2: Restructured length frequency distribution of *Cyprinus carpio* from the Ottu reservoir

According to [29] the growth performance index (ϕ') reflects the overall growth performance of fish populations, where the higher value of ϕ' indicate better growth potential. The Von Bertalanffy curvature parameter K has been linked to the longevity [8], and longevity is related to mortality rates [17], [33]. Species with higher K value generally showed higher natural mortality (M), whereas species with lower K values tend to have lower mortality rates. Slow growing species with low K values may be more vulnerable if natural mortality increases [34].

Studies performed in various water bodies provide quite diverse estimations of L_{∞} . [4] reported an L_{∞} value of 388.5 mm for *C. carpio* from Manasbal Lake, whereas [36] reported 367 mm from Abed Dam, Algeria. However, [24] reported a substantially higher L_{∞} value of 803.3 mm for *C. carpio* from 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 population's structure [35], [38].

3.2 Mortality

The natural mortality (M), Fishing mortality (F) and total mortality (Z) of *Cyprinus carpio* were estimated as 1.1 year^{-1} , 1.73 year^{-1} and 1.84 year^{-1} respectively. The length converted catch curve used for the estimation of total mortality (Z) is presented in Fig. 3.

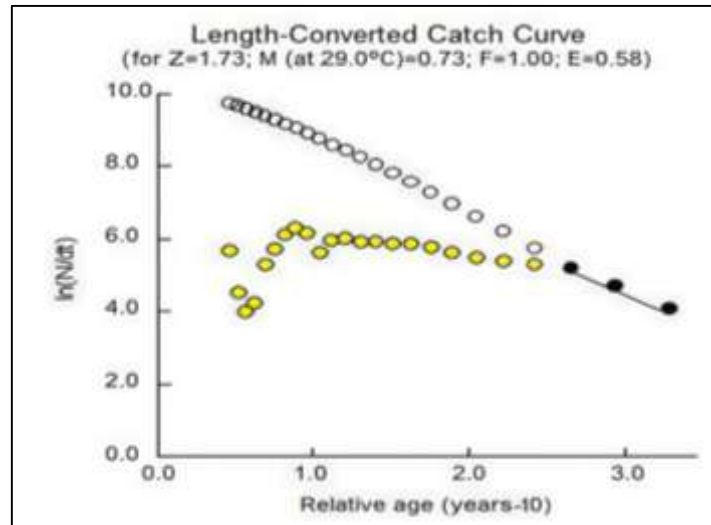


Fig 3: Length-converted catch curve of *Cyprinus carpio*

In the catch curve analysis, the darkened quadrilateral represents the points used in calculating Z through least-square linear regression. Whereas, the open circles represent the points that were either not fully recruited to the fishery or were close to the L_{∞} and were therefore excluded from the regression analysis. A good fit was observed along the descending right-hand arm of the catch curve.

Generally, mortality estimates are important measures of fishing pressure and fish population health. Fishing activities may play a significant impact on the population dynamics of *C. carpio* in the Ottu Reservoir, as indicated by the current study's finding that fishing mortality (F) was higher than natural mortality (M). Fish populations typically exposed two types of mortality including fishing mortality from harvesting activities and natural mortality from disease, predation and environmental causes.

The present results are comparable with those reported by [5] for *C. carpio* from Lake Karamik. Variations in mortality estimates among different water bodies may occur due to differences in growth rate, food availability, environmental conditions and fishing intensity [31]. Similar findings, correlating increased exploitation of economically significant fish stocks to higher fishing mortality, have been documented in a number of fisheries studies (Pauly, 1980).

3.3 Recruitment pattern

The recruitment pattern of *Cyprinus carpio* was determined by the ELEFAN II analysis [28], with the separation of the normal distribution of recruitment peaks using the NORMSEP program. The analysis indicated that the species is recruited into the fishery once annually. The recruitment pattern showed a major recruitment peak during August-September, with recruitment activity beginning earlier in March-April (Fig. 4).

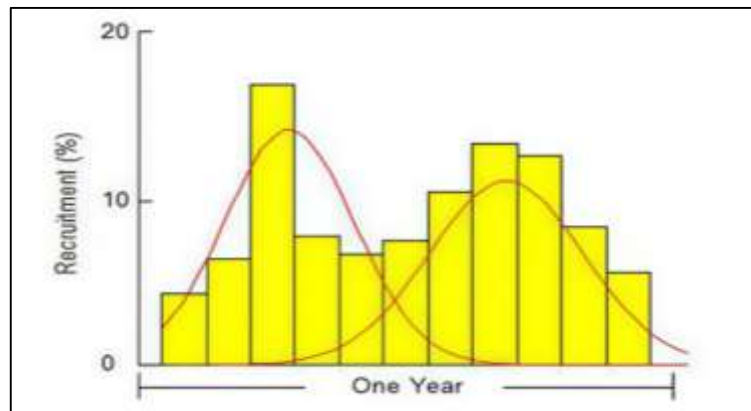


Fig. 4. Recruitment pattern of *Cyprinus carpio*

The current study's recruitment pattern indicates that *C. carpio* enters the fishery once a year, with a noticeable increase in recruitment occurring between August and September. The sustainability and abundance of fish populations in natural water bodies are significantly influenced by recruitment variation. Fish population recruitment patterns can be greatly influenced by environmental factors such as water temperature, food availability, spawning success and habitat conditions [40], [39]. Stronger recruitment peaks in the fisheries may arise from favourable environmental conditions during spawning and early life stages, which may improve juvenile survival rates.

3.4 Virtual population analysis

The length-structured virtual population analysis (VPA) of *Cyprinus carpio* from the Ottu reservoir showed that catches were very low in the smaller size groups (<150 mm). Moderate catches were observed in the range of 180–250 mm, while the highest catches were recorded between 250–300 mm (Fig. 5). Individuals larger than 300 mm were relatively low, indicating that very few fish survive to larger size classes. The analysis also indicates that survival rate was highest in the smaller size group and gradually declined with increasing fish size.

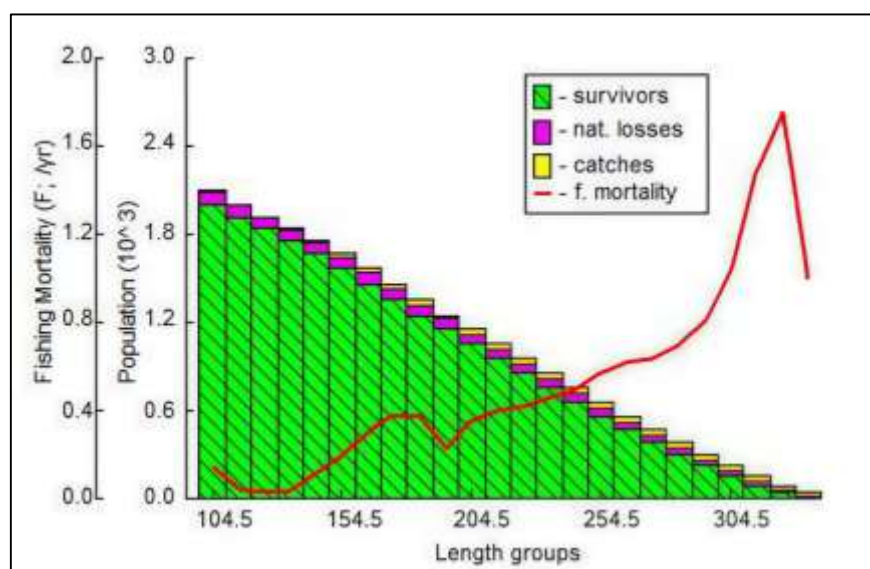


Fig. 5: Length structured VPA output for *Cyprinus carpio* from Ottu reservoir

The length-structured VPA results indicate that the majority of the catches was concentrated in the 250–300

mm size group, whereas individuals over 300 mm size were relatively low. This pattern suggests higher fishing pressure on larger individuals, which may reduce the proportion of older and larger fish in the population. In fisheries stock assessment, virtual population analysis is frequently used to rebuild past population sizes and identify trends of exploitation based on catch data [41], [34]. VPA helps fisheries managers create sustainable harvesting plans by providing important insights into stock structure and fishing mortality through the analysis of catch size or age composition [1].

3.5 Selection pattern/probability of capture

The probability of capture analysis for *Cyprinus carpio* indicated that the lengths corresponding to 25%, 50% and 75% probability of capture (L_{25} , L_{50} and L_{75}) were 271.26 mm, 296.15 mm and 307.71 mm respectively (Fig. 6). The length at first capture (L_c) was estimated at 296.15 mm (L_{50}), indicating the size at which 50% of the fish become vulnerable to the fishing gear used in the study area.

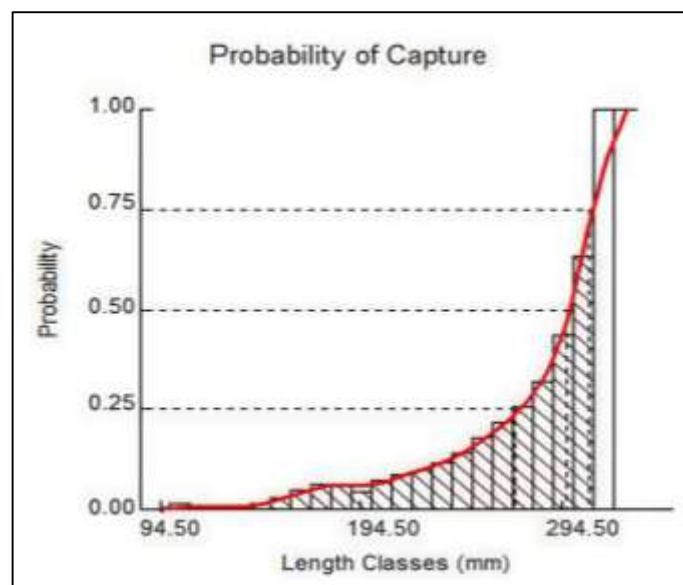


Fig. 6: Probability of capture of *Cyprinus carpio*

The majority of *C. carpio* individuals are harvested only after reaching a comparatively higher body size, based to the estimated length at first capture ($L_c = 296.15$ mm). This could assist ensure that fish have the chance to develop and contribute to the fishery before their capture. Because it represents the selectivity of fishing gear and the pattern of fish population exploitation, length at first capture is a crucial measure in fisheries management [35].

Comparable selectivity patterns where fishing gear targets medium to larger size groups have been documented in similar studies on cyprinid fish. For example, [5] observed that fishing methods and gear selectivity led the length at first capture of *Cyprinus carpio* in Lake Karamik (Turkey) to occur at larger size classes. Similarly, the mesh selectivity of fishing gear used in inland fisheries is reflected in [1] finding that the chance of catch increases gradually with fish size. In order to enable sustainable fishery management and long-term stock stability, it is crucial to regulate mesh size and fishing effort appropriately to ensure that fish achieve sufficient growth and reproductive phases prior to capture.

3.6 Exploitation ratio

The relative yield-per-recruit (Y'/R) and Biomass-per-recruit (B'/R) for *Cyprinus carpio* were calculated as a function of L_c/L_∞ and M/K , which were 0.80 and 1.01, respectively. The reference exploitation rates E_{10} ,

E_{50} and E_{max} were estimated to be 0.35, 0.447 and 1.00, respectively (Fig. 7).

The present study revealed that the value of the exploitation rate (E) was 0.63, which indicating that the fishing mortality exceeds the optimum exploitation level. The yield-per-recruit model further showed that the present exploitation level lies above the optimum reference point (E_{50}).

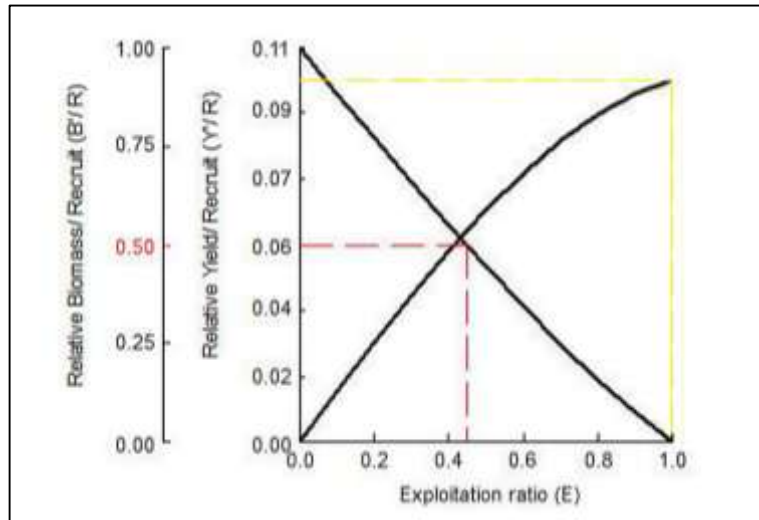


Fig. 7: Relative yield per recruit and biomass per recruit of *Cyprinus carpio*

The *C. carpio* stock in Ottu Reservoir may be subject to overexploited because the estimated exploitation rate ($E = 0.63$) in the current study is higher than the generally advised sustainable limit of 0.5. The fish stock is commonly regarded as being under excessive fishing pressure when the exploitation rate is greater than 0.5, according to [42]. Excessive levels of exploitation may lower recruitment potential and spawning biomass, which could eventually result in a decrease in stock abundance. Similar findings have been shown in a number of fisheries, where increased fishing pressure led to lower stock productivity [20], [18], [7]. Therefore, to ensure the sustainable exploitation of *C. carpio* in Ottu Reservoir, suitable management measures are required, such as limiting fishing effort, ensuring spawning seasons and imposing suitable mesh sizes.

4. Conclusion

The present study provides essential information on the Ottu Reservoir's *Cyprinus carpio* population dynamics and state of exploitation. The mortality study revealed that fishing mortality exceeded natural mortality, indicating significant fishing pressure on the population, whereas the estimated growth parameters indicated the species' moderate growth performance. The probability of capture indicated that most individuals are harvested after attaining an appropriate body size and recruitment analysis revealed a single annual recruitment peak. The population may be overexploited, nevertheless, as the calculated exploitation rate ($E = 0.63$) exceeded the suggested sustainable limit. Therefore, to ensure the sustainable use and long-term conservation of *C. carpio* in the Ottu Reservoir, proper fisheries management techniques are required, such as reducing fishing effort, protecting spawning periods and maintaining optimum mesh sizes.

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