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Population Assessment of Braond-Snout *Chondrostoma regium* using Specialist Technical Methods in Orontes River (Syria)

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Abstract

A thorough collection of 619 specimens of *Chondrostoma regium*, commonly known as the Brond-snout, was carried out in the Orontes River (a middle-reach) over a 12-month period from March 2023 to March 2024. Advanced analytical techniques, including artificial neural networks and fuzzy logic, were employed to examine these samples. The largest individual captured during the study measured 26.5 cm in length and was estimated to be seven years old. By applying the von Bertalanffy growth model to the total length data, the equation TLt = 33.43 ($^{1-e-0.207(t+0.647)}$) was established, indicating negative allometric growth (b = 2.97). The growth performance index (Φ') was calculated to be 2.36.

Additionally, various mortality coefficients for *Chondrostoma regium* were estimated, which included: Z = 1.10 y^{-1} (total mortality rate), F = 0.51 y^{-1} (fishing mortality rate), M = 0.59 y^{-1} (natural mortality rate), and E = 0.46 y^{-1} (exploitation rate). The survival coefficient (S) was noted to be 0.33 y^{-1}. Analysis of the fishing population growth (FP) of *Chondrostoma regium* in the Orontes River yielded a value of 33.1, suggesting a moderate growth rate within the local aquatic environment. However, the study also identified a fishing vulnerability (FV) for the population at 50.8.

The findings from this research offer important insights into the population dynamics of *Chondrostoma regium* in the Orontes River. The study concludes that sustainable management of this species necessitates the implementation of conservation measures. Furthermore, these results enhance our understanding of the growth, mortality, and fishing vulnerability of *Chondrostoma regium*, providing a solid foundation for future research and management strategies.

Keywords: *Chondrostoma regium*; Expert system; Growth; Vulnerability

Introduction

The *Chondrostoma regium* is a benthopelagic species and inhabits both still (lentic) and flowing (lotic) aquatic environments [1]. They reproduce during the period extending from late February to May, where the females lay their eggs on the shallow gravel edges of the river. *Chondrostoma regium* fish are native and endemic species found in Orontes River [2].

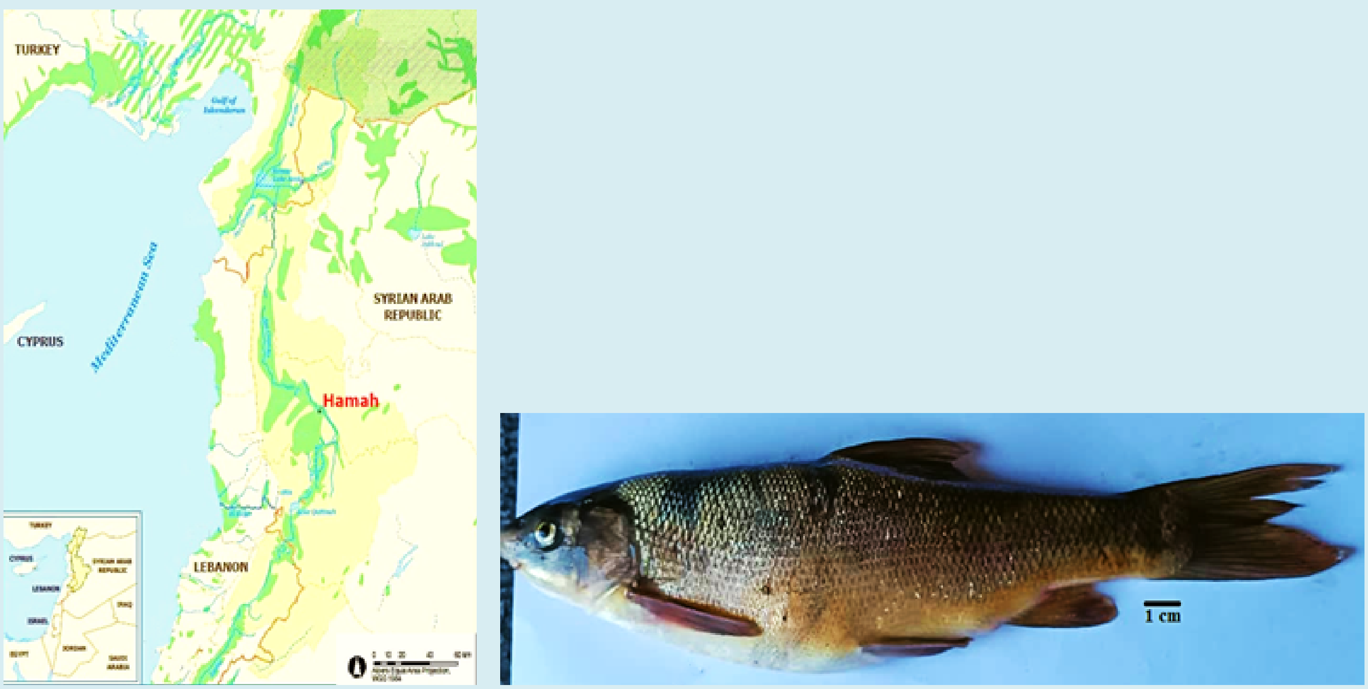
Chondrostoma regium underwent its latest assessment for inclusion on the IUCN Red List in 2013, at which time it was categorized as Least Concern [3].

Determining the age of fish using traditional methods can be challenging and typically requires skilled experts to analyze the annual growth rings. Recent studies, however, have shown that convolutional neural networks (CNNs) are capable of accurately predicting fish age by analyzing otolith images [4]. In the northwest Atlantic Ocean, have used high-resolution X-ray computed tomography to analyze vertebral centra for the purpose of estimating fish age, along with various growth models to analyze growth patterns [5]. Additionally, the maturity and age of several fish species, including *Gymnura altavela*, *Thunnus thynnus*, *Epinephelus aeneus*, *Siganus luridus*, *Seriola dumerili*, and *Pomadasys stridens*, have been effectively predicted with a specific setup of a Multilayer Perceptron artificial neural network model with a specific configuration [6-12]. Several studies have utilized contemporary methods, including expert systems, to evaluate various facets of fish vulnerability and conservation threats. This involves using a fuzzy logic expert system to assess the inherent vulnerability of marine fish to extinction due to fishing activities [13], applying an expert system to evaluate the vulnerability and conservation risks of marine species resulting from fishing activities [14]. This involves utilizing a fuzzy logic-based expert system to assess the inherent vulnerability of marine fish to extinction due to fishing practices [15], and assessing the vulnerability of particular Sparidae species in the eastern part of the Mediterranean Sea (off the Syrian coast) through the fuzzy logic approach [16]. Additionally, a model has been suggested to estimate the growth of fishery populations using an expert system grounded in fuzzy logic [17].

The biological features of the *Chondrostoma regium* species found in the Orontes River remain largely unexplored. This research initiative intends to fill this knowledge gap by investigating the growth patterns and vulnerability to fishing operations of this particular Cyprinidae fish. To this end, the study employed advanced analytical techniques, including fuzzy logic and artificial neural networks, within an expert system framework. Through this groundbreaking investigation, the researchers seek to acquire more profound insights into the characteristics of *Chondrostoma regium* and its interactions with fishing activities.

Materials and Methods

A thorough gathering of 619 specimens of *Chondrostoma regium* was conducted, commonly referred to as the Brond-snout, was conducted in the Orontes River (middle stream) (Figures 1a & 1b). From March 2023 to March 2024, a range of fishing techniques was implemented over the course of 12 months, including gill nets and fishing rods.



(a) **(b)**

Figure 1: a. Orontes River (a middle-reach river, Hamah). b. Female individual of *Chondrostoma regium* with a total length of 26.5cm.

Age and Maturity

Recent investigations by Hamwi [6] utilized an artificial neural network (Multilayer Perceptron) model with a specific configuration (1, 10, 2) to predict the age and maturity of the *Chondrostoma regium* species. This updated network model employed the fish's total length as the input parameter (Figure 2).

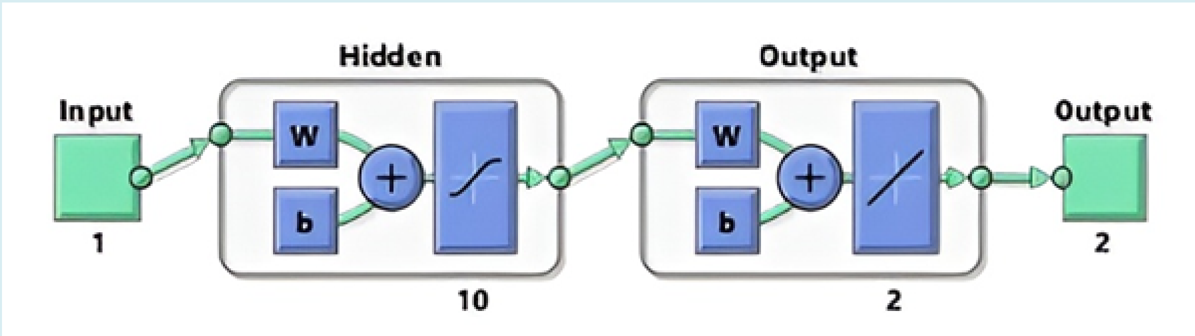


Figure 2: Artificial neural network, multilayer perceptron (MLP).

Fishing Population Growth (FP)

In an earlier study, Hamwi, et al. [17] designed a system utilizing fuzzy logic to assess the population growth of *Chondrostoma regium* in the Orontes River. This model incorporated distinct parameters (K, Tr, M, E) for input and utilized fuzzy logic methodologies for analysis and interpretation (Figure 3).

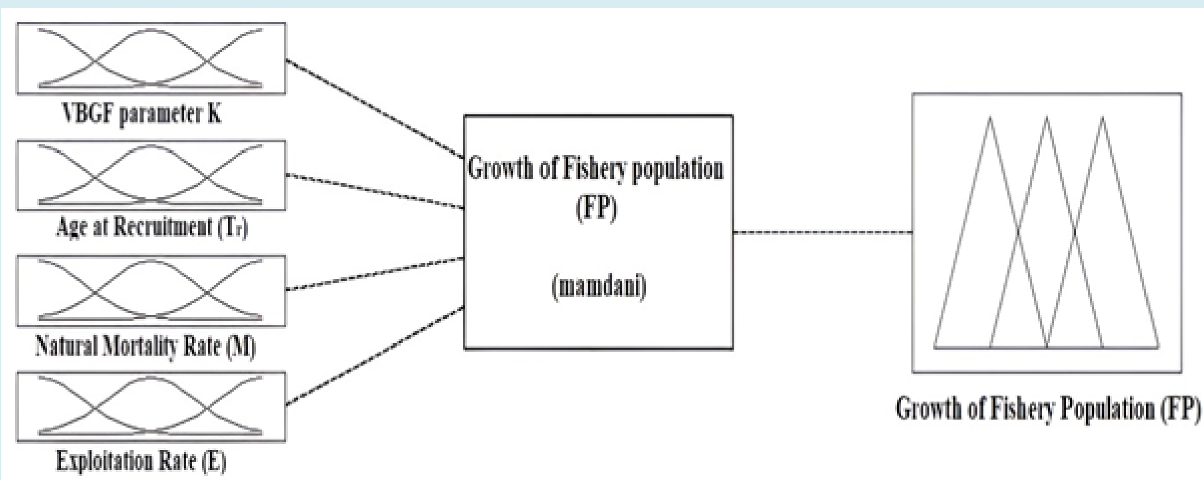


Figure 3: Fuzzy inference system variables (Inputs: K, Tr, M, E; Output: FP).

The von Bertalanffy equation was employed to determine the growth parameters (K, L_∞), and the Akaike Information Criterion (AIC) [AIC = N ln (WSS) + 2M] guided the selection of the appropriate growth model. In this equation, N represents the number of data points, WSS is the squares' weighted sum of residuals, and M denotes the number of model parameters. The study aimed to compare various growth models that illustrate the characteristics of the fish species [18]. The growth model of von Bertalanffy is utilized as follows: $L_t = L_\infty / [1 + e^{-K(t-t0)}]$.

Where L_t refers to the total length of the fish at a given age (t), L_∞ represents the hypothetical asymptotic total length (in cm) that the fish could potentially achieve, and K denotes the growth coefficient, and the theoretical age when the fish's length is assumed to be zero is t_0.

The total mortality rate (Z) was utilized in the Ricker method [19]. This method included calculating the regression equation for the catch curve (ln N_t = a - Zt) for the entire population.

By employing a specific relationship, the natural mortality rate (M) was determined:

$\text{Log } M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$ [20]

Where: L_∞ and K were used, along with the average surface water temperature (T) of 24.9°C in the fishing area.

The natural mortality rate (M) subtracted from the total mortality rate (Z) yields the fishing mortality rate (F) [21]: $F = Z - M$

The exploitation rate (E) was determined using the equation: $E = F/Z$ [22]

The survival rate (S) was calculated using the equation: $S = e^{-Z}$ [19].

Beverton and Holt's [23] equations were used to calculate the total length (L_c) and age (T_c) at first capture: $L_c = L' - [\, K (L_\infty - L') / Z \,]$; $T_c = -(1/K) * \ln (1 - L_c / L_\infty) + t_0$

Where L' represents the captured fish's average total length.

Similarly, Beverton and Holt's [23] equations were employed to determine the total length (L_r) and age (T_r) at recruitment: $L_r = L' - [\, K (L_\infty - L_0) / Z \,]$; $T_r = -(1/K) * \ln (1 - L_r / L_\infty) + t_0$

Where L0 denotes the total length of the fish at hatching or age zero.

Pauly, et al. [21] suggested a formula to calculate a growth performance index, represented as Φ', which reflects the growth characteristics of an organism: $\Phi' = \log K + 2 \log L_\infty$.

Building on the earlier work of Beverton and Holt [24], the relative yield-per-recruit (Y'/R) can be modelled as: $Y'/R = [E * U^{(M/K)}] * [1 - (3U / (1 + m)) + (3U^2 / (1 + 2m)) - (U^3 / (1 + 3m))]$

Where U, m, and E are defined as follows: $U = 1 - (L_c/L_\infty)$

$m = (1-E) / (M/K) = (K/Z)$

$E = F/Z$

Ricker [19] provided a relationship to estimate the relative biomass-per-recruit (B'/R):

$B'/R = (Y'/R) / F$

Fishing Vulnerability (FV)

Hamwi, et al. [16] constructed an expert system model that takes key parameters (TL_{max}, K, T_{max}, M, S) as inputs and employs fuzzy logic techniques to analyze and evaluate the fishing vulnerability of a species, such as *Chondrostoma regium* (Figure 4).

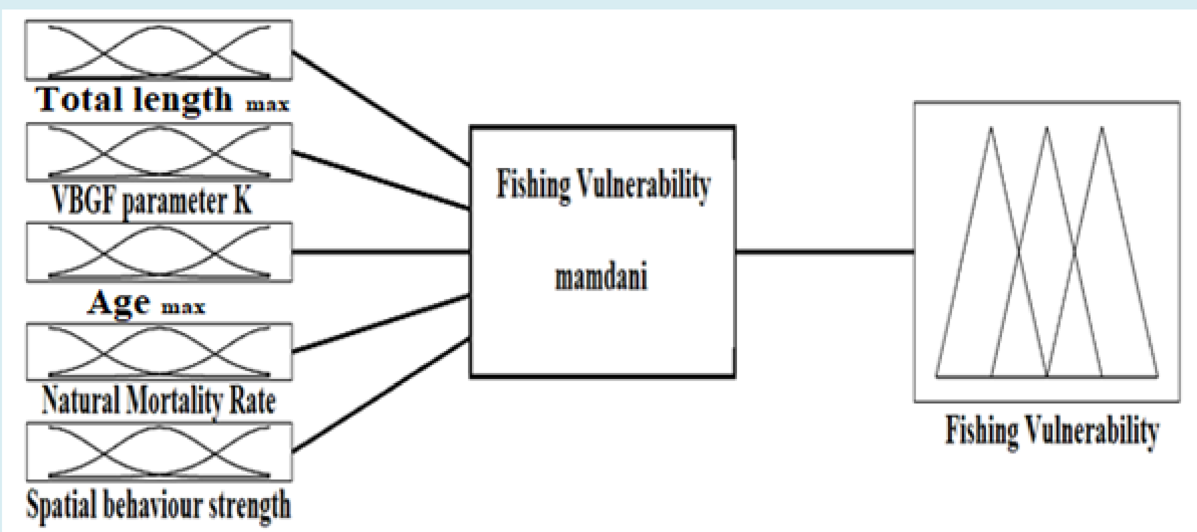


Figure 4: Variables of the fuzzy inference system (Inputs: TLmax, K, Tmax, M, S; Output: FV).

Results

Analysis of the age composition of the *Chondrostoma regium* population revealed 7 distinct age cohorts. The second age class was the most dominant, constituting 33.93% of the population. Conversely, the seventh age group represented only 0.16% of the overall catch (Figure 5a & 5b).

An analysis of the distribution of individuals across various total length (TL) categories showed that the most dominant size classes were 11.1-12 cm and 16.1-17 cm, constituting 9.05%, and 10.34% of the population, respectively. Conversely, individuals with total lengths of 24.1-25 cm and 25.1-26.5 cm were the least represented, each comprising only 0.32% of the population (Figure 5b).

(a) **(b)**

Figure 5: a. Age composition; b. Total length frequency distribution (TL) for Chondrostoma regium in Orontes River.

The data gathered during this study revealed that the maximum total length recorded for *Chondrostoma regium* individuals in Orontes River was 26.5 cm, which was observed in individuals aged 7^+ years. In contrast, the smallest recorded total length was 7.4 cm, which corresponded to an age of 1^+ year.

The von Bertalanffy growth equation parameters for total length were as follows:

$$TL_t = 33.43\ (1 - e^{-0.207\ (t + 0.647)})$$

Statistical analysis of this growth model yielded the following results: AIC = 46.0823; WSS = 0.0182; 95% Confidence Interval = 4.3487.

Analysis of the length-weight relationship for *Chondrostoma regium* revealed a negative allometric growth pattern, with a b-value of 2.97.

The average age and total length of *Chondrostoma regium* individuals at first capture were 2.82 years and 17.10 cm, respectively. Meanwhile, the average age and total length at recruitment were 2.02 years and 14.19 cm.

Calculating the growth performance index (Φ') for total length growth of *Chondrostoma regium* yielded a value of 2.36.

The total mortality coefficient (Z) for the *Chondrostoma regium* population was estimated to be 1.10 per year. Further analysis revealed that the fishing mortality coefficient (F) was 0.51 per year, while the natural mortality (M) was 0.59 per year. The calculated survival rate (S) was 0.33 per year. The exploitation mortality coefficient (E) was 0.46 per year.

The connection between the exploitation rate (E) and the relative yield per recruit (Y'/R), along with the relative biomass per recruit (B'/R), is illustrated in Figure 6. The analysis revealed several key values:

- E_{max}: This is the exploitation rate that maximizes yield per recruit, found to be 1 y^{-1}.

- $E_{0.1}$: This value, also determined to be 1 y^{-1}, indicates the point at which the marginal gain in relative yield per recruit reaches 10% of its value when E equals 0.
- $E_{0.5}$: This exploitation rate, at which the biomass of the stock is reduced to 50% of its unexploited level, was calculated to be 0.379 y^{-1} (Figure 6).

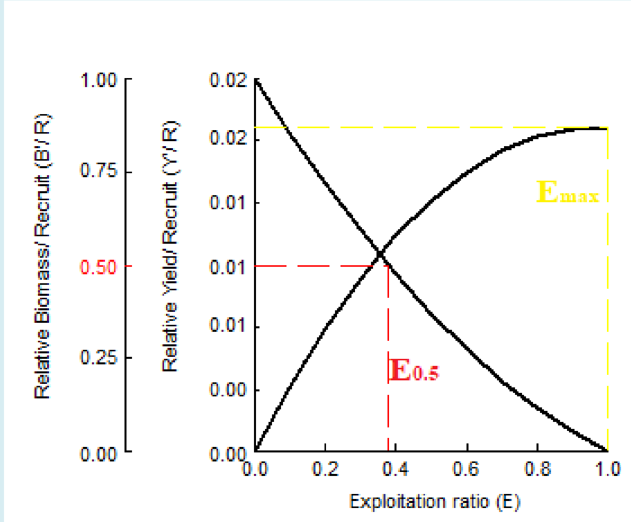


Figure 6: Relative yield per recruit (Y`/R) and biomass per recruit (B`/R) (Knife-edge selection) of *Chondrostoma regium* collected from Orontes River.

According to the fuzzy logic-based expert system developed by Hamwi, et al. [17], the growth value for the *Chondrostoma regium* population in the Orontes River was 33.1, as depicted in Figure 7.

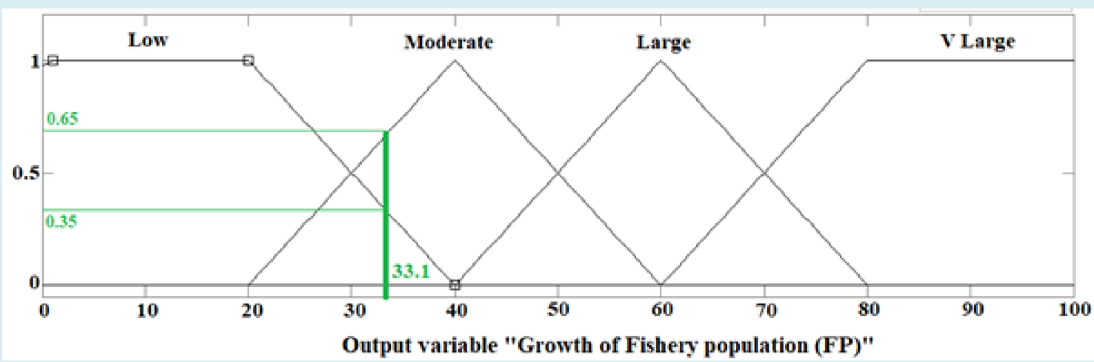


Figure 7: The growth of *Chondrostoma regium* population off the Orontes River.

The fuzzy logic-based expert system developed by Hamwi, et al. [16] also revealed that *Chondrostoma regium* had a fishing vulnerability of 50.8, with the maximum vulnerability value (FV) set at 100, as shown in Figure 8.

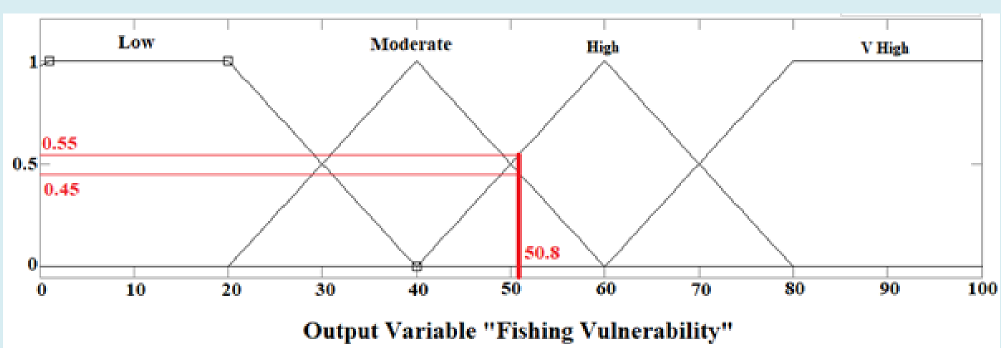


Figure 8: The vulnerability of *Chondrostoma regium* to fishing off the Orontes River.

Discussion

This study illuminates the reproductive dynamics of *Chondrostoma regium* in the Orontes River, where the observed lengths are comparable to those found in Almus Dam Lake (Turkey), ranging from 13.7 to 28.1 cm [1]. These lengths are slightly larger than those recorded in the Bibi-Sayyedan River (Iran), which reached a total length of 22 cm [25], and in Seyhan Dam Lake (Adana), where total lengths reached 23.55 cm [26]. The variability in *Chondrostoma regium* population sizes across these geographically distinct areas suggests that different environmental and ecological factors significantly influence the life history and dynamics of this species.

The growth coefficient (b) estimated for the *Chondrostoma regium* population in this study was 2.97, indicating a negative allometric growth pattern. This suggests that the total length of the fish increases at a relatively slower rate compared to other morphological dimensions (e.g., body weight) as the individual grows.

The negative allometric growth exhibited by *Chondrostoma regium* populations in this study is consistent with previous findings from the Zayandeh Roud River in Iran where the growth coefficient was reported as 2.77 [27] and from Tishreen Lake (Euphrates River) in Syria where it was 2.422. However, this contrasts with the positive allometric growth (b=3.281>3) reported for this species in the Almus Dam Lake of Turkey [1]. These differences in growth patterns may be related to variations in environmental conditions, resource availability, and population demographics across the different study locations.

The growth values indicate low growth at 0.35 and moderate growth at 0.65, based on a maximum fishery population growth (FP) value of 100 (Figure 7).

The ratio of the first capture's length (L_c) to the asymptotic length (L_∞) is a significant indicator for evaluating the exploitation status of a fish population. According to Pauly, et al. [28], a ratio of L_c/L_∞ greater than 0.5 indicates that most of the catch comprises mature individuals of the species.

In the present study, the estimated L_c/L_∞ ratio for the *Chondrostoma regium* population was 0.51. This value indicates that the current harvest in the *Chondrostoma regium* fishery mainly comprises mature fishes rather than juvenile individuals.

The prevalence of adult fish in the catch is often an indicator of overfishing, as evidenced by the calculated mortality coefficients and fishing vulnerability, which show a significant increase (50.8). This vulnerability value indicates a moderate vulnerability of 0.45 and a high vulnerability of 0.55 for this species (Figure 8), which is somewhat different from the low to moderate vulnerability of 30 reported by Froese, et al. [29].

Conclusions

This study provides valuable insights into the population dynamics of *Chondrostoma regium* in the Orontes River, highlighting the need for conservation efforts to ensure the sustainable management of this species. The findings enhance our understanding of *Chondrostoma regium*'s growth patterns, mortality rates, and vulnerability to fishing, establishing a foundation for future research and management strategies.

The outcomes of this research hold significant implications for the management of the *Chondrostoma regium* fishery in the Orontes River. Overfishing can severely impact the population's ability to sustain itself, leading to declining abundances. Consequently, the implementation of management strategies that minimize the catch of *Chondrostoma regium* and ensure the long-term sustainability of the fishery is of utmost importance.

Acknowledgment

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