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Assessment of Population Growth and Fishing Vulnerability of *Pomadasys stridens* along the Syrian Coast (Eastern Mediterranean Sea)

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Abstract

Between January 2023 and March 2024, 647 distinct *Pomadasys stridens* specimens were captured in the coastal waters of Syria in the eastern Mediterranean Sea. Advanced analysis techniques, such as artificial neural networks and fuzzy logic, were applied to these samples. During the study, the largest captured individual was 19.17 cm long and was estimated to be 8 years. By applying the von Bertalanffy growth equation to the total length data, had derived the formula $TLt = 21.53\ (1\text{-}e^{-0.23\ (t + 1.29)})$, which indicates positive allometric growth (b = 3.08). The growth performance index (Φ') was calculated as 2.03, providing a measure of growth efficiency. The study also estimated various mortality coefficients for *Pomadasys stridens*. The coefficients were as follows: $Z = 0.92\ y^{-1}$ (total mortality rate), $F = 0.23\ y^{-1}$ (fishing mortality rate), $M = 0.69\ y^{-1}$ (natural mortality rate), and $E = 0.25\ y^{-1}$ (exploitation rate). The survival coefficient (S) was determined to be $0.40\ y^{-1}$. Analysis of the population growth (FP) of *Pomadasys stridens* from the Syrian coast, a value of 34, indicated a moderate growth rate within the local marine environment. However, the study also found that fisheries were exploited at a fishing vulnerability of 50.9.

The population dynamics of *Pomadasys stridens* in Syrian seawater can be gleaned from the findings of this study. The sustainable management of this species requires the implementation of conservation measures, according to them. In addition, the results enrich our knowledge of *Pomadasys stridens'* growth, mortality, and vulnerability to fishing, creating the basis for future research and management strategies.

Keywords: Expert System; Growth; *Pomadasys stridens*; Syrian Water; Vulnerability

Abbreviations

CNNs: Convolutional Neural Networks; MLP: Multilayer Perceptron; FP: Fishing Population Growth; DW: Disc Width; FV: Fishing Vulnerability.

Introduction

Pomadasys stridens, also known as the striped piggy or lined piggy, is a species of grunt fish that originates from the western Indian Ocean. It is one of many Indo-Pacific marine organisms that have expanded their range into the Mediterranean Sea through the Suez Canal, a process referred to as Lessepsian migration [1].

This fish has a wide geographic distribution and is commonly found inhabiting coastal areas with soft seafloor habitats. In certain regions, *Pomadasys stridens* can be quite abundant [2].

The most recent assessment of *Pomadasys stridens*' conservation status was conducted by the IUCN in 2018. Based on this evaluation, the species is classified as Least Concern, indicating it is not currently considered threatened [3,4].

Determining the age of fish through traditional methods presents challenges and requires skilled individuals to meticulously analyze annual growth rings. However, recent research has demonstrated that convolutional neural networks (CNNs) can accurately predict fish age by analyzing images of otoliths [5]. In the northwest Atlantic Ocean, researchers have employed high-resolution X-ray computed tomography to examine vertebral centra and estimate fish age. Multiple growth models have also been utilized to study growth patterns [6].

The age and maturity of Epinephelus aeneus, Thunnus thynnus, Gymnura altavela, Siganus luridus, and Seriola dumerili were effectively estimated using a Multilayer Perceptron neural network model configured as (1, 10, 2) [7-12].

Various studies have utilized modern methodologies, such as expert systems, to assess different aspects of fish vulnerability and conservation risks. These include:

- The utilization of a fuzzy logic expert system to estimate the intrinsic vulnerability of marine fish to extinction caused by fishing [13].
- The application of an expert system to evaluate the vulnerability and conservation risks of marine species resulting from fishing activities [14].
- The use of fuzzy logic to determine the vulnerability of marine species to climate change [15].
- The estimation of the vulnerability of specific Sparidae fish species in the eastern Mediterranean Sea (Syrian coast) using the fuzzy logic approach [16].

Furthermore, a model has been proposed to estimate the growth of fishery populations using an expert system based on fuzzy logic [17].

Along the Syrian coast, the biological aspects of the *Pomadasys stridens* fish species have not been extensively researched. This study seeks to fill this knowledge gap by investigating the growth dynamics and vulnerability to fishing operations of this particular Haemulidae species. To accomplish this, the researchers have employed advanced techniques, including artificial neural networks and fuzzy logic, within an expert system framework. This study represents a groundbreaking endeavor to gain deeper insights into the characteristics of *Pomadasys stridens* and its interaction with fishing activities.

Materials and Methods

Over the period from January 2023 to March 2024, a comprehensive collection of 647 specimens of *Pomadasys stridens*, commonly referred to as the striped piggy, was conducted along the Syrian coastline. A variety of fishing methods, including Trammel nets, Gill nets, were utilized to obtain these specimens (Figures 1A & 1B).

Figure 1A: *Pomadasys stridens*.

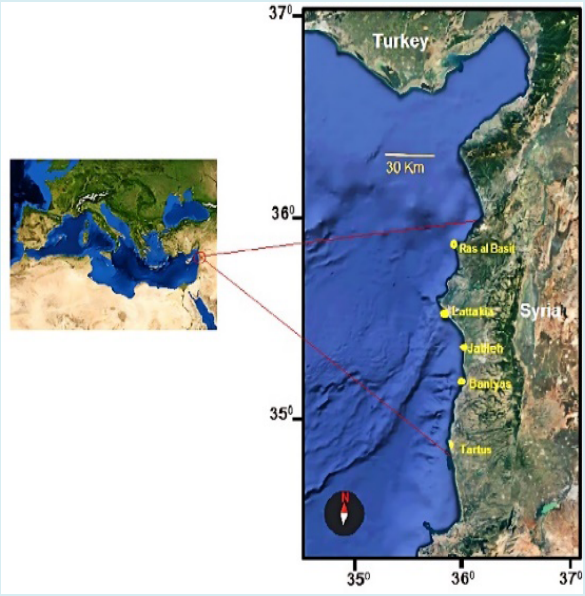

Figure 1B: Syrian coast (Eastern Mediterranean Sea).

Age and maturity

The research carried out by Hamwi [7,8] utilized a Multilayer Perceptron artificial neural network model with a (1, 10, 2) configuration to estimate the maturity and age of the *Pomadasys stridens* species. This updated network model used the total length of the fish as the input parameter (Figure 2).

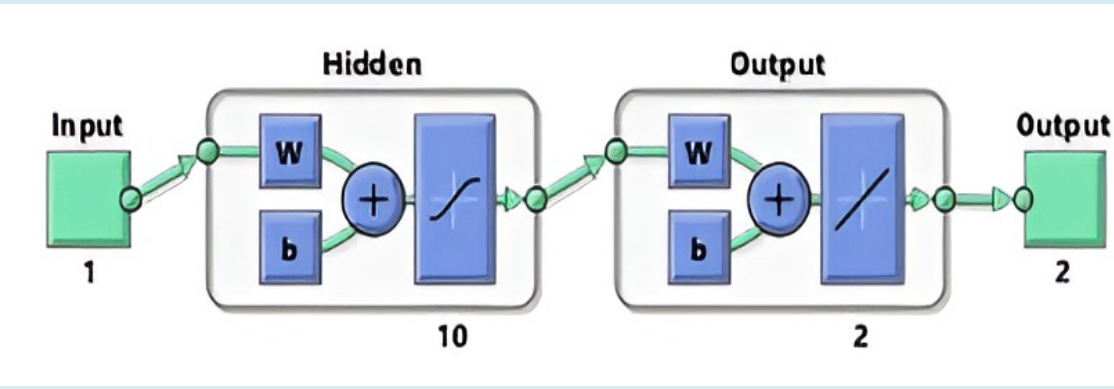

Figure 2: Artificial neural network, multilayer perceptron (MLP).

Fishing population growth (FP)

Hamwi, et al. [17] developed an expert system model based on fuzzy logic to estimate the growth of the *Pomadasys stridens* population along the Syrian coast. The model used specific parameters (K, Tr, M, E) as inputs and applied fuzzy logic techniques to analyze and interpret the data (Figure 3).

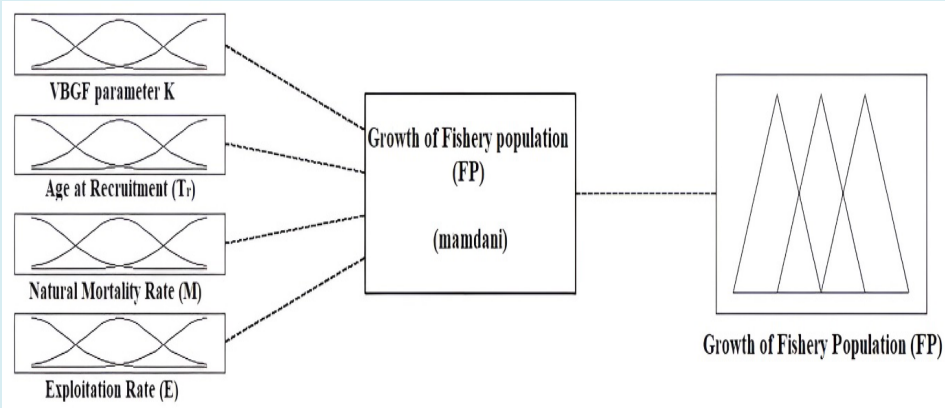

Figure 3: Fuzzy inference system variables (Inputs: K, Tr, M, E; Output: FP).

The von Bertalanffy equation was employed to determine the parameters (K, TL_{∞}), 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 weighted sum of squares of residuals, and M denotes the number of model parameters. The study aimed to compare different growth models that describe the characteristics of the fish species [18].

$$TL_t = TL_{\infty} / [1 + e^{-K(t-t0)}]$$

Here, TL_t refers to the total length of the fish at a specific age (t), while TL_{∞} represents the hypothetical asymptotic total length (cm) that the fish can potentially reach. The growth coefficient is denoted by K, and t_0 represents the theoretical age at which the length of the fish is assumed to be zero.

The Ricker method Ricker WE, et al. [19] was utilized to estimate the total mortality rate (Z). This method involved calculating the regression equation for the catch curve ($\ln N_t = a - Z_t$) throughout the entire population.

The natural mortality rate (M) was determined by employing a specific relationship:

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

The von Bertalanffy parameters TL_{∞} and K were used, along with the average surface water temperature (T) of 23.45 °C in the fishing area.

The fishing mortality rate (F) was determined by calculating the difference between the total mortality rate (Z) and the natural mortality rate (M) [21]: $F = Z - M$.

The exploitation rate (E) was computed using the formula $E = F / Z$ [22].

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

The total length (TL_c) and age (T_c) at first capture were calculated using equations proposed by Beverton and Holt [23]:

$$TL_c = TL' - [K (TL_{\infty} - TL') / Z]$$
$$T_c = - (1/K) * \ln (1 - TL_c / TL_{\infty}) + t_0$$

Where TL' refers to the average total length of the captured fish.

The total length (TL_r) and age (T_r) at recruitment were determined using the equations proposed by Beverton and Holt [23]:

$$TL_r = TL' - [K (TL_{\infty} - TL0) / Z]$$
$$T_r = - (1/K) * \ln (1 - TL_r / TL_{\infty}) + t_0$$

Where TL_0 represents the total length of the fish at the moment of hatching or age zero.

The growth performance index (Φ_{TL}`) was calculated using the equation proposed by Pauly and Munro [21]: $\Phi_{TL}` = \log K + 2\log TL_{\infty}$

The relative yield-per-recruit (Y'/R) model, derived from the Beverton and Holt model [24], is:

$$Y'/R = [E * U^{(M/K)}] * [1 - (3U / (1 + m) + (3U^2 / (1 + 2m) - (U^3 / (1 + 3m)]$$

Where: $U = 1-(L_c/L_{\infty})$; $m = (1-E) / (M/K) = (K/Z)$; $E = F/Z$.

The estimation of relative biomass-per-recruit (B'/R) is derived from the following relationship [21]: $B'/R = (Y'/R) / F$.

Fishing Vulnerability (FV)

To evaluate the vulnerability of *Pomadasys stridens* to fishing, the model developed by Hamwi and Ali-Basha [16] was utilized. This expert system utilized specific parameters (TL_{max}, K, T_{max}, M, S) as inputs and employed fuzzy logic techniques to analyze and assess the fishing vulnerability of the species (Figure 4).

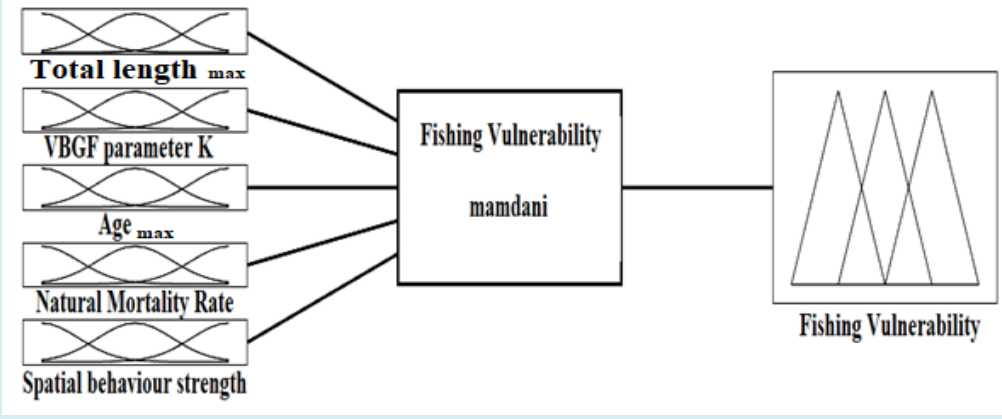

Figure 4: Fuzzy inference system variables (Inputs: TL_{max}, K, T_{max}, M, S; Output: FV).

Results

The analysis of the age composition of the *Pomadasys stridens* population revealed the presence of 8 distinct age groups. The third age group was the most dominant, accounting for 28.59% of the total population. In contrast, the eighth age group represented only 0.31% of the overall catch, indicating a long lifespan for this species along the Syrian coast (Figures 5A & 5B).

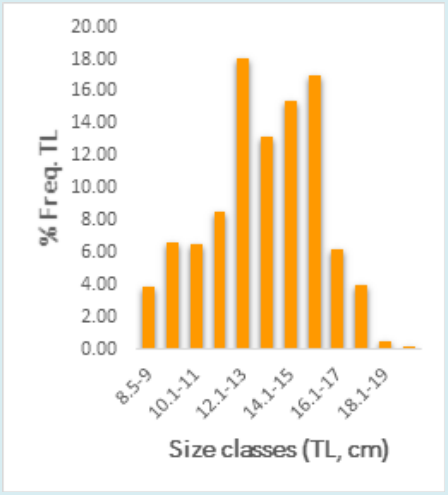

Figure 5A: Disc width frequency distribution (DW).

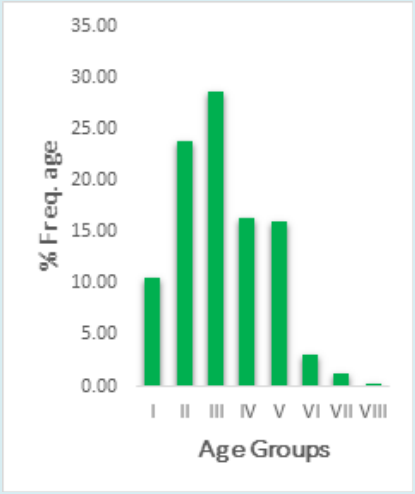

Figure 5B: Age composition for *Pomadasys stridens* in Syrian waters.

Examining the distribution of individuals across different total length (TL) categories, it was observed that the most prevalent size classes were those ranging from 12.1-13 cm and 15.1-16 cm, each comprising 18.08% and 17% of the population, respectively. In contrast, individuals with total lengths of 19.1-19.5 cm were the least represented, making up only 0.15% of the population.

The data collected within the scope of this study revealed that the maximum total length attained by *Pomadasys stridens* individuals along the Syrian coast was 19.17 cm, which was observed in 8 years. Conversely, the smallest recorded total length was 8.73 cm, corresponding to a 1^{+} year.

The von Bertalanffy growth equation parameters for total length were calculated as follows: $TL_t = 21.53\ (1 - e^{(-0.23\ (t + 1.29))})$.

The statistical analysis of this growth model yielded: AIC = 28.5021; WSS = 23.45; 95% Confidence Interval = 1.84.

The growth coefficient (k) derived from the von Bertalanffy equation for *Pomadasys stridens* was 0.09.

The length-weight relationship exhibited a positive allometric growth pattern (b = 3.08) for *Pomadasys stridens*.

The average age and total length of *Pomadasys stridens* individuals at first capture were 2.93 years and 13.38 cm, respectively. The average age and total length at recruitment were 1.82 years and 11.01 cm, respectively.

The growth performance index (Φ') for the total length growth of *Pomadasys stridens* was calculated to be 2.03.

The total mortality coefficient (Z) of *Pomadasys stridens* was estimated to be 0.92 per year. The fishing mortality coefficient (F) and natural mortality (M) were calculated as 0.23 per year and 0.69 per year, respectively, resulting in a survival rate (S) of 0.40 per year. The exploitation mortality coefficient (E) was found to be 0.25 per year.

The relationship between exploitation rates (E) and relative yield per recruit (Y'/R) as well as relative biomass per recruit (B'/R) is depicted in Figure 6. The exploitation rates considered ranged from 0.05 to 1.00.

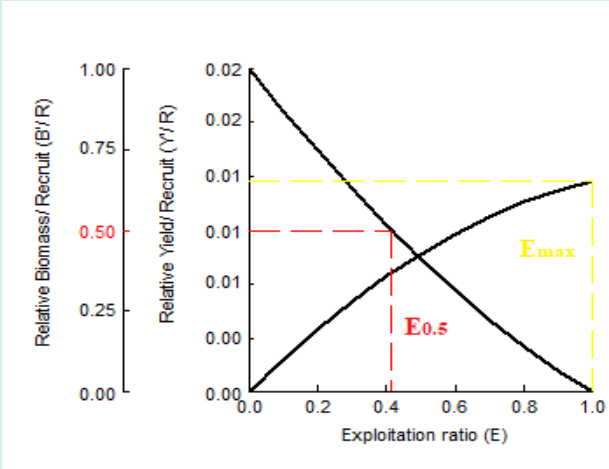

Figure 6: Relative yield per recruit (Y`/R) and biomass per recruit (B`/R) (Knife-edge selection) of *Pomadasys stridens* collected from Syrian coast.

The Analysis Identified Several Significant Values

- Emax, the exploitation rate that leads to maximum yield per recruit, was calculated as 1 y-1.
- The exploitation rate E0.1 was calculated as 1 y-1, where the marginal increase in relative yield-per-recruit reaches one-tenth of its value at E = 0.
- E0.5, the exploitation rate at which the stock's biomass has been reduced to 50% of its unexploited state, was 0.416 y-1.

The fuzzy logic-based expert system proposed by Hamwi, et al. [17] generated a growth value of 34 for the *Pomadasys stridens* population along the Syrian coast. This value corresponds to a moderate growth of 0.65 and a low growth of 0.35, given a maximum fishery population growth (FP) value of 100 (Figure 7).

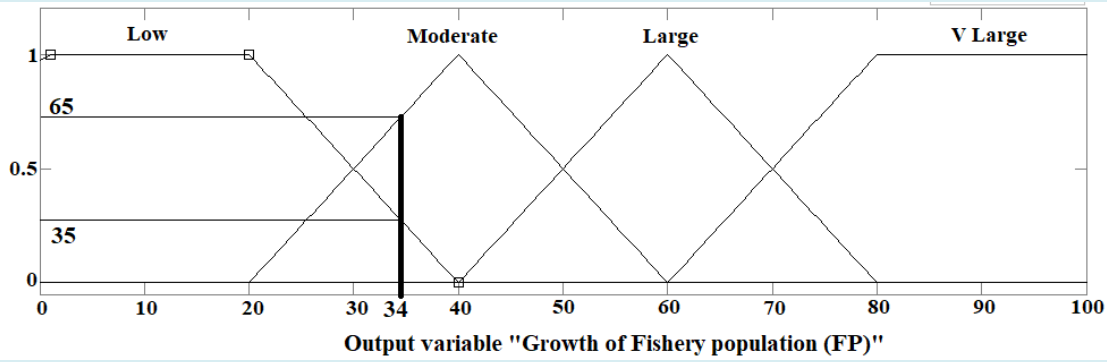

Figure 7: The growth of *Pomadasys stridens* population off the Syrian coast.

According to the expert system (fuzzy logic) developed by Hamwi, et al. [16], *Pomadasys stridens* demonstrated a fishing vulnerability of 50.9 FV, with the maximum vulnerability value (FV) being 100. This value indicates a high vulnerability of 0.55 and a moderate vulnerability of 0.45 (Figure 8).

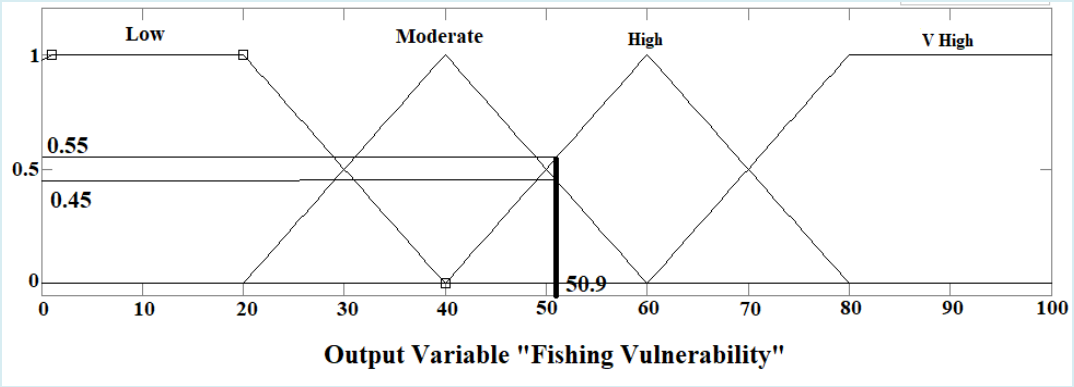

Figure 8: The vulnerability of *Pomadasys stridens* to fishing off the Syrian coast.

Discussion

This study found that *Pomadasys stridens* from the Syrian coast were longer than those from the Gulf of Alexandretta in the northeastern Mediterranean. The total lengths ranged from 7.3 cm to 18.9 cm, with an average of 12.32 cm at seven years of age [25]. In contrast, *Pomadasys stridens* from the Karachi coast of Pakistan were even longer, with the maximum observed total length being 21 cm [26] (Table 1).

The hypothetical maximum or asymptotic total length achieved by this species appears to vary by geographic region. Avşar, et al. [25] estimated it to be 22.01 cm in the Gulf of İskenderun, while Osman, et al. [27] reported a lower value of 20.4 cm in the Suez Gulf. The present study determined the asymptotic total length for this species to be 21.53 cm.

These differences in the hypothetical asymptotic total length may be attributable to a variety of factors, such as environmental conditions, habitat characteristics, fishing pressure, and genetic differences between local populations.

The growth rate of total length in *Pomadasys stridens* was assessed by utilizing the growth coefficient (k) obtained from the von Bertalanffy equation. The calculated value for the growth coefficient (k) was determined to be 0.23.

It is worth highlighting that this value appears to be relatively lower in comparison to the corresponding value of 0.29 documented in the Suez Gulf. However, it is interesting to note that the growth coefficient value of 0.23 aligns with the value of k = 0.22 observed along the Gulf of İskenderun in the northeastern Mediterranean [25].

The lower growth coefficient value of 0.23 found in the present study suggests a slower rate of total length growth for *Pomadasys stridens* compared to the faster growth rate indicated by the higher coefficient of 0.29 from the Suez Gulf region. This points to potential regional differences in growth patterns for this species.

This study provides insights into the growth characteristics of the *Pomadasys stridens* species, with a particular focus on its total length. The analysis of the data revealed a positive allometric growth pattern, as indicated by the growth coefficient (b) of 3.08. This suggests that the total length of the fish increases at a relatively faster rate compared to other morphological dimensions.

Interestingly, similar positive allometric growth patterns have been documented in other geographic regions. Specifically, growth coefficient (b) values of 3.096 and 3.24 were reported for *Pomadasys stridens* populations in the Suez Gulf and the Gulf of İskenderun, respectively [25,27].

The ratio of the length at first capture to the asymptotic length (L_c/L_∞) serves as an indicator of whether the harvested fish are predominantly juveniles or mature individuals. A ratio higher than 0.5 suggests that the majority of the catch consists of mature fish species [28]. In this study, the estimated (L_c/L_∞) ratio was 0.62, indicating that the majority of the catch in the *Pomadasys stridens* fishery mainly comprises mature fish.

Conclusion

The present study offers significant insights into the population dynamics of *Pomadasys stridens* along the Syrian coast, underscoring the significance of conservation measures in ensuring the sustainable management of this species. The findings contribute to our comprehension of *Pomadasys stridens*' growth patterns, mortality rates, and vulnerability to fishing, thereby establishing a foundation for future research and management strategies.

The outcomes of this study carry substantial implications for the management of the *Pomadasys stridens* fishery along the Syrian coast. Overfishing can profoundly affect the population's ability to sustain itself, resulting in decreased abundance. Hence, the implementation of management strategies that minimize the catch of *Pomadasys stridens* and ensure the long-term sustainability of the fishery is of utmost importance.

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