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Population Assessment of White Grouper Epinephelus aeneus Using Specialist Technical Methods Along Coastal Syrian Waters in The Eastern Mediterranean

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Abstract

The eastern Mediterranean Sea in Syria was the location of 112 different *Epinephelus aeneus* specimens captured from March 2023 to March 2024. Advanced analysis techniques, such as artificial neural networks and fuzzy logic, were applied to these samples. During the study, the largest captured individual was 105.6 cm long and was estimated to be eight years old. Applying the von Bertalanffy growth equation to the total length data, $TL_t = 136.76\ (1\text{-}e^{-0.187\ (t\ +\ 0.041)})$ was derived, indicating positive allometric growth (b = 3.19). The growth performance index (Φ') was 3.54.

The study also estimated various mortality coefficients for *Epinephelus aeneus*. The coefficients were as follows: Z = 0.55 y^{-1} (total mortality rate), F = 0.19 y^{-1} (fishing mortality rate), M = 0.36 y^{-1} (natural mortality rate), and E = 0.35 y^{-1} (exploitation rate). The survival coefficient (S) was 0.58 y^{-1}. Analysis of the population growth (FP) of *Epinephelus aeneus* from the Syrian coast, a value of 48.4, indicated a moderate growth rate within the local marine environment. However, the study also found a fishing vulnerability (FV) of the population was 61.6.

The findings of this study provide valuable insights into the population dynamics of *Epinephelus aeneus* in Syrian coast. The sustainable management of this species requires the execution of conservation measures, according to the study's conclusions. Additionally, the results enrich our knowledge of *Epinephelus aeneus*' growth, mortality, and vulnerability to fishing, creating a foundation for future research and management strategies.

Keywords: *Expert system, Epinephelus aeneus, Growth, Syrian water, Vulnerability.*

Introduction

The *Epinephelus aeneus* (white grouper) is a species of ray-finned marine fish belonging to the grouper subfamily Epinephelinae, part of the fish family Serranidae. White grouper occurred in the semitropical eastern Atlantic Ocean and the eastern and southern regions of the Mediterranean Sea (Pollard et al., 2018; IUCN, 2024).

The white grouper inhabits substrates made up of rock, mud, or sandy material. The juvenile fish are typically found in estuaries and coastal lagoons (Froese & Pauly, 2024), while the adult white groupers usually reside at depths ranging from 20 to 200 meters. (Pollard et al., 2018).

The white grouper, *Epinephelus aeneus*, was most recently evaluated for inclusion on The Threatened Species` IUCN Red List in 2016. According to this assessment, Epinephelus aeneus is called Near Threatened, based on criteria A2bd (IUCN, 2024).

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 (Ordoñez et al., 2020). In the northwest Atlantic Ocean, researchers have employed high-resolution X-ray computed tomography to examine vertebral centra and estimate fish age, while multiple growth models have also been utilized to study growth patterns (Parsons et al., 2018). The maturity and age of *Gymnura altavela* and *Thunnus thynnus* have been successfully predicted using a Multilayer Perceptron artificial neural network model with a configuration of (1, 10, 2) (Hamwi, 2024a; 2024b). Various studies have also employed modern methodologies, such as expert systems, to assess different aspects of fish vulnerability and conservation risks, including utilizing a fuzzy logic expert system to estimate the intrinsic vulnerability of marine fish to extinction caused by fishing (Cheung et al., 2005), applying an expert system to evaluate the vulnerability and conservation risks of marine species resulting from fishing activities (Cheung, 2007), using fuzzy logic to determine the marine species vulnerability to climate change (Jones and Cheung, 2017), and estimating the vulnerability of specific Sparidae fish species in the eastern Mediterranean Sea (Syrian coast) using the fuzzy logic approach (Hamwi and Ali Basha, 2019). Furthermore, a model has been proposed to estimate the growth of fishery populations using an expert system based on fuzzy logic (Hamwi et al., 2022).

The biological characteristics of the *Epinephelus aeneus* species along the Syrian coastline remain largely unstudied. This research project seeks to address this gap in knowledge by examining the growth dynamics and vulnerability to fishing operations of this particular Serranidae fish. Therefore, the study used advanced analytical methods, including fuzzy logic and artificial neural networks, executed within an expert system framework. Through this pioneering investigation, the researchers aim to gain deeper insights into the attributes of Epinephelus aeneus and its interactions with fishing activities.

Materials and Methods

A comprehensive collection of 112 specimens of the *Epinephelus aeneus*, commonly known as the white grouper, was carried out along the Syrian coastline over 12 months from March 2023 to March 2024. Various fishing methods were employed, including speargun fishing, hook and line (Figure 1).

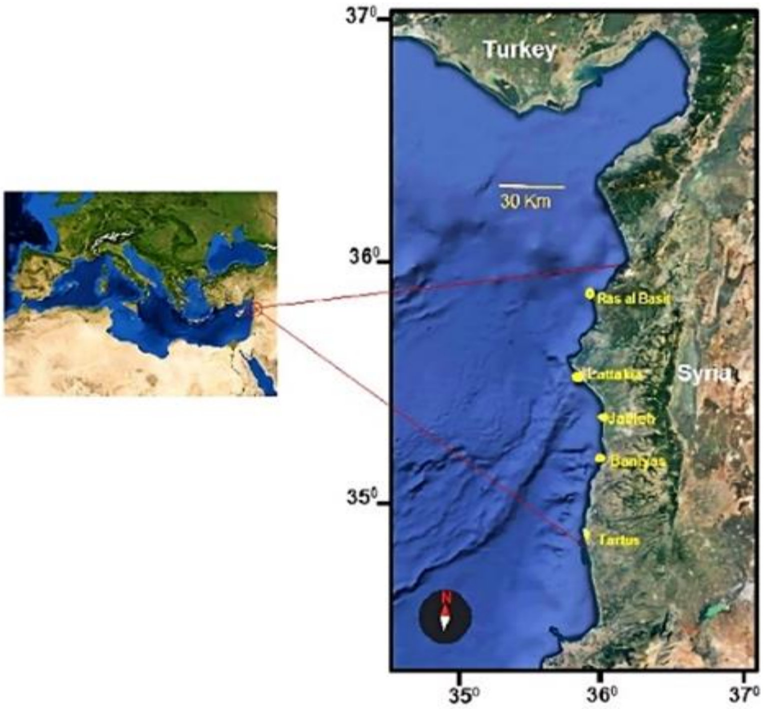

Fig 1: Syrian coast (Eastern Mediterranean Sea).

Age and maturity:

The research studies conducted by Hamwi (2024a; 2024b) employed a Multilayer Perceptron artificial neural network model with a (1, 10, 2) configuration to estimate the maturity and age of the *Epinephelus aeneus* species. This updated network model utilized the total length of the fish as the input parameter (Figure 2).

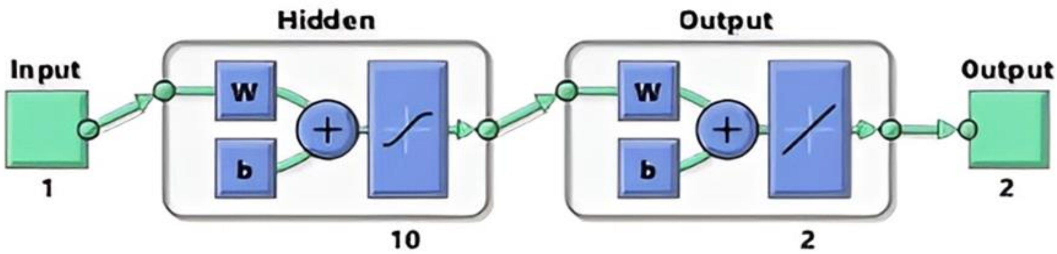

Fig 2: Artificial neural network, multilayer perceptron (MLP).

Fishing population growth (FP):

Hamwi et al. (2022) developed a fuzzy logic-based expert system model to estimate the population growth of the *Epinephelus aeneus* species along the Syrian coastline. The model took specific parameters (K, T_r, M, E) as inputs and applied fuzzy logic techniques to analyze and interpret the data (Figure 3).

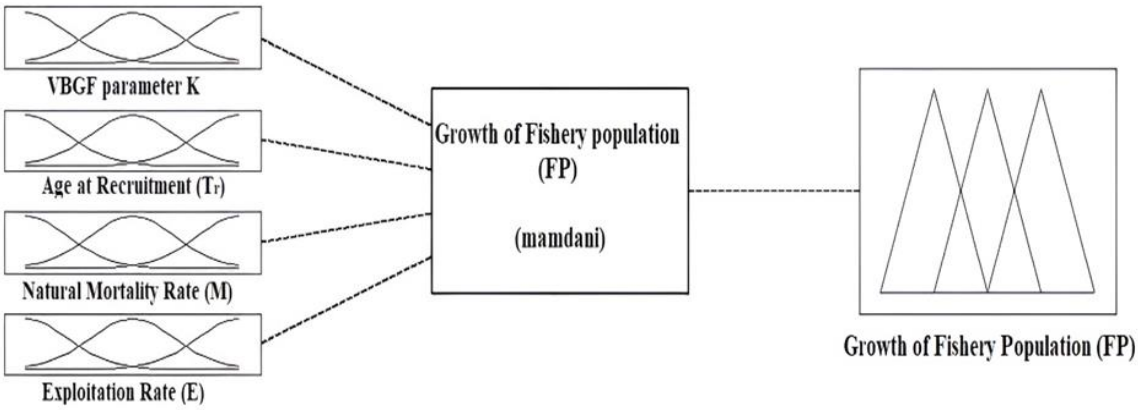

Fig 3: Fuzzy inference system variables (Inputs: K, T_r, M, E; Output: FP).

The von Bertalanffy equation was utilized 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 data points` number, WSS is the squares` weighted sum 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 (Hamwi, 2018). The von Bertalanffy growth model is used as follows:

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

Where TL_t is the total length of the fish at a specific age (t), TL_∞ is the hypothetical asymptotic total length (cm) the fish can potentially reach, K is the growth coefficient, and the theoretical age at which the fish`s length assumed to be zero is t_0.

The total mortality rate (Z) was utilized in the Ricker method (1975). This approach involved calculating the regression equation for the catch curve (ln N_t = a - Z_t) across the entire population.

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

$\text{Log } M = -0.0066 - 0.279 \log TL_\infty + 0.6543 \log K + 0.4634 \log T$ (Pauly, 1980)

Where: TL_∞ and K were used, along with the average surface water temperature (T) of 23.22 °C in the fishing area.

Taking the difference between the total mortality rate (Z) and the natural mortality rate (M) determines the fishing mortality rate (F) (Pauly and Munro, 1984):

$F = Z - M$

Determine the exploitation rate (E) using the equation:

$E = F/Z$ (Sparre & Venema, 1998)

Survival rate (S) was determined using the equation:

$S = e^{-Z}$ (Ricker, 1975).

The equations developed by Beverton and Holt (1957) were used to calculate the total length (TL_c) and age (T_c) at first capture:

$TL_c = TL' - [K (TL_\infty - TL') / Z]$

$T_c = - (1/K) * \ln (1 - TL_c / TL_\infty) + t_0$

Where TL' represents the average total length of the captured fish.

Similarly, Beverton and Holt's (1957) equations were employed to determine the total length (TL_r) and age

(T_r) at recruitment:

$TL_r = TL' - [K (TL_\infty - TL_0) / Z]$

$T_r = - (1/K) * \ln (1- TL_r / TL_\infty) + t_0$

In this case, TL_0 denotes the total length of the fish at hatching or age zero.

Pauly and Munro (1984) proposed a formula to calculate a growth performance index, denoted as $\Phi_{TL}`$, that captures an organism's growth characteristics:

$\Phi_{TL}` = \log K + 2\log TL_\infty$

Building on the earlier work of Beverton and Holt (1966), 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 (1975) provided a relationship to estimate the relative biomass-per-recruit (B'/R): B'/R = (Y'/R) / F

Fishing Vulnerability (FV):

Hamwi and Ali-Basha (2019) developed an expert system model that uses key parameters (TL_{max}, K, T_{max}, M, S) as inputs and applies fuzzy logic techniques to analyze and assess the fishing vulnerability of a species, such as *Epinephelus aeneus* (Figure 4).

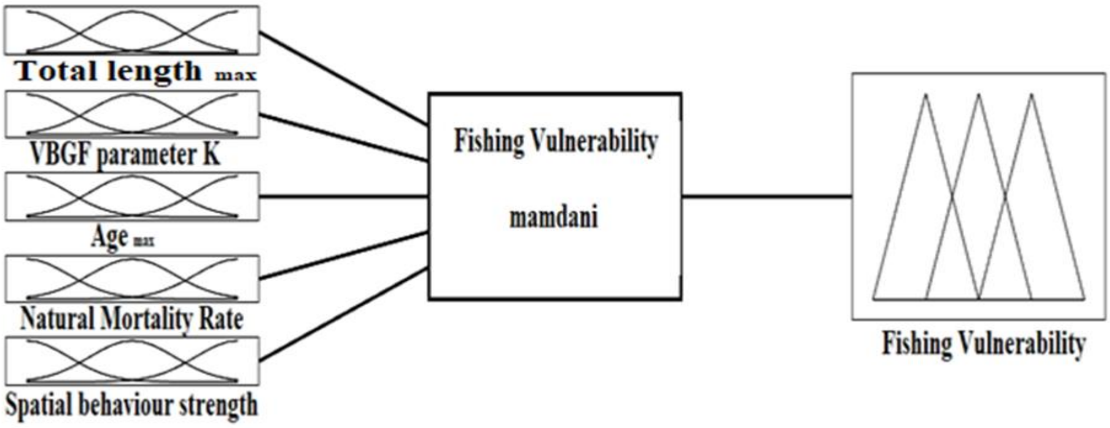

Fig 4: Fuzzy inference system variables (Inputs: TL_{max}, K, T_{max}, M, S; Output: FV).

Results

An examination of the age structure of the *Epinephelus aeneus* population uncovered the existence of 8 well-defined age cohorts. The second age group was the most prevalent, comprising 39.29% of the population. Conversely, the eighth age group accounted for a mere 0.89% of the overall catch (Figure 5).

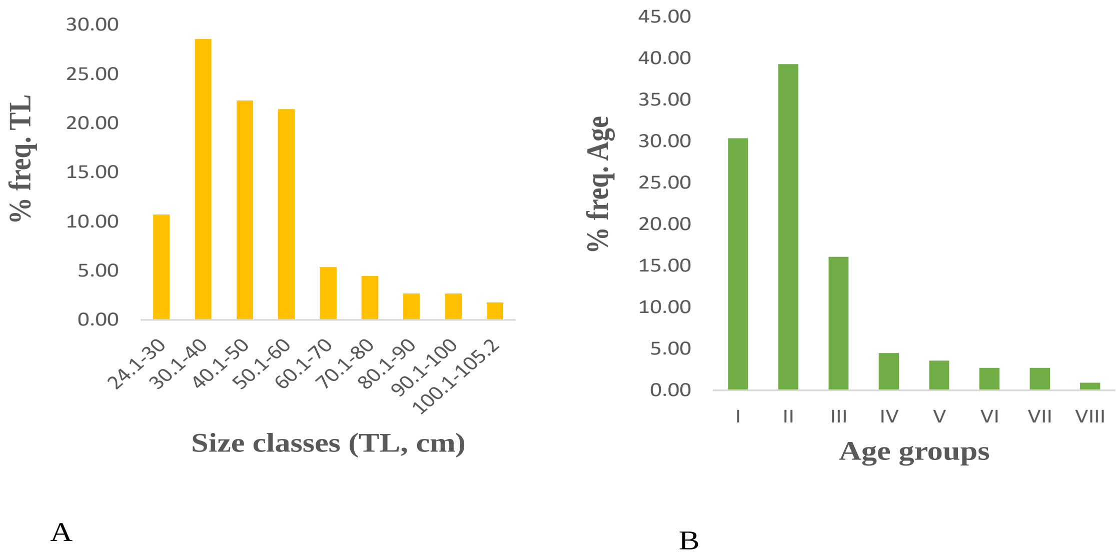

Fig 5: **A.** Total length frequency distribution (TL); **B.** Age composition for *Epinephelus aeneus* in Syrian waters.

Examining the distribution of individuals across different total length (TL) categories, the most prevalent size class was 30.1-40 cm, comprising 28.57% of the population. In contrast, individuals with total lengths of 100.1-105.6 cm were the least represented, making up only 1.79% of the population.

The data collected as part of this study showed that the maximum total length observed for *Epinephelus aeneus* individuals along the Syrian coast was 105.6 cm, which occurred in 8^+ years. In contrast, the smallest recorded total length was 24.5 cm, corresponding to a 1^+ year.

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

$TL_t = 136.76\ (1 - e^{-0.187\ (t + 0.041)})$

Statistical analysis of this growth model yielded the following results:

AIC = 14.588

WSS = 2.9257

95% Confidence Interval = 4.6825

Analysis of the length-weight relationship for *Epinephelus aeneus* revealed a positive allometric growth pattern, with a b-value of 3.19.

The average age and total length of *Epinephelus aeneus* individuals at first capture were 2.45 years and 50.92 cm, respectively. Meanwhile, the average age and total length at recruitment were 1.11 years and 26.56 cm.

Calculating the growth performance index (Φ') for total length growth of *Epinephelus aeneus* yielded a value of 3.54.

The total mortality coefficient (Z) for the *Epinephelus aeneus* population was estimated to be 0.55 per year.

Further analysis revealed that the fishing mortality coefficient (F) was 0.19 per year, while the natural mortality (M) was 0.36 per year. The calculated survival rate (S) was 0.58 per year. The exploitation mortality coefficient (E) was 0.35 per year.

The relationship between exploitation rate (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 in the analysis ranged from 0.05 to 1.00.

The analysis identified several values:

- E_{max}, the exploitation rate that results in the maximum yield per recruit, was calculated to be 0.600 y^{-1}.

- The exploitation rate $E_{0.1}$ was determined to be 0.507 y^{-1}. Where the point the marginal increase in relative yield-per-recruit reaches one-tenth of its value at E = 0.

- $E_{0.5}$, the exploitation rate at which the stock's biomass is 50% of its unexploited state, was calculated as 0.324 y^{-1}.

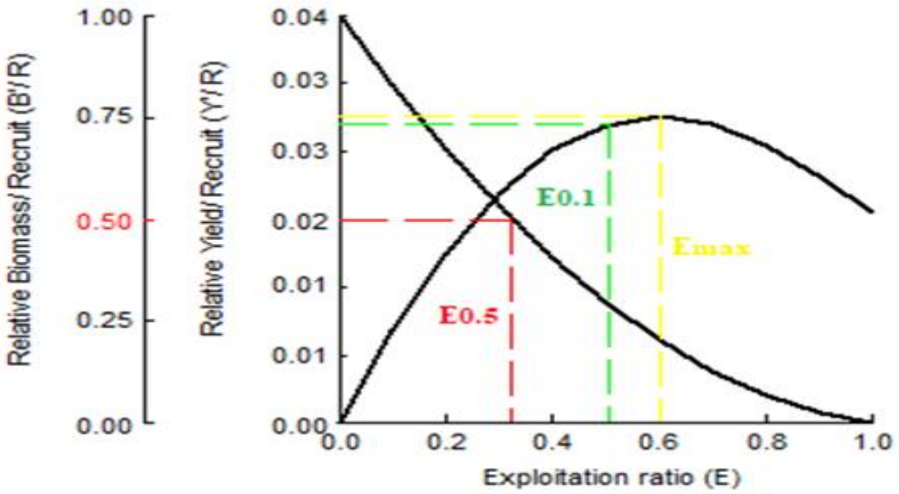

Fig 6: Relative yield per recruit (Y`/R) and biomass per recruit (B`/R) (Knife-edge selection) of *Epinephelus aeneus* collected from Syrian coast.

The fuzzy logic-based expert system proposed by Hamwi et al. (2022) generated a growth value 48.4 for the *Epinephelus aeneus* population along the Syrian coast (Figure 7).

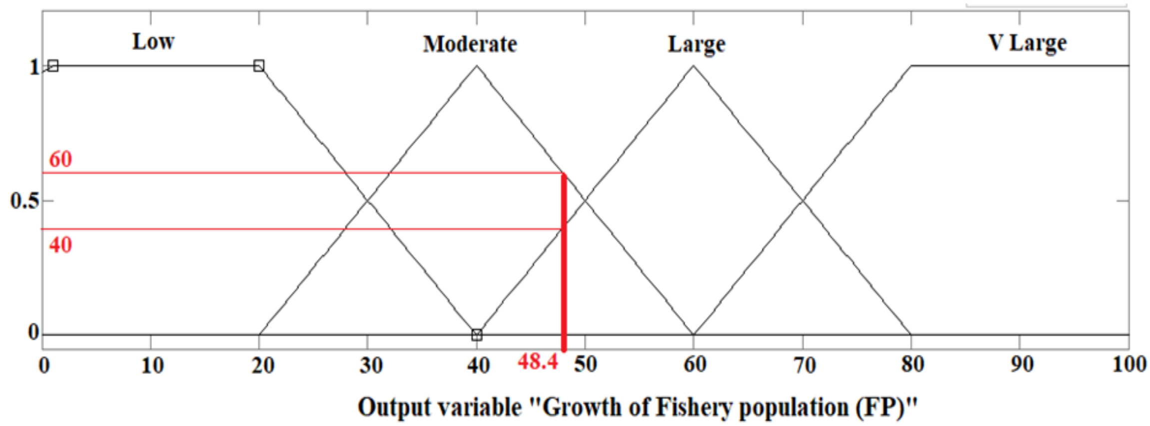

Fig 7: The growth of *Epinephelus aeneus* population off the Syrian coast.

Additionally, according to the expert system (fuzzy logic) developed by Hamwi and Ali Basha (2019), *Epinephelus aeneus* demonstrated a fishing vulnerability of 61.6, with the maximum vulnerability value (FV) being 100 (Figure 8).

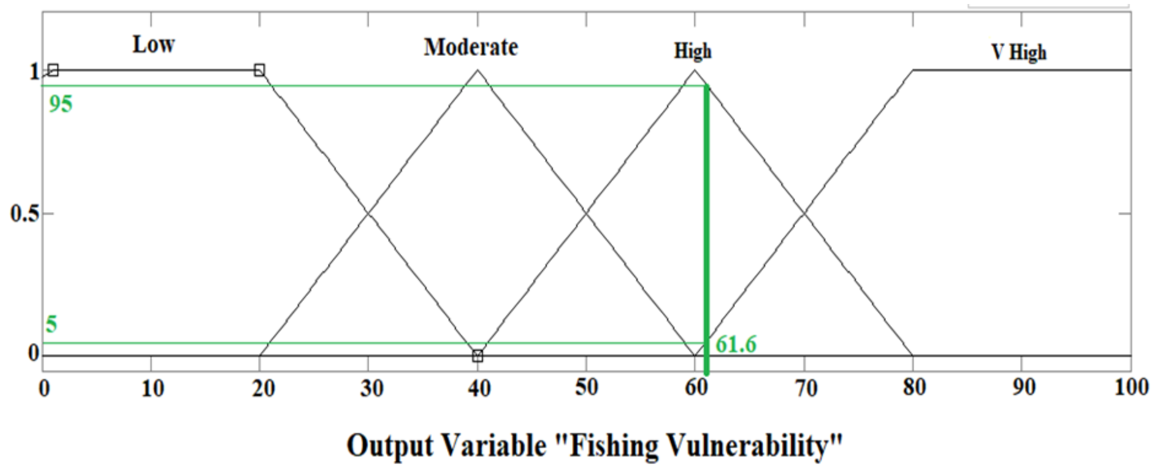

Fig 8: The vulnerability of *Epinephelus aeneus* to fishing off the Syrian coast.

Discussion

This study highlights the population dynamics of *Epinephelus aeneus* on the Syrian coast. On the Senegalese coast, the total lengths of *Epinephelus aeneus* ranged from 10 to 110 cm (Ndiaye et al., 2013). Similarly, along the southwest coast of Senegal, the total lengths spanned from 17.9 to 94.8 cm (Ndiaye et al., 2015). In contrast, *Epinephelus aeneus* populations in Syrian offshore waters in the eastern Mediterranean are relatively larger than their counterparts off the coast of Senegal. This marked difference in the size of *Epinephelus aeneus* populations between the two geographically distant regions suggests the influence of different environmental and ecological factors that may shape the species` life history and dynamics.

The growth coefficient (b) estimated for the *Epinephelus aeneus* population in this study was 3.19, indicating a positive allometric growth pattern. Suggests that the total length of the fish increases at a relatively faster rate compared to other morphological dimensions (e.g., body weight) as the individual grows.

The positive allometric growth exhibited by *Epinephelus aeneus* populations in this study is consistent with that of a Mediterranean beach (Sinai/Egypt) of 3.1141 (El-Aiatt et al. 2021), while contrasting with the negative allometric growth ($b=2.96<3$) reported for this species in the south-western beach of Senegal (Ndiaye et al. 2015). These differences in growth patterns may be related to different environmental conditions, resource availability, population demographics, or other factors affecting the genetic evolution and morphological adaptations of local *Epinephelus aeneus* populations.

The growth value corresponds to a moderate growth of 0.60 and a large growth of 0.40, given 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 and Soriano (1986), a ratio of L_c/L_∞ less than 0.5 suggests the majority of the catch consists of juvenile individuals of the species.

In the present study, the estimated L_c/L_∞ ratio for the *Epinephelus aeneus* population was 0.37. This value indicates that the current harvest in the *Epinephelus aeneus* fishery mainly comprises juvenile fishes rather than mature individuals.

The prevalence of small 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 (61.6). This vulnerability value suggests a high vulnerability of 0.95 and a very high vulnerability of 0.05 for this species (Figure 8), which is similar to that reported by Froese and Pauly (2024) of 58 (high vulnerability).

Conclusions

The present study offers valuable insights into the population dynamics of *Epinephelus aeneus* along the Syrian coast, underscoring the importance of conservation measures to ensure the sustainable management of this species. The findings contribute to our understanding of *Epinephelus aeneus*' growth patterns, mortality rates, and vulnerability to fishing, thereby establishing a foundation for future research and management strategies.

The outcomes of this study carry significant implications for the management of the *Epinephelus aeneus* fishery along the Syrian coast. Overfishing can profoundly impact the population's capacity to sustain itself, decreasing abundance. Therefore, the execution of management strategies that minimize the catch of *Epinephelus aeneus* and ensure the long-term sustainability of the fishery is of paramount importance.

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