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Stock Status of Yellowbar Angelfish, *Pomacanthus maculosus* from Southern Arabian Gulf of the United Arab Emirates, Using Length Frequency Data

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ABSTRACT **Original Research Article**

This study assessed the population structure, growth characteristics, mortality dynamics, recruitment pattern, and relative yield-per-recruit of the Yellowbar angelfish, *Pomacanthus maculosus*, in the southern Arabian Gulf of the United Arab Emirates over the period January–December 2024. Length-frequency data were processed using FiSAT software to derive major population parameters, including asymptotic length (L_∞), growth coefficient (K), and recruitment pattern. The analysis produced an asymptotic length of 41.8 cm and a growth coefficient of 0.25 year^{-1}, while the growth performance index (Φ) was estimated at 2.64. The species displayed negative allometric growth ($b < 3$), with an estimated asymptotic weight (W_∞) of approximately 1,723.5 g. Recruitment was observed throughout the year and was characterised by one dominant annual recruitment pulse. Analysis of the length-converted catch curve yielded an estimated total mortality (Z) of 1.01 year^{-1}, comprising natural mortality (M) of 0.65 year^{-1} and fishing mortality (F) of 0.36 year^{-1}. The exploitation rate (E) was estimated at 0.36, slightly below the $E_{0.5}$ value of 0.39, representing the exploitation level associated with a reduction of the stock to 50% of its unexploited biomass. Overall, the findings indicate that *P. maculosus* in the study area is currently subjected to a level of fishing pressure that remains within a sustainable range.

Keywords: Growth, Yield per recruit, Stock, *Pomacanthus maculosus*, Mortality.

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Introduction

Pomacanthidae, a family of tropical reef-dwelling fish, inhabiting the Atlantic, Indian, and Pacific oceans (Fricke et al. 2022). Despite its relatively low species count 88 species across 8 genera, it remains one of the most conspicuous components of coral reef fish assemblages, with representatives in all tropical seas (Alwany et al. 2007; Allen et al. 1998; Delbelius et al. 2003). Among its members, *Pomacanthus maculosus*, commonly known as the Yellowbar angelfish, is found in the Red Sea, Arabian Gulf, and Sea of Oman (Froese and Pauly, 2019). It has been recorded on distinct but uncommon occasions in the eastern Mediterranean Sea (CIESM, 2021; Barich, 2010; Salameh, 2012). In the southern Arabian Gulf, *P. maculosus* is caught incidentally by traditional fishing vessels using dome-shaped wire traps (Grandcourt et al. 2010; Farrag et al. 2021 & 2024). Its total landing remains small 141 tons, constituting only 0.24% of the overall catch (FCSA, 2023).Previous investigations into stock status have primarily focused on high-value target species, with by-catch species like *P. maculosus* receiving limited attention. Grandcourt et al. (2010) estimated age-based life history parameters for certain by-catch species, including *P. maculosus*, highlighting the need for broader evaluations. Understanding the status of non-target species is essential for a comprehensive assessment of the demersal fisheries resource base and the ecological impacts of by-catch. Thus, this study aims to estimate the growth, mortality, and stock status of significant non-target species in the demersal fishery of the southern Arabian Gulf of the United Arab Emirates by using length frequency distribution analysis.

Materials and Methods

Sample Collection

A total of 1,085 specimens of *P. maculosus* were obtained from fish-landing sites used by fishing vessels operating in the Arabian Gulf region of the United Arab Emirates between January and December 2024. The collected specimens were classified into 1.0 cm length-frequency intervals. Population growth was estimated using the basic form of the von Bertalanffy Growth Function (Bertalanffy, 1957), expressed as $L_t = L_\infty [1 - \exp\{-K(t - t_0)\}]$, while the corresponding weight-at-age relationship was represented as $W_t = W_\infty [1 - \exp\{-K(t - t_0)\}]^b$. In these equations, L_∞ denotes asymptotic length, W_∞ represents asymptotic weight, K is the growth coefficient, t_0 refers to the theoretical age at which the fish would have zero length or weight, and Lt and Wt represent the predicted length and weight at age t, respectively. The population parameters were estimated through two analytical procedures. First, Electronic Length Frequency Analysis (ELEFAN I) was applied to the length-frequency observations to estimate L_∞ and K (Pauly et al., 1981). Second, the Powell-Wetherall plot was employed to estimate the Z/K ratio and asymptotic length, following Powell (1979) and Wetherall (1986).

The growth performance of the species was assessed using the growth performance index (Φ), calculated according to the expression $\Phi = 2 \log_{10} L_\infty + \log_{10} K$ (Pauly and Munro, 1983). The relationship between body length and weight was determined using the conventional length-weight model, $W = aL^b$ (Ricker, 1975), where W represents body weight in grams, L denotes total length in centimetres, and a and b are the constants of the fitted equation. These analyses provided the basis for describing the growth characteristics and length-weight relationship of *P. maculosus* within the study population.

Mortality parameters were estimated using FiSAT II. The total instantaneous mortality coefficient (Z) was derived from the length-converted catch curve following the procedure described by Pauly (1984). Natural mortality (M) was estimated using the empirical formulations proposed by Pauly (1980) and Richter and Efanove (1976), and the mean estimate obtained from these approaches was adopted for subsequent analyses. Fishing mortality (F) was then determined as the difference between total and natural mortality, expressed as $F = Z - M$. The exploitation rate (E), representing the proportion of total mortality attributable to fishing activities, was calculated using $E = F/Z$.

The exploitation status of the stock was interpreted using the reference proposed by Gulland (1971), whereby an exploitation rate of $E = 0.5$ represents an equilibrium condition, $E < 0.5$ indicates underexploitation, and $E > 0.5$ suggests overexploitation. The length at first capture, or Lc50, was estimated from the length-converted catch curve generated through FiSAT II and represented the length at which 50% of the population becomes vulnerable to capture. In addition, the lengths corresponding to the 25th and 75th cumulative catch probabilities were determined. The optimum length associated with maximum yield, Lopt, was estimated following the procedure of Beverton (1992).

Relative yield-per-recruit (Y′/R) and relative biomass-per-recruit (B′/R) analyses were conducted using the Beverton and Holt (1966) model as refined by Pauly and Soriano (1986). From these analyses, the maximum exploitation rate (Emax) associated with the highest relative yield-per-recruit was estimated as a reference for evaluating the maximum sustainable yield (MSY). The E0.5 value, representing the exploitation rate corresponding to a reduction of the relative biomass-per-recruit to 50% of its unexploited level, was also determined. Finally, the status of the fishery resource was assessed by comparing the estimated fishing mortality with the biological reference points for optimum and limiting fishing pressure. Following Patterson (1992), the target fishing mortality (Fopt) was defined as 0.5M, whereas the limiting fishing mortality (Flimit) was calculated as 2/3M.

Results

The observed total length of *P. maculosus* specimens used in the length–weight analysis varied from 17.0 to 40.0 cm, while body weight ranged between 159.0 and 1,450 g. The estimated length–weight relationship, illustrated in Fig. 1, was expressed as $W = 0.0684 \times L^{2.715}$ ($R^2 = 0.93$). The estimated exponent (*b*) was significantly different from the theoretical value of 3 ($p < 0.05$), demonstrating that the species exhibited negative allometric growth, whereby body weight increased at a proportionally lower rate than length. The length-frequency distribution for the sampling period from January to December 2024 is presented in Fig. 2. The distribution indicates that specimens belonging to the 23.0 and 24.0 cm length groups occurred most frequently in the catch, whereas individuals measuring 17.0 and 40.0 cm represented the least frequently recorded length groups.

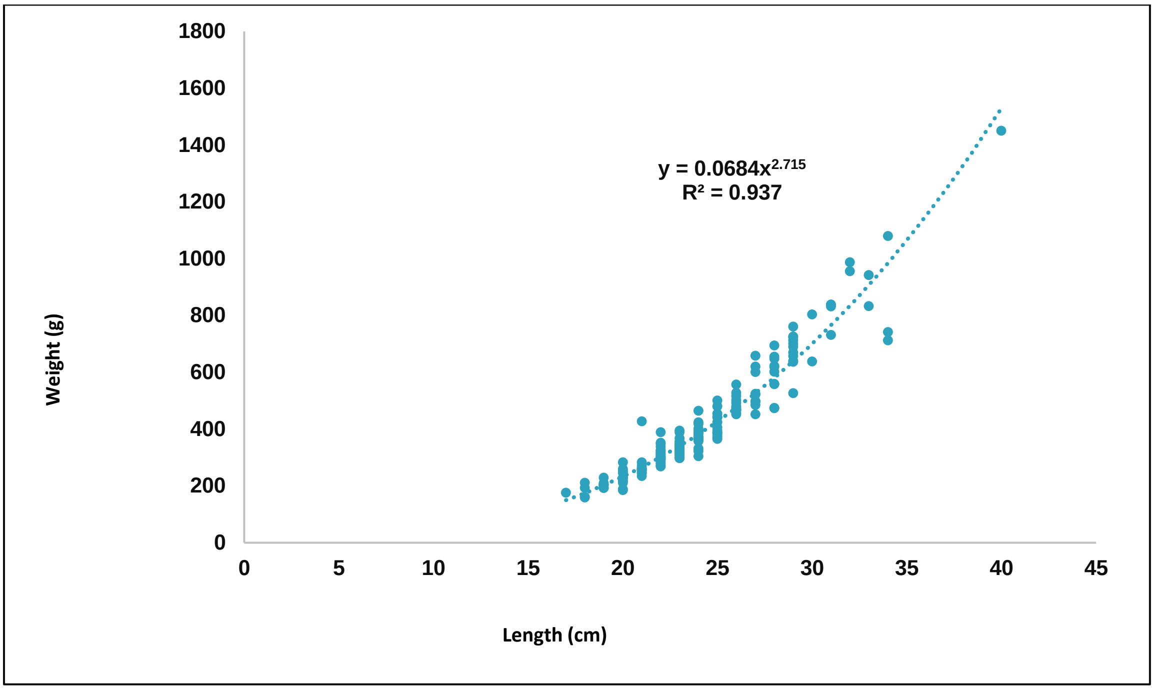

Fig. 1. Length weight relationship of *P.maculosus*

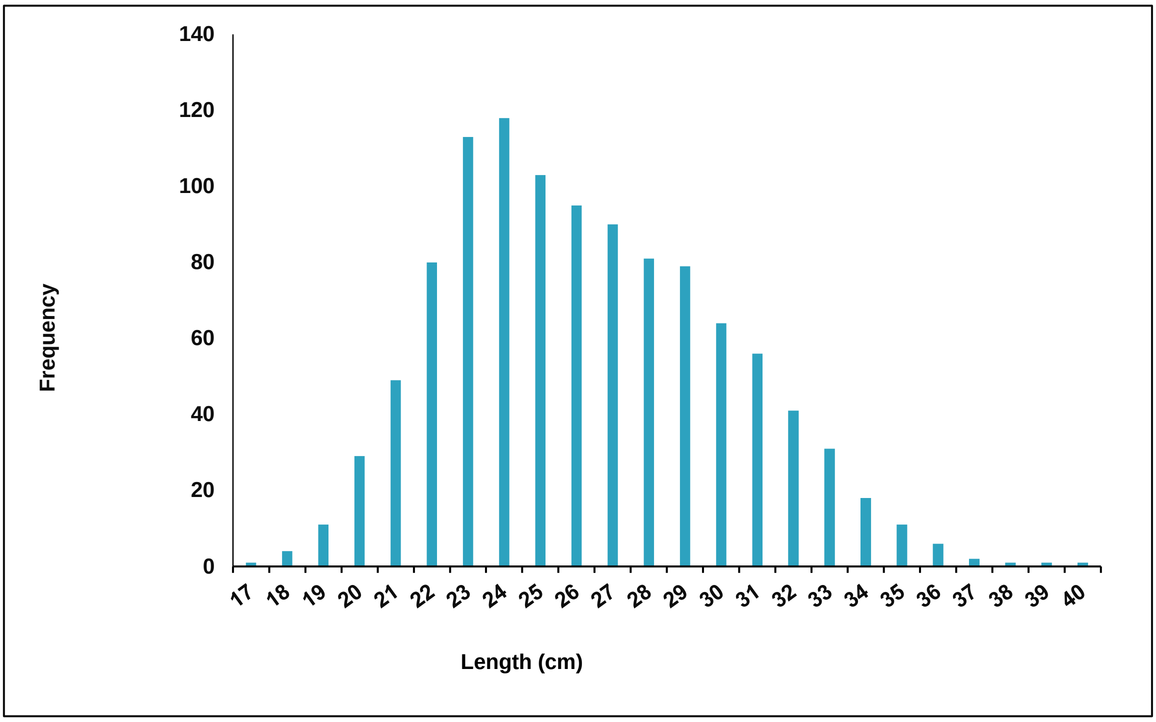

Fig. 2. Length frequency distribution of *P. maculosus*

Figure 3 displays the restricted length frequency data with the estimated growth curve overlay. The growth performance indicator Φ of 2.64 was computed for p. maculosus. t_o value was assessed at -0.58 per year.

The length at time *t* was expressed as L_t=41.80*(1-exp$^{-0.25*(t+0.58)}$).The correspond-ding model for growth in grams as a function of age was described by the equation: W_t=1723.49*[1-exp$^{-0.25*(t+0.58)}$]$^{2.715}$.

A preliminary estimate of asymptotic length (L_∞) was obtained by Powell and Wetherall method, which gave the following parameters: L_∞ = 41.59cm and Z/K =4.087 with r = 0.96.The month-wise data on size distribution of *p. maculosus* collected during 2024 was used for the estimation of growth parameters through ELEFAN I program.

A preliminary estimate of (K) was obtained with an input of $L_\infty$of 41.59cm, which gave the value of K as 0.25.The ELEFAN I program exercise produced the following growth parameters: L_∞ = 42.0 cm and K = 0.25 (annual) with R_n = 0.264.

The instantaneous total mortality coefficient (Z) for *P. maculosus* was estimated using the catch curve method, yielding a value of 1.01 year^{-1} (95% CI: 0.90–1.11), with a high coefficient of determination (r^2 = 0.97; Figure 4). Natural mortality (M) was calculated using two approaches.

The first, Pauly's equation (Pauly, 1980), incorporated parameters L_∞ = 41.80 cm, K = 0.25, and a mean annual temperature of 27.5°C, resulting in an M value of 0.65 year^{-1}. The second method, based on the empirical equation by Richter and Efanove (1976), produced a similar estimate of 0.647 year^{-1}.

Consequently, the average natural mortality rate was determined to be 0.65 year^{-1}.

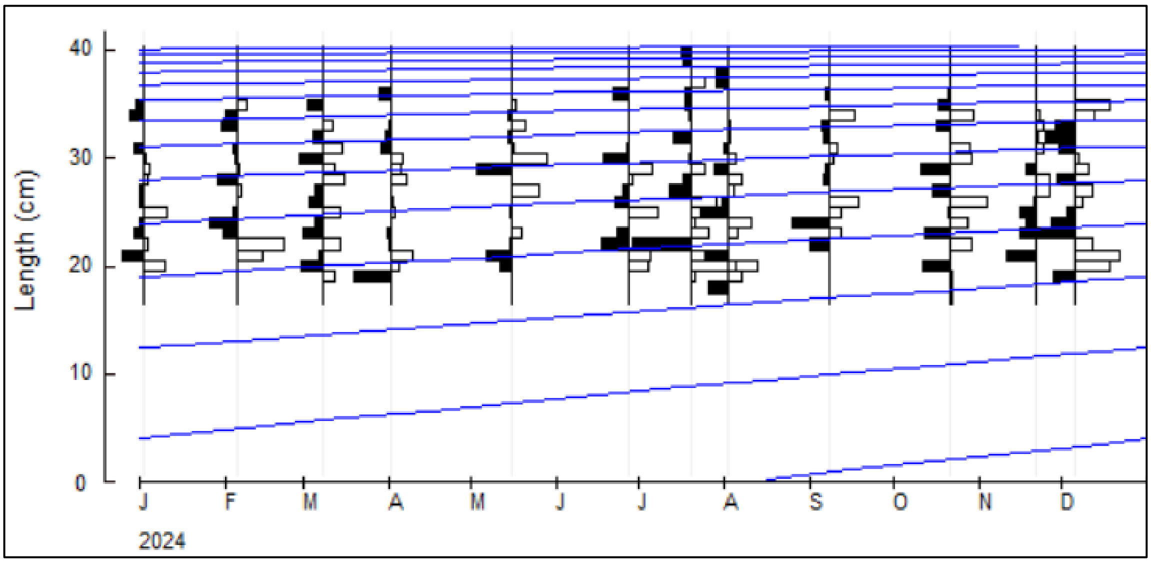

Fig. 3. Estimation of growth parameter through ELEFAN I program of *p. maculosus*

The fishing mortality (F) was estimated at 0.36 year^{-1}, which is close to the target reference point (F_{target} = 0.32) and below the limit reference point (F_{limit} = 0.43). These findings suggest that *P. maculosus* is currently being exploited at a sustainable level.

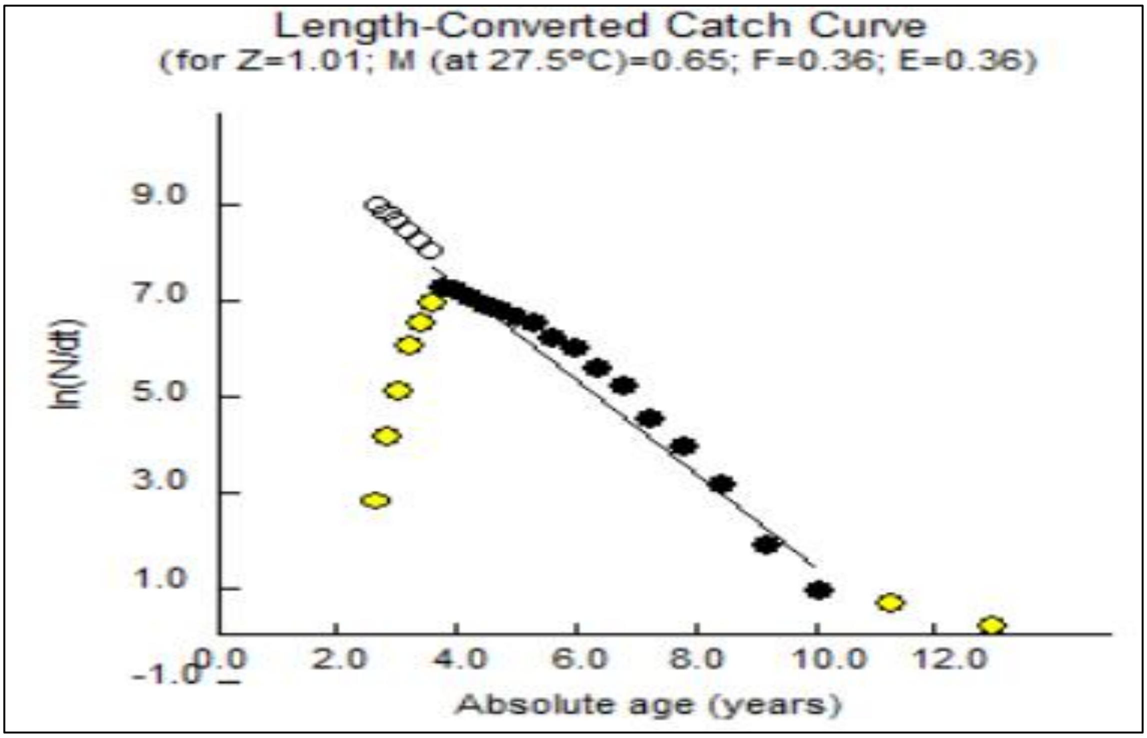

Fig. 4. Length converted catch curve for estimation of total mortality coefficient of *P. maculosus.*

Figure 5 illustrates the selectivity range based on the probability of capture for *P. maculosus*. The lengths at which the probability of capture reached 25%, 50%, and 75% (L25, L50, and L75) were 21.38 cm, 22.38 cm, and 23.38 cm, respectively. The optimal length for maximum yield (L_{opt}) was calculated at 22.41 cm, which closely aligns with both the mean size at first capture (L_c = 22.38 cm) and the mean size at first sexual maturity (L_m = 22.11 cm).

Figure 6 presents the recruitment pattern of *P. maculosus* in the southern Arabian Gulf, United Arab Emirates, showing the percentage of recruitment over time. Recruitment occurred continuously throughout the year, with a notable peak in September (20.71%). The estimated juvenile retention rate was 8.66%.

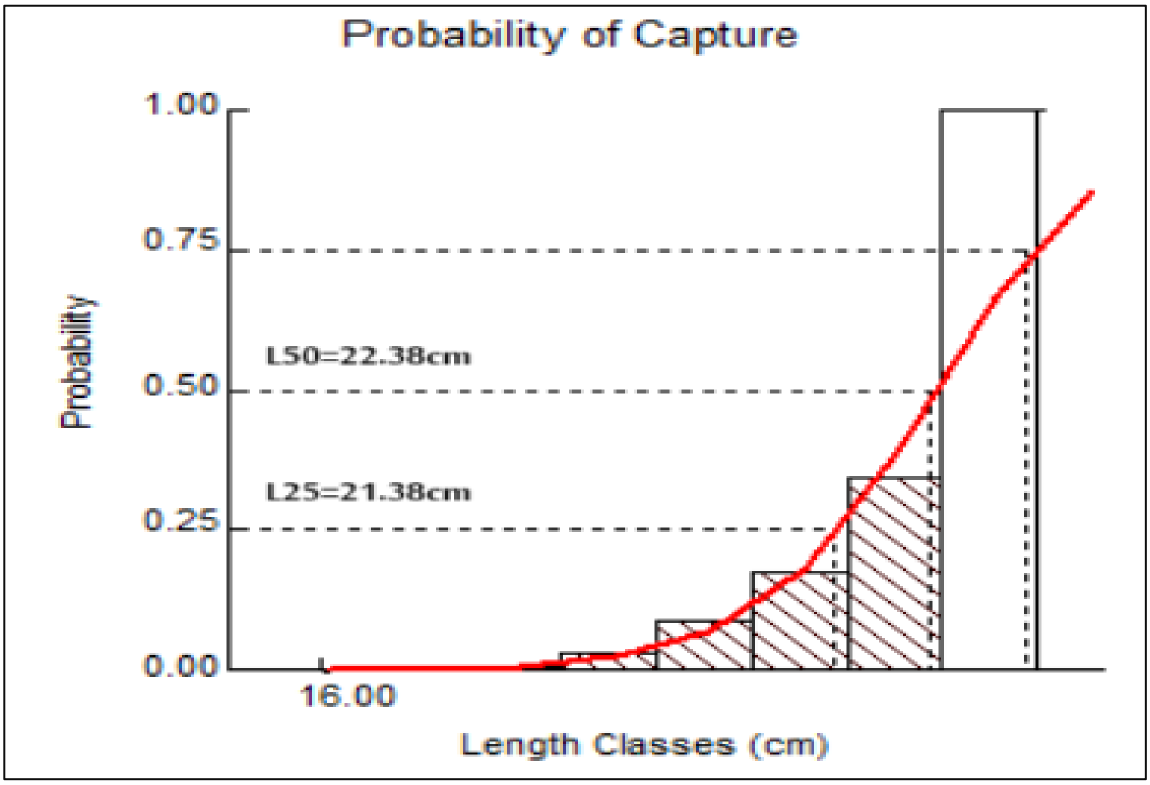

Fig. 5. Probability of capture of *P. maculosus* from southern Arabian Gulf of the UAE.

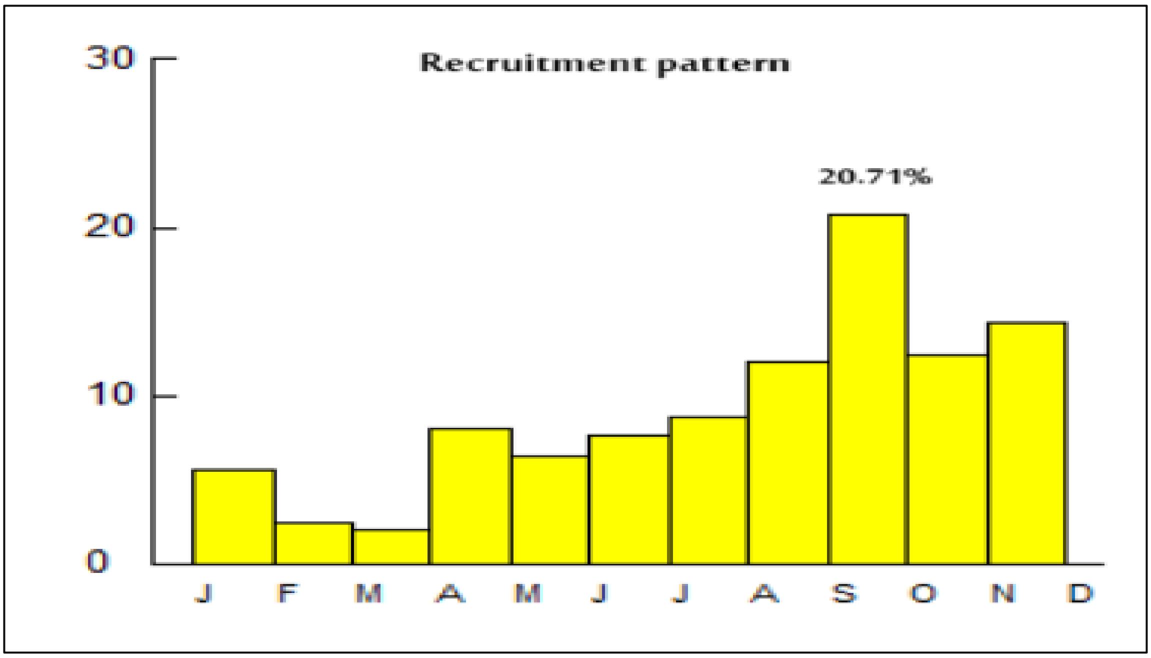

Fig. 6. Recruitment pattern of *P. maculosus* from southern Arabian Gulf of the UAE.

The relative yield per recruit (Y′/R) and relative biomass per recruit (B′/R) was analyzed as a function of varying exploitation ratios (E). As shown in Figure 7, under the current conditions, the length at first capture (Lc = 22.38 cm) and natural mortality rate (M = 0.65 $year^{-1}$) the maximum yield per recruit (Y′/R) is achieved at an exploitation rate of E_{max} = 1.0. This value is notably higher than the current exploitation rate (Ec_{ur}= 0.36). However, Ec_{ur} remains below the optimum exploitation rate ($E_{0.5}$ = 0.38), suggesting that the stock is being harvested at a level that is both conservative and sustainable.

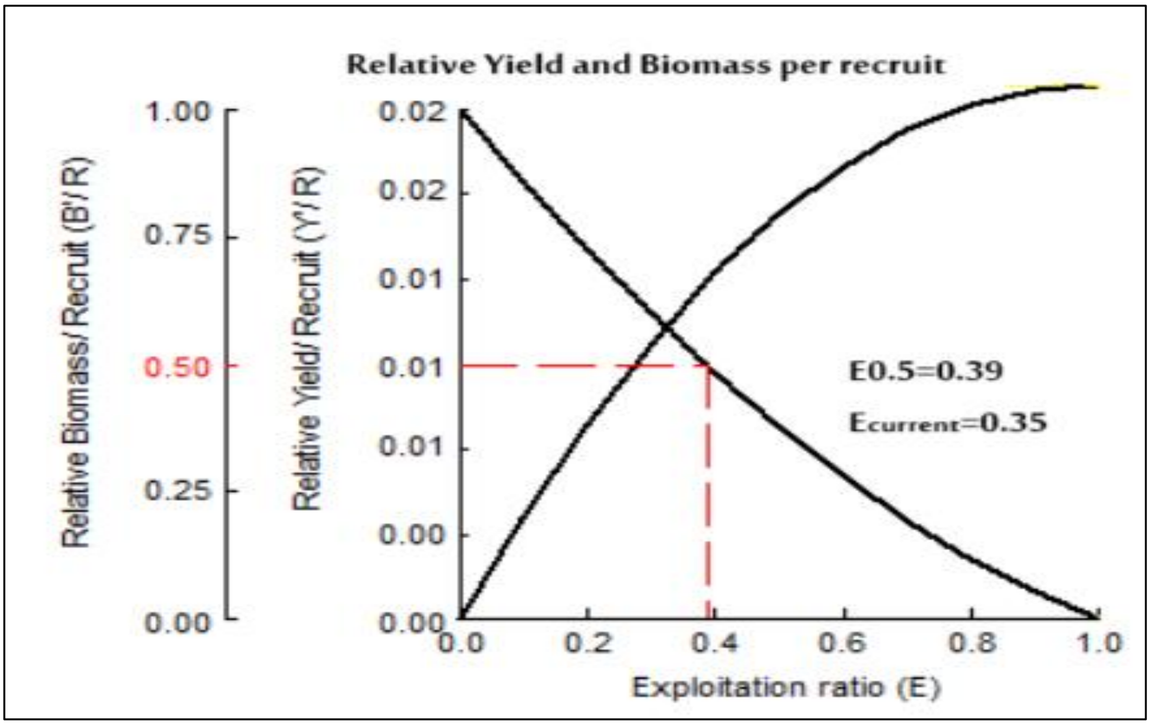

Fig. 7. Relative yield per recruit (Y′/R) and relative biomass per recruit (B ⁄ R) of *P.maculosus*, UAE.

Discussion

The maximum fork length (FL = 40.0 cm) recorded in the present investigation was greater than that reported by Grandcourt et al. (2010) from the Abu Dhabi waters of the Arabian Gulf, although Kuiter and Tonozuka (2001) reported a larger maximum length of 50.0 cm for this species from Australian waters. Data on length–weight relationships in the family Pomacanthidae is scarce; although Chung and Woo (1999) and Feitosa et al. were negative allometric growth Pomacanthus imperator (Bloch, 1787) (b) coeficient b = 2.77 and Pomacanthus paru (Bloch, 1787) with b coefficient (2017). The b value observed in this study (2.715) is within the general range of 2.5–3.5 reported by Carlander (1977), but below the theoretical isometric value of 3 which indicates negative allometric growth for *P. maculosus*. The length-frequency distribution further confirmed that individuals of 23–25 cm represented the most frequent size group among total catch, with a share of around 31%.

The von Bertalanffy growth function is a fundamental component of biological knowledge essential for effective resource management and conservation, as it helps define appropriate utilization strategies. In this study, the asymptotic length ($L\infty$) of *P. maculosus* was estimated at 41.80 cm, with a growth coefficient (K) of 0.25 year^{-1} values that differ from those reported by Grandcourt et al. (2010).

The estimated age at zero length (t_0) was -0.58, suggesting that juveniles grow more rapidly than predicted by the adult growth curve (King, 1995). Branstetter (1991) proposed a classification scale for species growth rates based on the von Bertalanffy growth coefficient (K): slow growth ($0.05 \leq K \leq 0.1$), moderate growth ($0.1 < K \leq 0.2$), and rapid growth ($0.2 < K \leq 0.5$). According to this framework, *P. maculosus* in the southern Arabian Gulf of the United Arab Emirates falls within the rapid growth category. The species exhibited high growth rates in the present study, with individuals reaching a maximum age of 12 years and showing a relatively high natural mortality rate.

The data used to estimate total mortality were obtained from the trap fishery, where *P. maculosus* is primarily caught as bycatch. The resulting total mortality value was considered high, suggesting that a larger and more representative sample particularly of older individuals is needed to better characterize the population. Natural mortality (M) was estimated using two different methods, yielding an average value of 0.64 year^{-1}. This estimate is notably higher than the value reported by Grandcourt et al. (2010), who found a natural mortality rate of 0.12 year^{-1}. The current fishing mortality (F_current) is very close to the target biological reference point (F_target) and remains well below the limit reference point (F_limit), supporting the conclusion that *P. maculosus* is being exploited sustainably. However, Grandcourt et al. (2010) cautioned that relying solely on these reference points may lead to an overestimation of sustainable harvest rates for this species.

This study revealed that 9.0% of *P. maculosus* individuals are retained before reaching sexual maturity. This early retention is attributed to the species' vulnerability to capture at a mean size smaller than the size at sexual maturation. These findings underscore the importance of implementing management measures to adjust the selectivity parameters of the demersal trap fishery. Grandcourt et al. (2010) noted that *P. maculosus* possesses a demographic profile that makes it particularly susceptible to fishing pressure. However, the practice of discarding live fish may have mitigated potential negative impacts of the fishery on the population status of this species.

Conclusion

In the present study, the exploitation rate is within safe biological limits, and the presence of individuals close to the asymptotic length suggests that the population is not under excessive fishing pressure. For the proper management of the multispecies resource in this area, further studies must be undertaken on the other species inhabiting the present investigated region.

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