

Stock assessment and management of freshwater mullet, *Planiliza abu* in the East Hammar Marsh, Iraq

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Received Date: 18 February 2026 | Accepted Date: 22 March 2026 | Published Date: 30 April 2026

ABSTRACT: The present study assessed various parameters of freshwater mullet, *Planiliza abu*, in the East Hammar marsh, including growth parameters, mortality rates, probability of capture, recruitment pattern, yield-per-recruit, and virtual population analysis, using FISAT II software. Monthly specimens were collected from November 2023 to October 2024, totalling 4,274 samples for analysis. Results indicated that the asymptotic length (L_{∞}), growth constant (K), age at zero length (t_0) and growth performance index (ϕ') for the species were reported to be 19.7 cm, 0.50, -0.32 and 2.288, respectively. The total mortality (Z) was measured at 3.83, while natural mortality (M) and fishing mortality (F) were recorded at 1.20 and 2.63, respectively. The recruitment pattern for the species showed a bimodal recruitment distribution with varying strengths throughout the year. A virtual population analysis (VPA) revealed that most fishing mortality occurred for lengths ranging from 10.0 to 13.0 cm. It was also noted that the length at first maturity was greater than the size at first capture. Currently, the exploitation rate (E_{cur}) is 0.69, indicating that the population is overexploited, as E_{cur} exceeds the standard value of 0.5, but remains below the biological reference points ($E_{0.1}$ and E_{max}). To improve fisheries management, the mesh sizes of fishing nets must be increased, and the marsh regions must be protected from reducing fishing pressure to promote sustainability and ensure resource availability.

Keywords: Growth and exploitation, Khishni, mortality, recruitment, yield-per-recruit.

INTRODUCTION

Mulletts belong to the family Mugilidae and are found worldwide in coastal temperate and tropical waters, and some species spend part or even their whole life cycle in fresh water (González-Castro and Ghasemzadeh, 2015). Currently, consists of about 24 genera and 75 valid species (Fricke and Fong, 2025). The freshwater mullet or Khishni, *Planiliza abu* (Heckel, 1843), is a mugilid that is endemic and widely distributed in the Tigris-Euphrates River basins and Pakistani waters (Ay and Gülnaz Özcan, 2016; Coad, 2017; Jorfipour et al., 2021). It was initially classified under genus *Liza* and later reclassified into the genus *Planiliza* (Durand et al., 2012).

This species is commonly found in schools and is considered one of the most abundant species in several aquatic environments in Iraq. For instance, it constitutes 37.1% of the population in the Al-Hawizeh marsh (Mohamed et al., 2008), 35.8% in the East Hammar marsh

(Hussain et al., 2009), 62.0% in the Chybayish marsh (Mohamed et al., 2012), 14.1% in the Euphrates River near Al-Hindyah Barrier (Abbas et al., 2017), 14.2% in the Al-Diwaniya River (Mohamed & Al-Jubouri, 2017), 8.8% in the Shatt Al-Arab River (Mohamed and Abood, 2017), 13.4% in the East Hammar marsh (Mohamed et al., 2017), 35.99% of the fish assemblage in the Hawr Ad Dalmaj Marsh (Al-Zaidy et al., 2019) and 25.99 % of the fish assemblage in the Al-Chibayish marsh (Abdullah et al., 2024). Moreover, the landing of this species was 232 tons in 2023, accounting 11.3% of the total landing of Basrah inland fisheries (Mohamed and Abood, 2024).

Extensive studies have been conducted on the age, growth, and reproduction of *P. abu* in various water bodies in Iraq, Iran, and Turkey (Bilici, 2021; Mohamed and Al-Jubouri, 2021; Jorfipour et al., 2021, 2023). Unfortunately, there have been few studies conducted on the population

of *P. abu* related to its stock assessment. Mohamed *et al.* (2016) assessed the *P. abu* population in the East Hammar marsh in Iraq from January 2009 to May 2010. Birecikligil *et al.* (2017) described the population parameters of the species in Azaplı Lake and Kartalkaya Dam Lake in the Ceyhan River Basin, Turkey, during August 2014 and May and July of 2015. In addition, Mohamed and Abood (2020) examined the population dynamics of *P. abu* in the Shatt Al-Arab River, Iraq, from November 2015 to October 2016. Furthermore, Mohamed (2022) assessed the stock expectations and conducted a virtual population analysis of the species in the same river.

This study aims to characterise the population dynamics of *P. abu* in the East Hammar marsh. From November 2023 to October 2024, the growth parameters, mortality rates, probability of capture, recruitment pattern, yield-per-recruit, and virtual population analysis were described. This research provides vital information for developing a sustainable fisheries management strategy for this species in the marsh.

MATERIALS AND METHODS

Study area

The study was conducted in the East Hammar marsh, a wetland in northern Al-Basra City (Figure 1). This marsh extends approximately 33 km in length, with water depths ranging from 1.2 to 3.0 meters, depending on the tides from the Arabian Gulf through the Shatt Al-Arab and Garmat Ali Rivers (Hussain and Sabbar, 2020). It lies south of the Euphrates River and is bordered to the east by the Shatt Al-Arab River and to the west by the West Hammar Marsh. The predominant aquatic vegetation in the marsh includes *Typha domingensis*, *Phragmites australis*, and *Schoenoplectus littoralis* (Sabar and Al-Saadi, 2020). Mohamed *et al.* (2017) identified 47 fish species in the marsh, which include 24 freshwater species and 23 marine species, both native and non-native.

Fish sampling

Monthly fish samples were collected from three locations within the marsh: Al-Saddah, Al-Sallal, and Al-Nakara, from November 2022 to October 2023 (Figure 3). The fish were captured using four types of nets and electrofishing equipment, which provides 230V and 10A, with assistance from local fishermen. The net included drift gill nets (100 to 150 m long with a mesh size of 27 mm), trammel nets (120 to 150 m long with mesh sizes of 23-26 mm), and cast nets (4 to 7 m in diameter with a mesh size of 35 mm). Water temperature was measured with a graduated mercury thermometer (0-100°C) to estimate the mean water temperature, which will be used to calculate the natural mortality rate in the FiSAT II program. After collection, the

specimens were transported on ice in a cooler box to the laboratory for further analysis.

Data analyses

The total length (TL) of each specimen of *P. abu* was carefully measured using a standardised measuring board with a precision of 0.1 cm. Monthly length-frequency data were analysed using the FiSAT II software (FAO-ICLARM Stock Assessment Tool) version 1.2.2, as outlined by Gayanilo *et al.* (2005), after grouping the data into 1.0 cm classes. A subsample of the fish was also measured to the nearest 0.01 cm in total length (TL) and weighed to the nearest 0.01 g in total weight (W). The length at 50% maturity (L_{m50}) was calculated using the following equation from Binohlan and Froese (2009): $\log(L_{m50}) = -0.1189 + 0.9157 \times \log(L_{max})$, where L_{max} represents the largest individual observed in the sample. The commonly used length-weight relationship ($W = aL^b$) was applied (Le Cren, 1951), where W represents the weight (g), L is the total length (cm), and a and b are constants. The standard error for the slope (b) was calculated, and the hypothesis of isometric growth ($b = 3$) was tested through Student's t-test, with values of $p < 0.05$ considered significant (Froese, 2006). All calculations were performed using Microsoft Office Excel 2010.

The ELEFAN I procedure in FiSAT II was utilised to sequentially organise and restructure the monthly length-frequency dataset for assessing population parameters such as asymptotic length (L_{∞}) and growth coefficient (K). The initial seed value of L_{∞} was estimated based on L_{max} , derived from the mean of the largest 1% of fish in the sample, using the formula: $L_{\infty} = L_{max}/0.95$ (Pauly and Munro 1984). The theoretical age at (t_0) was estimated using the following formula from Pauly (1983):

$$\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10} L_{\infty} - 1.0381 \log_{10} K$$

Moreover, the growth performance index (ϕ') was calculated following Pauly and Munro's (1984) approach:

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

The instantaneous rate of total mortality (Z) for *P. abu* was computed using the length-converted catch curve method incorporated in the FiSAT package. Based on Pauly's empirical equation, $\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.463 \log_{10} T$ (Pauly, 1980), the natural mortality (M) was determined. Here, K represents the growth coefficient, L_{∞} is the asymptotic length, and T signifies the average temperature of the ecosystem, assumed to be 24.6°C. Subsequently, the fishing mortality (F) was calculated using the formula: $F = Z - M$, which represents the difference between total mortality (Z) and natural mortality (M). Further insights into the current exploitation level (E_{cur}) were obtained using the formula E



Figure 1. Sampling sits of *P. abu* in the East Hammar Marsh.

= F/Z (Sparre and Venema, 1998).

The linearised catch curve used to estimate (Z) was extrapolated backwards, using (M) as input in FiSAT II. The inbuilt logits method calculated size values at capture for probabilities of 0.25% (L_{25}), 0.5% (L_{50}), and 0.75% (L_{75}), where L_{50} represents the length at first capture, L_{c50} (Pauly, 1984). Recruitment patterns were derived by projecting length frequencies onto a one-year timescale incorporated in the FiSAT package (Pauly, 1983).

The model of Beverton and Holt (1966), updated by Pauly and Soriano (1986), was employed to predict the species' relative yield per recruit (Y'/R) and Biomass per Recruit (B'/R) using the knife-edge analysis incorporated into the FISAT software. The data of L_c/L_∞ and M/K values were used to estimate the biological reference points, including $E_{0.1}$, $E_{0.5}$, and E_{max} . $E_{0.1}$ represents the exploitation point at which the related increase in yield per recruit reached 1/10 of the related increase computed at a very low value of E . Conversely, $E_{0.5}$ indicates the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit (B/R), while E_{max} signifies the exploitation point that gives the maximum relative yield per recruit. The stock status was indicated by the biological target reference points ($E_{0.1}$ and E_{max}) and the current

exploitation rate, E_{cur} (Cadima, 2003).

The length-structured virtual population analysis (VPA) is a method that allows for the reconstruction of the population from total catch data by length (Jones and van Zalinge, 1981). The input parameters for the VPA analysis included L_∞ , K , M , F and the constants of the length-weight relationship (a and b). The initial step was to estimate the terminal population (N_t), followed by the successive estimation of fishing mortality (F) values. Finally, the population sizes were computed for each length class (midpoint).

RESULTS

Length-frequency distribution

A total of 4,274 *P. abu* were analysed, with their length-frequency data grouped into one-centimetre intervals (Figure 2). The lengths of the species varied from 5.4 cm to 18.0 cm. The most frequently observed length groups were 10.0 cm and 11.0 cm, accounting for 27.1% and 28.0% of the total, respectively. Additionally, lengths ranging from 7.0 cm to 13.0 cm comprised 96.7% of the

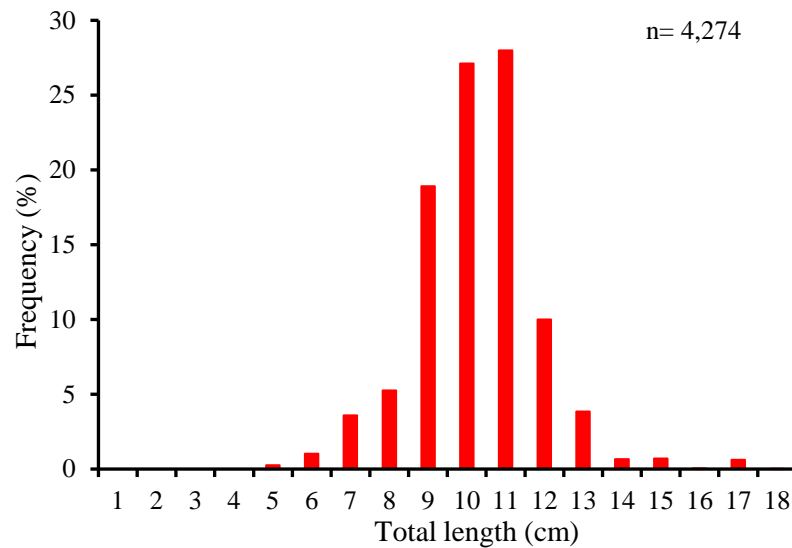


Figure 2. The overall length-frequency distribution of *P. abu*.

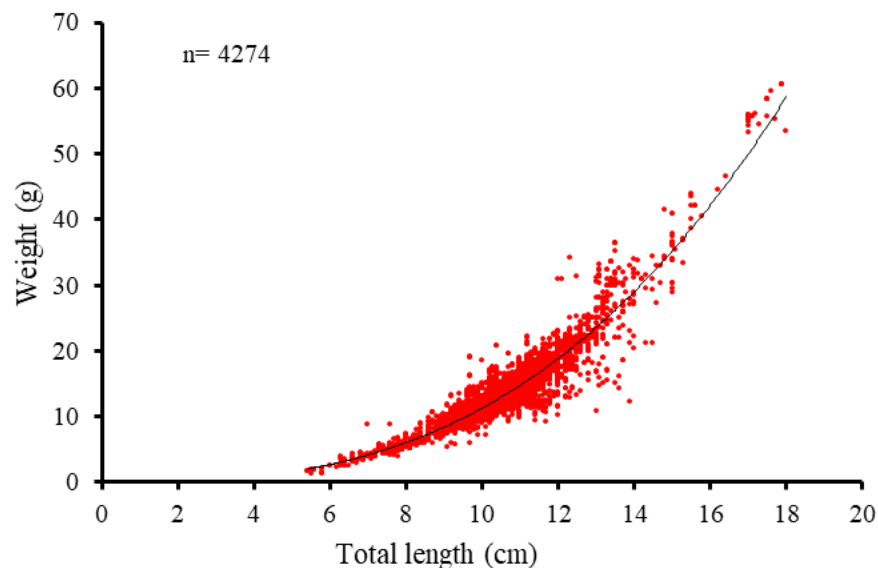


Figure 3. The length-weight relationship of *P. abu*.

overall sample. The length at first maturity (L_{m50}) was 10.7 cm, while the maximum length in the fish samples for both sexes was 18 cm.

The length-weight relationship

The length–weight relationship of 4,274 specimens of *P. abu* is shown in Figure 3. Total lengths of all samples ranged from 5.4 cm to 18.0 cm, while body weights varied from 1.3 g to 60.5 g. The length-weight relationship was represented by the equation $W = 0.0018TL^{2.801}$. The

calculated b-value differed significantly from 3 ($t = 12.584$, $p < 0.05$), indicating that the species exhibits negative allometric growth.

Growth model

A total of 4,274 specimens of *P. abu* were collected over 12 months to determine the growth parameters using the ELEFAN I analysis. The response surface (R_n) was calculated to be 0.297, which identified the optimal growth parameters $L_\infty = 19.7$ cm and $K = 0.50$ (Figure 4). The

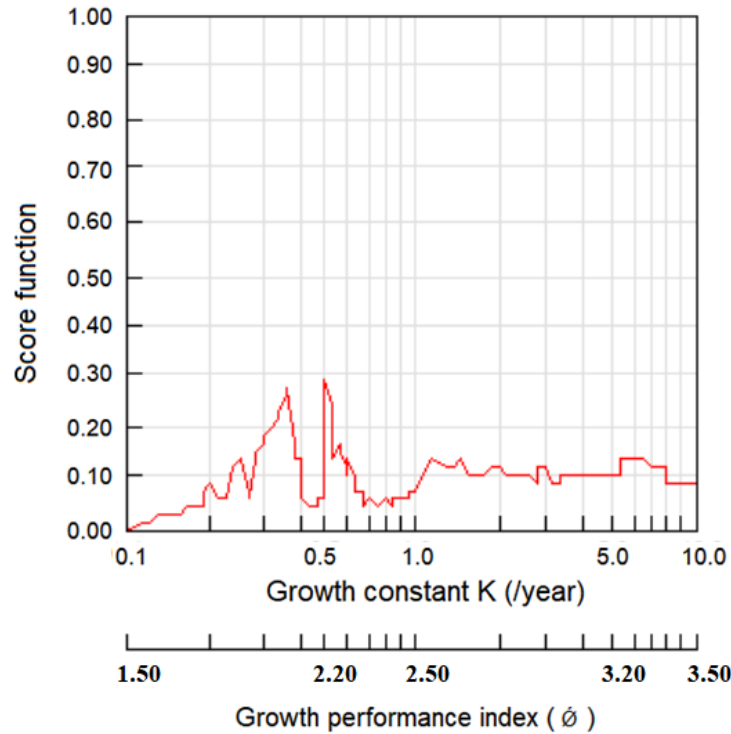


Figure 4. K-scan routines of *P. abu*.

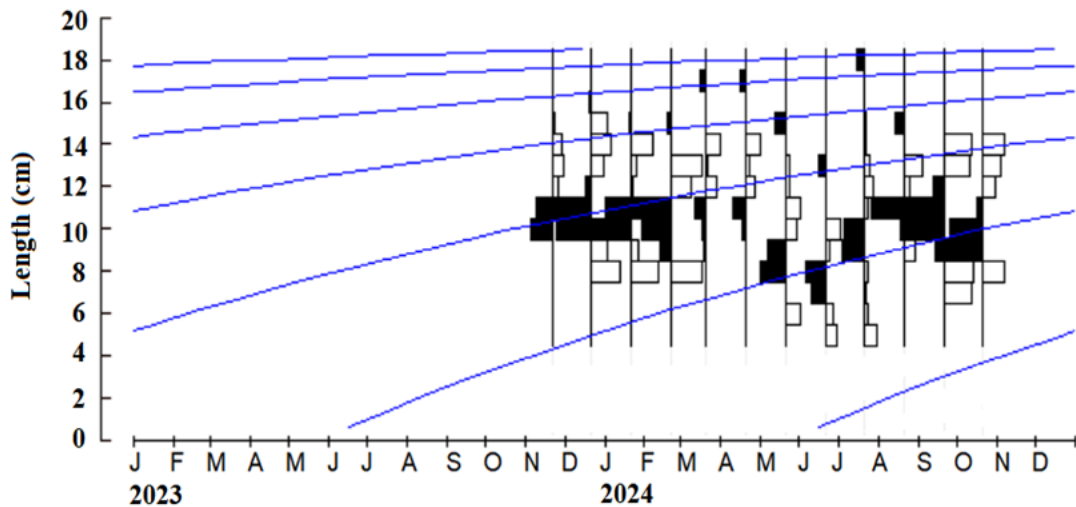


Figure 5. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *P. abu*.

optimised growth curve was overlaid on the restructured length-frequency histograms (Figure 5). The age at zero length (t_0) was estimated to be -0.32. The overall growth performance index (ϕ') was determined to be 2.288. The growth equation of von Bertalanffy of *P. abu* is expressed as follows:

$$L_t = 19.7 [1 - e^{-0.50(t + 0.32)}].$$

Mortality parameters

The length-converted catch curve of *P. abu* provided an estimate of the total mortality coefficient ($Z = 3.83$), as illustrated in Figure 6. The darkened quadrilaterals represent the points used in calculating Z via least squares linear regression. The blank circles indicate points that are either not fully recruited or nearing L_∞ and were therefore

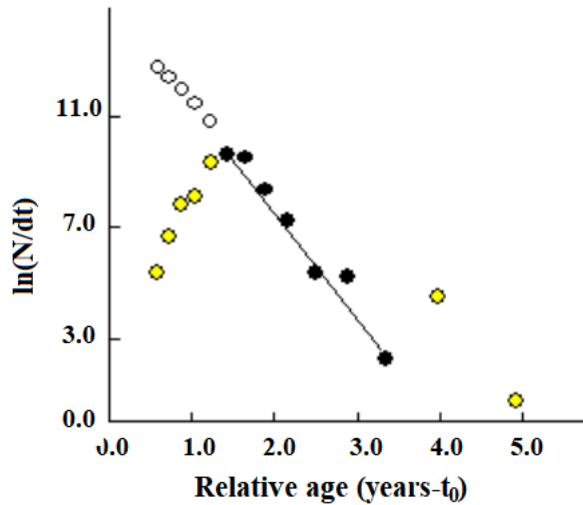


Figure 6. Length converted catch curve for estimation of Z for *P. abu*

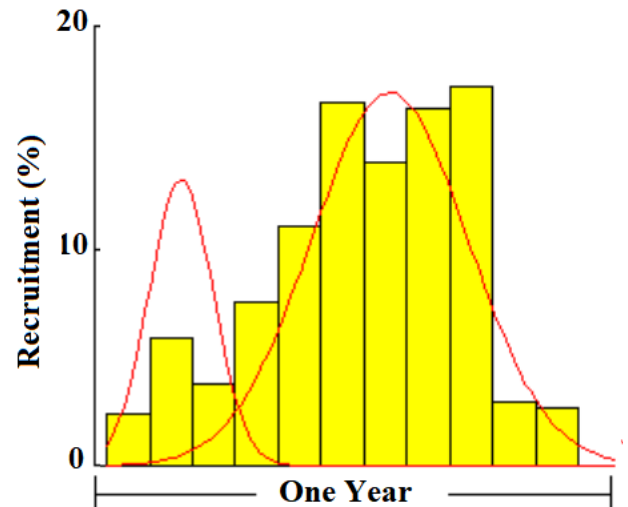


Figure 8. Recruitment pattern of *P. abu*.

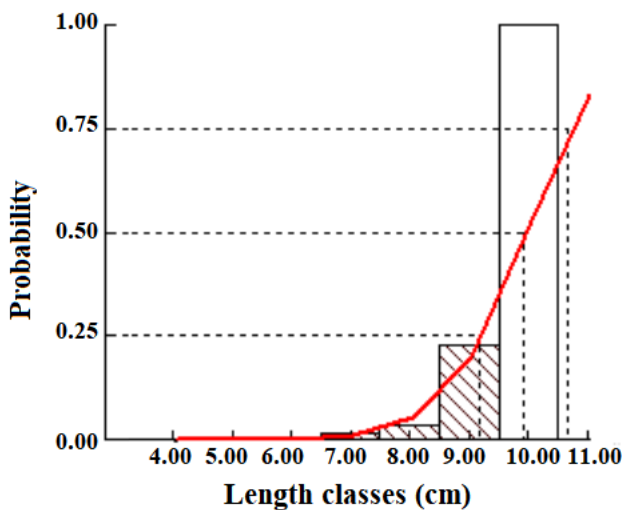


Figure 7. Probability of capture for *P. abu*.

excluded from the calculation. The natural mortality (M) was estimated at 1.20, based on the mean annual water temperature of 24.6°C. As a result, the fishing mortality rate (F) and the current exploitation rate (E_{cur}) were calculated as 2.63 and 0.69, respectively.

Length at first capture

The logistics of the probability of capture for *P. abu* are presented in Figure 7. The computed lengths L_{25} , L_{50} , and L_{75} were 9.19, 9.93 and 10.67 cm, respectively. Thus, the length at which 50% of the stock biomass is vulnerable to capture is estimated to be $L_{50} = 9.93$ cm. In contrast, the length at first maturity (L_{m50}) of *P. abu* is estimated to be 10.7 cm.

Recruitment pattern

The recruitment pattern of *P. abu* displays two distinct peaks, suggesting a bimodal distribution of recruitment throughout the year (Figure 8). The minor peak occurs in February, accounting for 5.88% of total recruitment, and lasts from January to March. In contrast, the major recruitment pulse occurred in September, accounting for 17.32% of total recruitment and extending from June to September. The highest levels of recruitment are observed from May to September, which together comprise 74.78% of total recruitment for the year.

Virtual population analysis

The results of the length-structured virtual population analysis for *P. abu* are provided in Table 1 and Figure 9. The highest number of catches for this species was recorded at lengths between 10.0 and 11.0 cm, while the highest natural mortality of the species occurs in fish measuring up to 8.0 cm in length. Beyond this size, most of the fishing mortality occurred for lengths between 10.0 and 13.0 cm, with a peak mortality rate of 2.517 at a length of 11.0 cm. The greatest biomasses (0.1) were found at the lengths of 6.0 to 11.0 cm. As the length increased towards 9.0 cm, survival rates and natural losses declined; however, catches and fishing mortality increased to a maximum at a length of 11.0 cm.

Yield per recruit (Y'/R) and biomass per recruit (B'/R)

The outcomes of relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) for *P. abu* based on M/K ratio of 2.40 and the L_{C50}/L_{∞} ratio of 0.503 were 0.022 and 0.221, respectively (Figure 10). The model also revealed

Table 1. FiSAT II output of virtual population analysis of *P. abu*

Mid-Length	Catch (in numbers)	Population (N)	Fishing mortality (F)	Steady-state Biomass (tons)
5.0	11	16239	0.0054	0.00
6.0	44	21378	0.0239	0.01
7.0	153	11526	0.0931	0.01
8.0	225	9401	0.1568	0.01
9.0	808	7454	0.6878	0.01
10.0	1159	5237	1.3837	0.01
11.0	1196	3073	2.5167	0.01
12.0	427	1306	1.8129	0.00
13.0	164	597	1.3064	0.00
14.0	28	282	0.3673	0.00
15.0	30	162	0.6222	0.00
16.0	2	75	0.0682	0.00
17.0	26	37	3.1319	0.00
18.0	1	1.5	2.6300	0.00

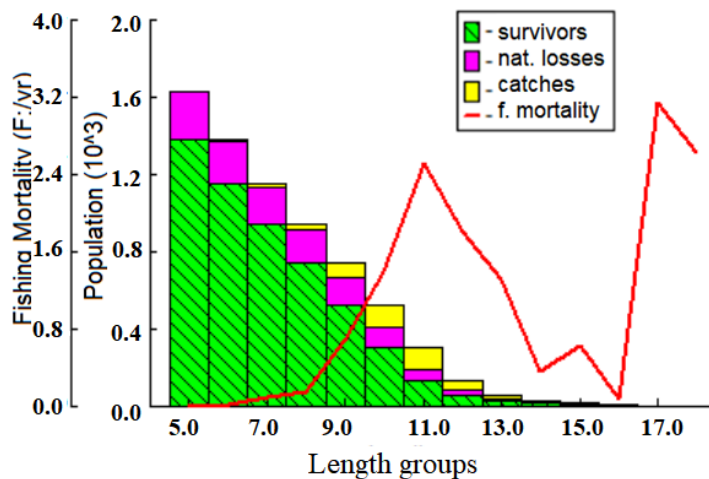


Figure 9. Length-structured virtual population analysis of *P. abu*.

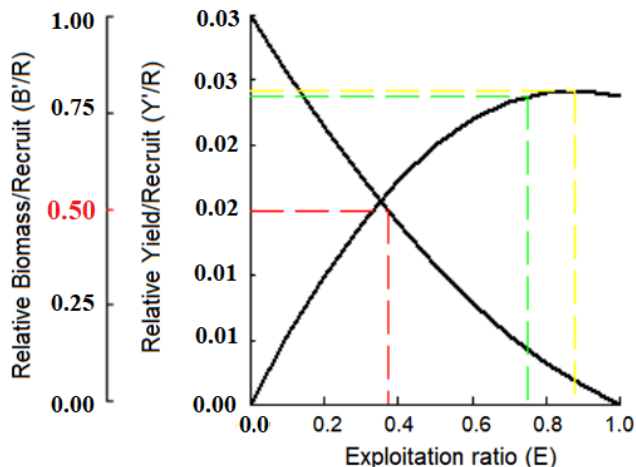


Figure 10. Relative yield per recruit (Y/R) and biomass per recruit (B/R) analyses of *P. abu*.

the biological target reference points for the species, with $E_{0.1}$ and E_{max} values of 0.752 and 0.875, respectively.

DISCUSSION

The length composition study revealed that the size ranges of *P. abu* individuals are generally comparable to those reported for the species in various regions. For example, sizes documented include 10.9-20.3 cm in the Tigris River, Turkey (Unlü *et al.*, 2000), 12.6-22.8 cm in Atatürk Dam Lake, Turkey (Şahinöz *et al.*, 2011), and 11.1-22.2 cm in the same lake (Doğu *et al.*, 2013). Additional size ranges reported are 2.0-22.0 cm, 4.0-20.0 cm, and 3.0-19.0 cm in the East Hammar, Huwazah, and Chybaish marshes, respectively (Mohamed, 2014). Other studies found sizes of 2.3-19.4 cm in the Orontes River, Turkey (Ay and Gülnaz Özcan, 2016), 1.4-21.3 cm in East Hammar marsh (Mohamed *et al.*, 2016), and 4.0-23.1 cm in the Ceyhan River Basin, Turkey (Birecikligil *et al.*, 2017). Moreover, size ranges include 3.7-20.9 cm in the Hawr Ad Dalmaj marsh, Iraq (Al-Zaidy *et al.*, 2019), 6.4-19.7 cm in the Shatt Al-Arab River, Iraq (Mohamed and Abood, 2020), and 7.0-20.0 cm in the Al-Diwaniya River, Iraq (Mohamed and Al-Jubouri, 2021). Lastly, sizes 12.9-19.5 cm were noted in the Tigris River, Turkey (Bilici, 2021), and 9.3-17.3 cm in the Karun River, Iran (Jorfipour *et al.*, 2023). The variations in size among fish individuals in different habitats may relate to several factors. These include environmental conditions, food availability, population density, fishing pressure, and fishing gears (Nikolsky, 1963; Riedel *et al.*, 2007; Takar *et al.*, 2022).

In the present study, the value of the constant (b) in the length-weight relationship for *P. abu* was found to exhibit a negative allometry growth pattern. This indicates that the fish's length increases at a faster rate than its weight, as noted by Riedel *et al.* (2007). These findings align with those of Doğu *et al.* (2013) in the Atatürk Lake, Turkey, Mohamed (2014) in the restored southern marshes, Iraq, Mohamed *et al.* (2016) in East Hammar marsh, Iraq, Al-Zaidy *et al.* (2019) in Hawr Ad Dalmaj marsh, Iraq and Mohamed and Al-Jubouri (2021) in the Al-Diwaniya River, Iraq. In contrast, some studies have reported positive allometric growth. This includes research by Unlü *et al.* (2000) in the Tigris River, Turkey; Ay and Özcan (2016) for female species in the Orontes River, Turkey; and Bilici (2021) in the Tigris River, Turkey. Conversely, other authors have found values for (b) that indicate isometric growth for *P. abu*. This is evident in studies by Ay and Gülnaz Özcan (2016) for male specimens in the Orontes River, Turkey; Birecikligil *et al.* (2017) in the Ceyhan River Basin, Turkey; and Shakir *et al.* (2018) in the Euphrates River, Iraq. The variation in growth coefficient (b) values for this species across different habitats can be attributed to several factors. These factors include habitat conditions, seasonal changes, stomach fullness, gonad maturity, sex, health, preservation techniques, and differences in the

lengths of the observed specimens due to catch methodology (Ricker, 1975; Froese, 2006; Cuadrado *et al.*, 2019; Pachla *et al.*, 2020).

Table 2 presents the growth parameters of *P. abu* in various studied regions, analysed using FISAT II software. The asymptotic length (L_{∞}) observed in this study is lower than that reported by previous authors. Notably, Birecikligil *et al.* (2017) documented the highest value for L_{∞} in the Ceyhan River, Turkey. The growth rate (K) estimated for *P. abu* in this study was higher than estimates from other research; in contrast, Birecikligil *et al.* (2017) reported the lowest value for K in the Ceyhan River. Furthermore, the growth performance index (Φ) of *P. abu* in this study, recorded at 2.30, falls within the range reported for the same species in other waters. The observed variations in the growth parameters of this species across different locations may be attributed to several factors, including geographical differences, habitat conditions, food availability, reproductive activities, genetic makeup, sampling techniques, and fishing pressure (Sparre and Venema, 1998; Wootton, 2011; Panda *et al.*, 2018; Turan, 2022).

The size at first capture (L_{c50}) for *P. abu* in this study was approximately the same as that reported for the same species in the Shatt Al-Arab River, Iraq (Mohamed and Abood, 2020). The L_{c50} value in fish is influenced by the types of nets used and their mesh sizes (Beverton and Holt, 1966; Ofori-Danson *et al.*, 2018; Amponsah *et al.*, 2021). Additionally, the study determined that *P. abu* reaches the length at first maturity (L_{m50}) at 10.7 cm, which is lower than previously reported lengths for the same species. Earlier studies noted sizes of 11.5-11.7 cm Fork Length (FL) in the Tigris River, Turkey (Unlü *et al.*, 2000), 17.20 cm in the Atatürk Dam Lake, Turkey (Şahingöz *et al.*, 2011), and 11.49-11.82 cm FL in the Orontes River (Ay and Gülnaz Özcan, 2016). When comparing the L_{m50} value with the L_{c50} value of *P. abu* in this study, the results indicate that the species does not meet the criteria for good management ($L_{c50} < L_{m50}$). This suggests that the fish may be vulnerable to capture by the available fishing gear before maturity. As a result, each individual may not get at least one opportunity to breed during their lifetime, which is essential for sustaining fish populations over the long term (Udoh and Ukpatu, 2017; Panda *et al.*, 2018). The length at which an animal first reaches sexual maturity is a critical point in its life history and must be considered for successful fish management (Almeida *et al.*, 2018).

The total mortality (Z), natural mortality (M), fishing mortality (F), and current exploitation (E_{cur}) rates for *P. abu* obtained in this study are compared with data from other research conducted in different water bodies (Table 2). Our study recorded the highest rates for Z, M, F, and E_{cur} . In contrast, the lowest values for these rates were observed in the Ceyhan River, Turkey (Birecikligil *et al.*, 2017). Several factors affecting the mortality rates of fish include water temperature, salinity, migratory behaviour, predation, food availability, diseases and fishing activity (Sparre and Venema, 1998; Allen and Hightower, 2010;

Table 2. The results of the FiSAT analyses for *P. abu* in different ecosystems.

References	L_{∞}	K	\emptyset	L_c	Z	M	F	E	Ecosystems
Mohamed (2014)	23.2	0.37	2.30	-	2.13	0.90	1.22	0.58	East Hammar marsh, Iraq
Mohamed (2014)	21.1	0.44	2.29	-	1.69	1.06	0.63	0.38	Huwazah marsh, Iraq
Mohamed (2014)	20.0	0.41	2.22	-	2.30	1.01	1.29	0.56	Chybaish marsh, Iraq
Mohamed <i>et al.</i> (2016)	24.6	0.44	2.94	-	3.27	1.03	2.24	0.68	East Hammar marsh, Iraq
Birecikligil <i>et al.</i> (2017)	27.9	0.19	2.89	-	0.40	0.33	0.07	0.17	Ceyhan River, Turkey
Mohamed & Abood (2020)	21.2	0.44	2.30	9.40	2.52	1.08	1.44	0.57	Shatt Al-Arab River, Iraq
Present study	19.7	0.50	2.29	9.93	3.83	1.20	2.63	0.69	East Hammar marsh, Iraq

Björnsson *et al.*, 2022; Campos *et al.*, 2023, 2024). The exploitation rate observed in this study is consistent with previous research on the species conducted in the same marsh (Mohamed *et al.*, 2016). Gulland (1971) and Pauly (1980) suggested that the rate of exploitation should be 0.5, with values below 0.5 indicating underexploitation and values above 0.5 suggesting overexploitation. Based on this criterion, it is clear that the *P. abu* stock in the marsh is overexploited.

The recruitment pattern for *P. abu* observed in this study reveals two distinct peaks. A minor peak occurs between January and March, while a major peak is noted from June to September. These findings are consistent with observations made by Mohamed *et al.* (2016) in the East Hammar marsh and by Mohamed and Abood (2020) in the Shatt Al-Arab River. Food availability and favourable weather conditions are the primary factors that influence fish recruitment (Gebrekiros, 2016; Nissar *et al.*, 2024).

Virtual Population Analysis (VPA) helps reconstruct historical populations of species based on their lengths, utilising data on individual deaths that occur each year, which are categorised into catches from fisheries and natural mortality, to estimate the population that must have been present in the water to produce the observed catch (Sparre and Venema, 1998; Shepherd and Pope, 2002; Baharti, 2017). In this study, the VPA indicated that the highest natural mortality rate of *P. abu* occurs in small fish measuring up to 8.0 cm in length, as these fish can escape through the net's mesh. In contrast, the maximum fishing mortality rate, recorded at 2.492, occurs at a length of 11.0 cm. Mohamed (2022) observed that natural losses of this species in the Shatt Al-Arab River were most prominent for lengths between 6.0 and 9.0 cm. Meanwhile, the fishing mortality rate increased steadily among mid-sized fish measuring between 10.0 and 16.0 cm, reaching a peak value of 1.670 at a length of 15.0 cm. The size of the mesh is an important factor in catch efficiency. Larger mesh sizes tend to trap larger fish, while smaller mesh sizes are more likely to catch juvenile or immature fish. Therefore, assessing suitable mesh sizes that are optimal for the fishery stock is crucial for sustainable exploitation (Soe *et al.*, 2022).

The current exploitation rate (E_{cur}) of *P. abu* in this study is above 0.5, indicating that the population is overexploited based on the criteria set by Gulland (1971) and Pauly

(1980). However, with a current exploitation rate of $E_{cur} = 0.69$, it is still below the optimal level of $E_{0.1} = 0.752$ and the maximum economic yield ($E_{max} = 0.875$), according to Cadima (2003). This suggests that while the species is overexploited, it has not yet reached the critical thresholds of $E_{0.1}$ and E_{max} . Similarly, Mohamed and Abood (2020) reported an exploitation rate of *P. abu* in the Shatt Al-Arab River of 0.57, which also falls below the biological target reference points $E_{0.1}$ and E_{max} .

Conclusions

The current information on the population status of *P. abu* is vital for developing effective conservation plans and ensuring the sustainable use of this fish resource in the marsh. The individual fish sizes, growth patterns, and values of L_{∞} and K are comparable to those reported in various regions. *P. abu* exhibits a bimodal recruitment pattern. However, the current exploitation rate (E_{cur}) is above 0.5, indicating that the stock is overexploited, but was below the biological reference points ($E_{0.1}$ and E_{max}). Additionally, the length at first capture (L_{c50}) is slightly lower than the size at first maturity (L_{m50}). To enhance fisheries management, it is crucial to increase the mesh size of fishing nets and to protect marsh areas by strictly enforcing Iraqi laws that safeguard aquatic life. These marshes are vital feeding grounds for numerous species and are frequently threatened by illegal fishing practices. By implementing these measures, we can ensure the long-term replenishment of fish stocks and promote sustainable fishing practices.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

ACKNOWLEDGEMENTS

The authors thank the Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, for providing the essential research facilities required for this study.

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