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Research Article

Stock Status and Management of Greenback mullet, *Planiliza subviridis* in the East Hammar marsh, Iraq

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Abstract
Assessing the various parameters of population dynamics is crucial for managing fish stocks. In this context, the present study analysed the growth, mortality, recruitment, yield-per-recruit, and virtual population analysis (VPA) parameters of *Planiliza subviridis* inhabiting the East Hammar marsh, in Iraq, using FiSAT II software. 3,429 specimens of *P. subviridis* measuring between 12.3 and 30.0 cm in total length (TL) and weighing between 21.1 and 303.5 g were sampled from November 2022 to October 2023. The length-weight relationship, expressed as $W= 0.0142*TL^{2.928}$ exhibited negative allometric growth. The growth parameters, including asymptotic length ($L\infty$) and the growth constant (K), were calculated as 33.0 cm and 0.33, respectively. The length at first maturity was higher than the size at first capture. Mortality estimates indicated total mortality (Z) at 1.91, natural mortality (M) at 0.79, and fishing mortality (F) at 1.12, resulting in an exploitation rate (E) of 0.58. Recruitment of *P. subviridis* continued throughout the year, with one prominent peak in June. The relative yield per recruit analysis indicated that the current exploitation rate (E_{cur}= 0.58) is below the biological target reference points for the species ($E_{0.1}$= 0.609) and (E_{max}= 0.748), suggesting that the studied stock is under-exploited. VPA results showed that mid-length (19 cm) was the highest fishing mortality (1.563). For effective management, it is essential to adjust net mesh sizes and adopt sustainable fishing practices to fulfil the criteria for good management (Lc50 < Lm50), ensuring the long-term sustainability of *P. subviridis* in this feeding region.

Keywords: East Hammar marsh, Growth and mortality, Iraq, *Planiliza subviridis*, Yield-per-recruit,

INTRODUCTION

Mullets of the family Mugilidae (Perciformes) are ray-finned fish found in the Indo-Pacific region. They typically inhabit coastal seas in temperate, subtropical, and tropical regions. Depending on the species, mullets may spend part or all of their life cycle in coastal lagoons, lakes, and rivers (González-Castro and Ghasemzadeh, 2015). The latest taxonomic revision identifies 75 valid species across 24 genera worldwide in this family (Fricke and Fong, 2025). Mullets, in general, are catadromous, detritivore and euryhaline fishes moving in shoals between distinctive environments, habitually living in estuary brackish waters and fresh water in rivers (Panda *et al*., 2018; Pereira *et al.,* 2024). In Iraqi waters, five species of mullets were recorded, namely abu mullet *Planliza abu*, Klunzinger's mullet *Planliza klunzengeri*, greenback mullet, *P. subviridis*, keeled mullet *P. carinata* and silver mullet *Osteomugil speigleri* (Mohamed *et al*., 2016). *P. subviridis* and *P. klunzengeri* are marine species that migrate into rivers and marshes in southern Iraq for feeding and are locally known as Beyah. In contrast, *P. abu*, also known as Khishni, is found in rivers, lakes, drains, and marshes (Mohamed *et al*., 2016). All species except *O. speigleri*, which was previously classified under the genus *Liza*, are now included in the genus *Planiliza* (Durand *et al*., 2012).

Mullets are commercially valuable fish species found in Iraqi waters. In 2023, the total catch of mullet species from Iraqi marine waters amounted to 2,863 tons, representing approximately 9.72% of the overall landings (Mohamed and Abood, 2024a). Additionally, the catch of mullets from the Basrah inland waters fisheries was 318 tons, accounting for 15.4% of the total landings (Mohamed and Abood, 2024b).

The Greenback mullet, *Planiliza subviridis* (Valenciennes, 1836), belongs to the Mugilidae family and is locally known as 'Beyah'. This species is widely distributed throughout the Indo-Pacific region, including the Arabian Gulf, Pakistan, India, Bangladesh, Burma, Vietnam, and the Philippines, extending through the South China Sea to the northern part of the region, and southward to the north coasts of Australia. *P. subviridis* is a herbivorous or detritivorous species that feeds on detritus, diatoms, algae, higher plants, zooplankton, and fish (Fatema *et al*., 2013; Rahman *et al*., 2016; Langsa *et al*., 2021; Mohamed and Al-Hassani, 2023). The species is a marine migrant mugilid fish that spawns in the sea. After spawning, juveniles enter lagoons, estuaries, rivers, and marshes to feed and grow until maturity. Once mature, they embark on a return journey to the sea for breeding (Thomson, 1984; Saha and Kabir, 2014).

P. subviridis is commonly found in the marine waters of Iraq and enters the rivers and marshes in southern Iraq to feed. The species constituted 60% of the fish assemblage in the Shatt Al-Basrah Canal (Al-Daham and Yousif, 1990), 27% of the fish assemblage in the Khor-Al-Zubair (Ali and Hussain, 1990), 1.6%-2.9% of the fish assemblage in the East Hammar marsh (Mohamed *et al*., 2009; Mohamed *et al*., 2012), 6.1% of the fish structure in the Shatt Al-Arab River (Mohamed and Abood, 2017) and 25% of the fish structure in the Al-Sweib River, Iraq (Abdullah *et al*., 2018).

Several studies have been conducted on the population of *P. subviridis* in various waters worldwide. Notable research includes: Mohd Rosli (2012) in the Merbok Estuary, Malaysia; Mohamed *et al.* (2013) in the East Hammar Marsh, Iraq; Djumanto and Setyobudi (2015) in the estuary of the Opak River, Yogyakarta, Indonesia; Rahman *et al.* (2016) from Parangipettai Waters, India; Mohamed and Abood (2020) in the Shatt Al-Arab River, Iraq; Mohamed and Al-Hassani (2021) in Iraqi marine waters; Mohamed (2022) in the Shatt Al-Arab River, Iraq.

The most recent population assessment of *P. subviridis* was conducted between 2009 and 2010 (Mohamed *et al.*, 2013).

Updating the data on this species will improve stock assessments and support sustainable fisheries management strategies for the species in the East Hammar marsh. Thus, this study aimed to evaluate growth, mortality, capture probability, recruitment, yield per recruit, and virtual population analysis of *P. subviridis* in the East Hammar marsh from November 2022 to October 2023, providing decision-makers with recommendations for management strategies.

MATERIALS AND METHODS

The East Hammar Marsh is a remarkable wetland area located in Al-Basra province. It is bordered to the north by the Euphrates River, extends eastward alongside the Shatt Al-Arab River, and is bounded to the west by the West Hammar Marsh. To the south, it connects to the Garmat Ali River, which links it to the Shatt Al-Arab River. After flooding in April 2003, the marsh received its water mainly from the Shatt Al-Arab River via the Garmat-Ali River. This led to its classification as a tidal marsh, influenced by the semidiurnal tides from the Arabian Gulf. Consequently, it differs from other Iraqi marshes due to the regular occurrence of these tidal influences (Hussain *et al*., 2009). A total of 47 fish species, representing 35 genera and 20 families, were collected from the marsh, including 24 freshwater species and 23 marine species (Mohamed *et al*., 2017). The East Hammar marsh hosts 43 species of aquatic plants, belonging to 33 genera and 21 families. The three most dominant perennial species include *Typha domingensis*, *Phragmites australis*, and *Schoenoplectus litoralis* (Sabar and Al-Saadi, 2020).

Monthly fish specimens were collected with the assistance of local fishermen from three locations in the marsh: Al-Saddah, Al-Sallal, and Al-Nakara (Fig. 1) from November 2022 to October 2023. A variety of fishing techniques were employed to collect samples. These included drift gill nets, fixed gill nets, trammel nets and cast nets. Additionally, electro-fishing was performed using a generator engine that provided 230V and 10A. The water temperature was measured using a graduated mercury thermometer (0-100°C). The caught fish were stored in iceboxes and transported to the Department of Fisheries and Marine Resources laboratory for further examination.

In the laboratory, all *P. subviridis* samples were measured for their total length (TL, cm) using a measuring board accurate to 0.1 cm, which allowed the creation of a length-frequency distribution for the species. A subsample was taken for biological study. Each fish's total length (TL) was measured to the nearest millimeter, and its weight was recorded to the nearest 0.1 grams using an electronic balance. The length at which 50% of the fish reach maturity (L_m50) was calculated using the following equation (Binohlan and Froese, 2009):

$$\log(L_m50) = -0.1189 + 0.9157 * \log(L_{max}) \quad (1)$$

where L_{max} is the maximum observed length from the samples.

The length-weight relationship was established using the regression method based on the following formula

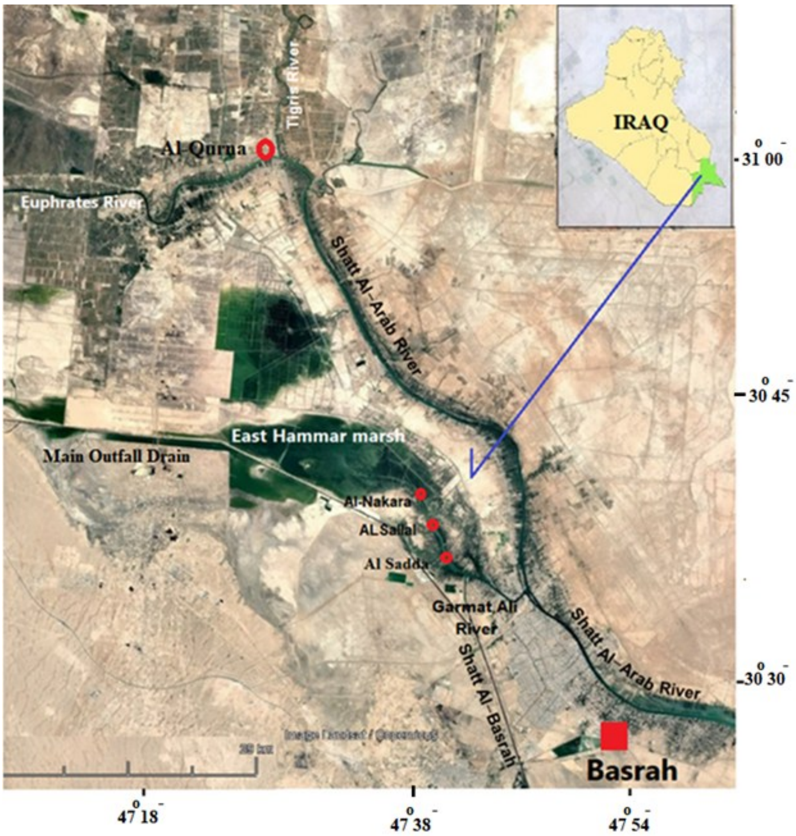

Fig. 1. *Sampling sites of Planiliza subviridis in the East Hammar Marsh*

(Le Cren, 1951):

$W = a L^b$ (2)

where W represents the total weight of the fish (in grams), L denotes the total length of the fish (in millimeters), and a and b are the regression constants. A significant deviation of the b value was performed by a t-test to detect growth types, isometric or allometric (Froese, 2006). All the calculations were done using Microsoft Office Excel 2010.

Estimation of all population parameters was conducted using the FiSAT-II software (Version 1.2.2), developed by the FAO-ICLARM (Gayanilo *et al*., 2005). The two key growth parameters of the von Bertalanffy model, asymptotic length (L∞) and growth constant (K), were determined using the ELEFAN-I module. The best growth curve was fitted based on a non-parametric scoring system derived from the goodness-of-fit index known as the "R_n value." The theoretical age at (t□) was calculated using the following relationship established by Pauly (1983):

$\log_{10}(-t_0) = -0.3922 – 0.275 \log_{10}L\infty – 1.0381 \log_{10}K$ (3)

The growth performance index (Ø') was generated using the formula by Pauly and Munro (1984):

$(Ø') = 2\log L\infty + \log K$ (4)

To estimate the total mortality rate (Z), the length-converted catch curve method described by Pauly (1984) was implemented in the FiSAT II software. The natural mortality (M) was calculated using FiSAT II, applying the equation provided by Pauly (1980):

$\log_{10} M = -0.0066 – 0.279 \log_{10} L\infty + 0.6543 \log_{10} K + 0.463 \log_{10}T$ (5)

where the growth constant is denoted by K, asymptotic length by L∞, and mean water temperature by T (24.6° C). Fishing mortality (F) was calculated as the difference between total mortality (Z) and natural mortality (M). The current exploitation rate (E_{cur}) was calculated as F / Z (Sparre and Venema, 1998). Z was estimated using a linearized catch curve extrapolated backwards using the FiSAT software. Length at capture probabilities of 0.25% (L_{25}), 0.5% (L_{50}), and 0.75% (L_{75}) were derived using the inbuilt logits method, where L50 represents the length at first capture, L_c50 (Pauly 1984).

Monthly recruitment patterns were analyzed using FiSAT II software, employing backward projection of length frequencies based on growth parameters (Pauly, 1983).

The Beverton and Holt analysis, performed using the knife-edge module of FiSAT II, plotted relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) against exploitation rate (Beverton and Holt, 1966; Pauly and Soriano, 1986). Biological reference points ($E_{0.1}$, $E_{0.5}$, and E_{max}) were calculated using L_c/L∞ and M/K values. These reference points represent the exploitation rate at 10% marginal increase in Y'/R ($E_{0.1}$), 50% reduction in unexploited biomass ($E_{0.5}$), and maximum sustainable exploitation (E_{max}). Stock status was then determined by comparing the current exploitation rate (E_{cur})

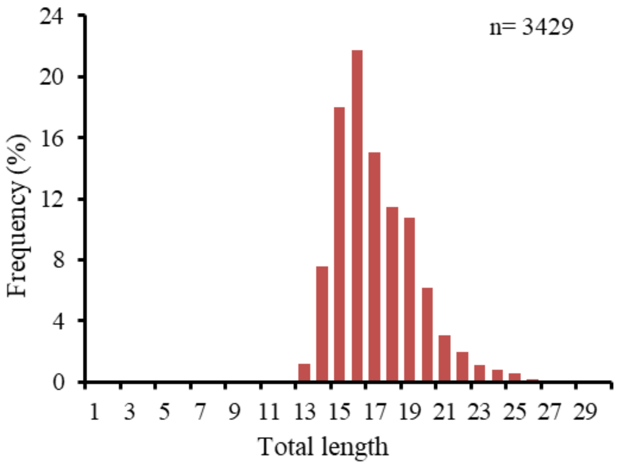

Fig. 2. *The overall length-frequency distribution of Planiliza subvirisids*

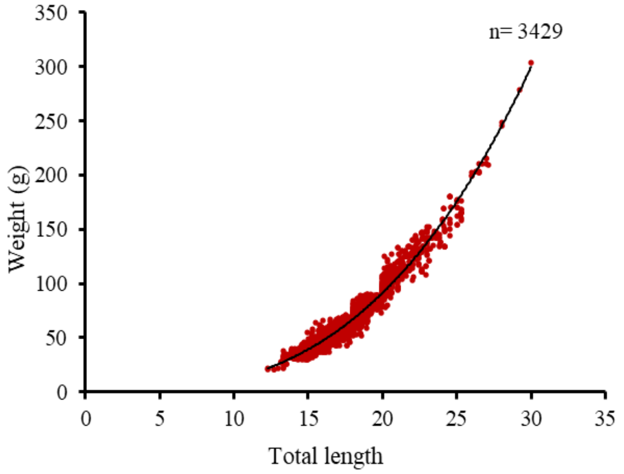

Fig. 3. *The length-weight relationship of Planiliza subvirisids*

to the biological target reference points $E_{0.1}$ and E_{max} (Cadima, 2003).

Using the growth coefficients from the length-weight relationship equation, along with growth and mortality parameters, a length-structured virtual population analysis (VPA) was conducted. This analysis provided data on population sizes, catches, and both natural and fishing mortality rates for each length class (Jones and van Zalinge, 1981; Pauly, 1984).

RESULTS

Growth parameters

A length frequency distribution was created for 3,429 individuals of *P. subviridis*, ranging from 12.3 to 30.0 cm, as shown in Fig. 2. The 16.0 cm length group accounted for 21.76% of the total, followed by the 15.0 cm group at 17.99%. Fish measuring between 14.0 and 20.0 cm were the most abundant in the catch.

The length-weight relationship of 3429 samples of *P. subviridis* is illustrated in Fig. 3. The total lengths of the species ranged from 12.3 to 30.0 cm, while their weights varied from 21.1 to 303.5 g. The length-weight relationship can be expressed by the equation $W= 0.0142TL^{2.928}$. A t-test revealed that the regression slope (b) was significantly different from 3 (t = 5.994, P > 0.05), indicating negative allometric growth for this species.

We estimated growth parameters for *P. subviridis*, specifically asymptotic length (L_∞) and growth coefficient (K), by analyzing total length measurements from 3,429 specimens (12.3-30.0 cm) using the ELEFAN I module in FiSAT software. A K-scan routine, yielding a response surface value (Rn) of 0.259, ensured a reliable K estimate (Fig. 4). Fig. 5 illustrates the restructured length frequency distribution of *P. subviridis*, along with superimposed growth curves. The asymptotic length (L_∞) was measured at 33 cm, with a growth rate (K) of 0.33 per year. The estimated age at zero length (t□) was -0.63 years, and the growth performance index (Ø') was 2.556.

Mortality parameters

The linearized length-converted catch curve (Fig. 6) estimated the instantaneous total mortality (Z) of *P. subviridis* to be 1.91. Natural mortality (M) was 0.79, fishing mortality (F) was 1.12, and the exploitation rate (E) was 0.58.

Probability of capture

The probabilities of the capture of *P. subvirisids,* L_{25}, L_{50}, and L_{75} were 14.11, 14.59 cm and 15.07 cm, respectively (Fig. 7). Therefore, the length-at-first capture (L_{c50}) was 14.59 cm. Moreover, the total length at which *P. subvirisids* first reaches sexual maturity (L_{m50}) was 15.9 cm.

Recruitment pattern

Recruitment of *P. subviridis* peaked in June (18.68%) with a single prominent peak (Fig. 8). Recruitment ranged from 0.25% in November to the June peak, with 77.34% of total recruitment occurring between April and August.

Virtual population analysis

The virtual population analysis (VPA) indicated that the primary loss of fish measuring up to 14 cm occurred due to natural causes. After this stage, fishing mortality increased as the fish became more vulnerable. The highest recorded fishing mortality rate was 1.563, which occurred for fish measuring 19 cm (Fig. 9).

Yield per Recruit (Y'/R) and Biomass per Recruit (B'/R)

The Beverton-Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) estimated for the

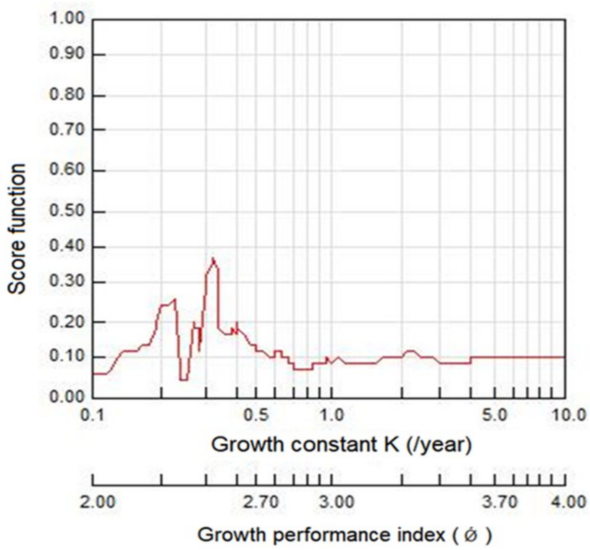

Fig. 4. *K-scan routines of Planiliza subvirisids*

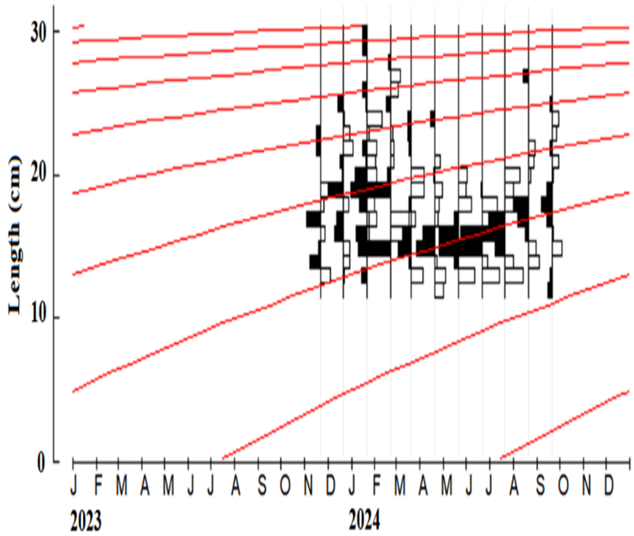

Fig. 5. *Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for Planiliza subvirisids*

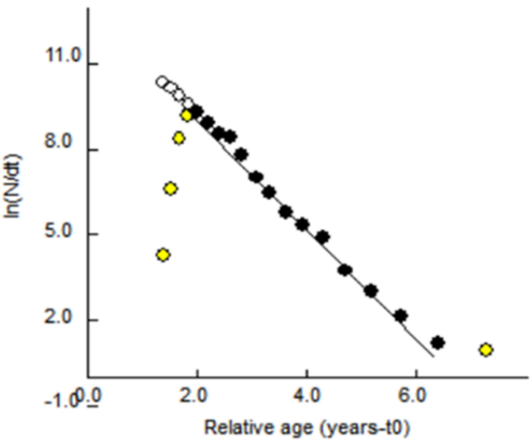

Fig. 6. *Length converted catch curve for estimation of Z for Planiliza subvirisids*

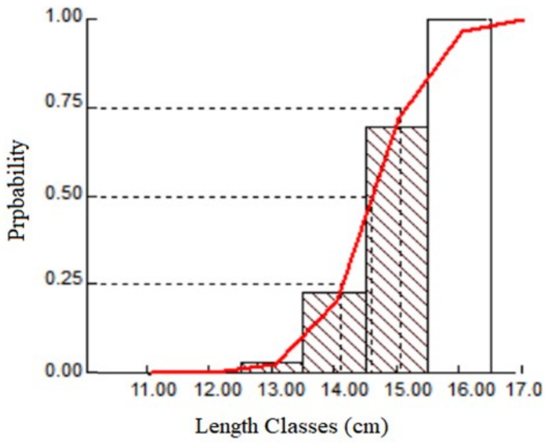

Fig. 7. *Probability of capture for Planiliza subvirisids*

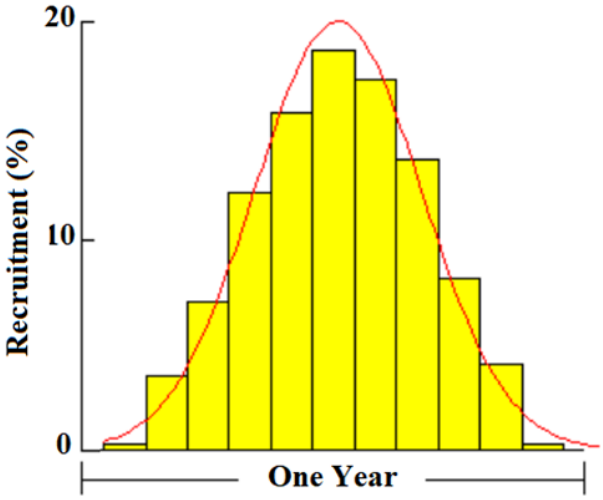

Fig. 8. *Recruitment pattern of Planiliza subvirisids*

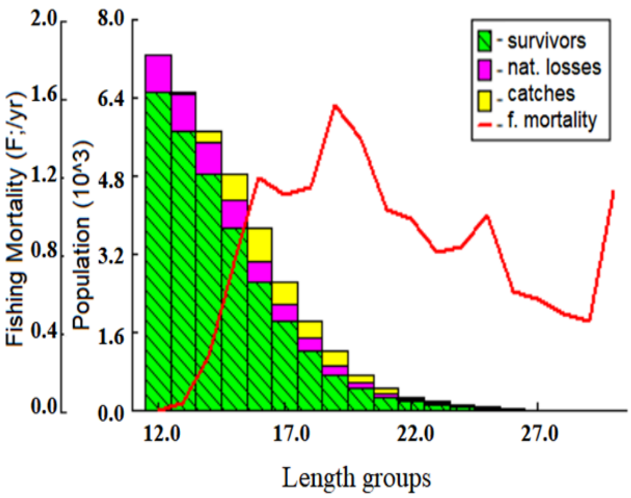

Fig. 9. *Length-structured virtual population analysis of Planiliza subvirisids*

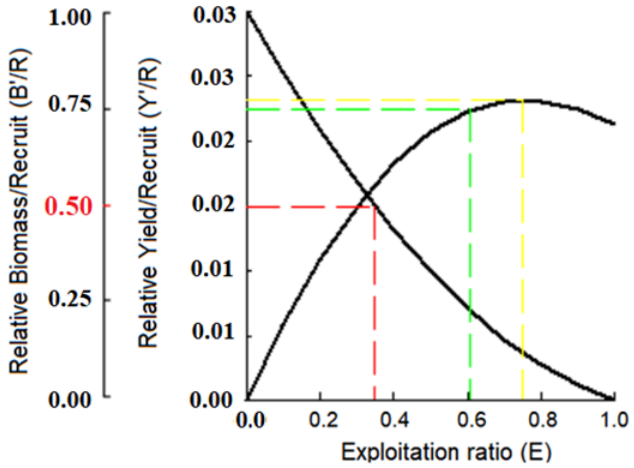

Fig. 10. *Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for Planiliza subvirisids*

species were found to be 0.019 and 0.265, respectively. These estimates were calculated using a function of M/K (2.394) and L_c/L_∞ (0.440). The study found that the biological target reference points, $E_{0.1}$ and E_{max}, were 0.609 and 0.748, respectively (Fig. 10). The current exploitation rate (E_{cur}) was recorded at 0.58, which is below the biological target reference points ($E_{0.1}$ and E_{max}). This suggests that the species is currently under-exploited.

DISCUSSION

The stock assessment aims to provide decision-makers with the information needed to make informed choices about the optimal levels of exploitation and management of aquatic living resources (Kebtieneh *et al*., 2016). The study found that the length range of *P. subviridis* individuals, 12.3-30.0 cm (Fig. 2), was comparable to that reported for the same species in other bodies of water. Specifically, previous studies noted lengths of 5.6 to 25.6 cm in the Iraqi marine waters (Mohamed *et al*., 1998), 14.5 to 31.0 cm in the Shatt Al-Basrah Canal (Al-Daham and Wahab, 1991), 8.7 to 29.2 cm in the East Hammar marsh (Mohamed *et al*., 2013), 12.0 to 30.0 cm in the Iraqi marine waters (Mohamed and Al-Hassani, 2021), 12.0 to 30.5 cm in the Makassar straits, Indonesia (Rahmadhani *et al*., 2023) and 13.6 to 30.3 cm in the Segara Anakan Cilacap, Indonesia (Sukmaningrum *et al*., 2023). In contrast, the size of *P. subviridis* observed in the present study was larger than those reported by Samad and Abbas (1999) for the Sandspit backwaters along the Karachi coast, Pakistan (11.5 to 20.2 cm); Zolkhiflee (2016) from the Pinang River Estuary in Malaysia (9.3 to 19.6 cm); Mohamed and Abood (2020) from the Shatt Al-Arab River (9.8 to 26.5 cm); and while Islam *et al.* (2023) from the coastal waters of Southern Bangladesh (6.5 to 19.7 cm). According to Djumanto and Setyobudi (2015), the recorded lengths of *P. subviridis* in the Opak River, Indonesia, ranged from 7.2 to 35.9 cm. These variations can be attributed to several factors, including environmental conditions, food availability, population density, fishing pressure, and possibly the use of different types of fishing gear (Riedel *et al*., 2007; Wootton, 2011).

The estimated growth coefficient (b) of the length-weight relationship for *P. subviridis* in this study indicates a negative allometric growth pattern (b<3), meaning that the fish's body weight becomes proportionally lighter as its length increases (Riedel *et al*., 2007). A similar growth pattern for the species has been observed in various locations, including the following studies: Mohamed *et al*. (1998) in the Iraqi marine waters, Arabian Gulf; Shadi *et al*. (2011) in the Iranian waters, Arabian Gulf; Mohd Rosli (2012) in the Merbok estuary, Malaysia; Mohamed *et al*. (2013) in the East Hammar marsh; Rahman *et al*. (2013) in the Parangipettai Waters, India; Baloch *et al*. (2015) in Damb Harbour, Pakistan; Zolkhiflee (2016) in the Pinang River, Malaysia; Fitriah *et al.* (2021) in the Banten Bay Indonesia; Mohamed and Al-Hassani (2021) in the Iraqi marine waters, Arabian Gulf; Mohamed (2022) in the Shatt Al-Arab River, Iraq; and Rahmadhani *et al*. (2023) in the Makassar straits, Indonesia. The length-weight relationship of fish is influenced by several factors, including habitat, season, sex, gonad maturity, stomach fullness, stress and sampling methodology (Froese, 2006; Mili *et al*., 2017; Cuadrado *et al*., 2019).

Table 1 compares the growth and mortality parameters of *P. subviridis* across different studies using the FiSAT II software. The asymptotic length (L_∞) of *P. subviridis* reported in the present study is similar to the values found by Mohamed *et al*. (2013) and Mohamed and Al-Hassani (2021). However, it is higher than the values noted by Mohamed *et al.* (1998), Rahman *et al*. (2016), Mohamed and Abood (2020), and Islam *et al.* (2023). Other studies, such as those by Mohd Rosli (2012) and Djumanto and Setyobud (2015), reported even higher L_∞ values for *P. subviridis* across different waters. The growth coefficient (K) and the growth index (Ø') for *P. subviridis* were found to be intermediate between the values reported for this species (Table 1). Differences in growth rates of the same species across locations can be attributed to several factors. These include ecological conditions, habitat type, food availability, metabolic and reproductive activities, fish sizes, sampling methods, and fishing pressure (Nikolsky, 1963; Spare and Venema, 1998; Wootton, 2011; Panda *et al*., 2018; Çiloğlu and Ateş, 2022).

The length at first capture (L_{c50}) for *P. subviridis* is lower than the value reported by Mohamed and Al-Hassani (2021) but higher than the measurements recorded by Mohd Rosli (2012) and Mohamed and Abood (2020). The L_{c50} value in fish is influenced by the type of nets

Table 1. The results of the FiSAT analyses for *Planiliza subviridis* in different ecosystems

Author	L∞ (cm)	K	Ø'	L_c	Z	M	F	E	Region
Mohamed *et al.* (1998)	30.8	0.23	0.62	-	-	-	-	-	Iraqi marine waters, Arabian Gulf
Mohd Rosli (2012)	35.1	0.62	-	11.2	3.19	1.25	1.92	0.60	Merbok Estuary, Malaysia
Mohamed *et al.* (2013)	33.7	0.27	-	-	1.20	0.69	0.51	0.43	East Hammar marsh, Iraq
Djumanto and Setyobud (2015)	37.3♀	0.34	2.67	-	1.56	0.84	0.72	0.46	Estuary of Opak River, Indonesian
Rahman *et al.* (2016)	27.8	1.0	4.71	-	0.56	0.73	0.30	0.32	Parangipettai waters, India
Mohamed and Abood (2020)	29.3	0.40	2.54	12.8	1.68	0.75	0.93	0.45	Shatt Al-Arab River, Iraq
Mohamed and Al-Hassani (2021)	33.8	0.3	2.54	17.5	1.11	0.74	0.38	0.34	Iraqi marine waters, Arabian Gulf
Islam *et al*. (2023)	20.8	1.02	2.64	-	2.23	1.57	0.66	0.30	Coastal waters of Southern Bangladesh
Present study	33.0	0.33	2.56	14.6	1.91	0.79	1.12	0.58	East Hammar Marsh, Iraq

used and their mesh size (Beverton and Holt, 1966; Ofori-Danson *et al*., 2018; Amponsah *et al.,* 2021). In this study, the total length at which *P. subviridis* first reaches sexual maturity (L_m50) is seen to be 15.8 cm. Samad and Abbas (1999) reported that the length at 100% sexual maturity in males ranged from 14.5 to 14.9 cm, and in females from 13.8 to 14.1 cm, as observed in the Sandspit backwaters along the coast of Karachi, Pakistan. Al-Daham and Wahab (1991) mentioned that the smallest mature male and female *P. subviridis* found in the Shatt Al-Basrah Canal in Iraq measured 13.7 cm and 14.2 cm, respectively. In Parangipettai waters, India, the minimum lengths at first sexual maturity (L_{m50}) were recorded as 13.1 cm for males and 14.5 cm for females (Rahman *et al*., 2016). Additionally, Islam *et al*. (2023) estimated the L_{m50} of *P. subviridis* to range from 9.21 to 14.74 cm in the coastal waters of Southern Bangladesh. Based on the results of this study, it can be concluded that the estimated length at first capture (L_c50) is lower than the length at first maturity (L_m50), which is 15.8 cm.

This indicates that the bulk of *P. subviridis* individuals were captured before reaching maturity, suggesting that the captured species do not meet the criteria for effective management, $L_{c50} < L_{m50}$ (Udoh and Ukpatu, 2017; Panda *et al*., 2018).

The total (Z), natural (M), and fishing mortality rates for *P. subviridis* in this study fall within the ranges reported for this species in various locations (Table 1). The lowest recorded rates of Z and F were observed in the Parangipettai waters, India (Rahman *et al.,* 2016), while the lowest value of M was observed in the East Hammar marsh, Iraq (Mohamed *et al*., 2013). Conversely, the highest values of Z and F were reported in the Merbok estuary, Malaysia (Mohd Rosli, 2012), and the maximum value of M was reported in the coastal waters of Southern Bangladesh (Islam *et al*., 2023). Fishing effort and the catchability coefficient can affect the F value through fishermen's activities (Sparre and Venema, 1998). Furthermore, natural mortality is affected by various environmental and biological factors, including water temperature, salinity, migratory behaviour, predation, food availability, and diseases (Allen and Hightower, 2010; Björnsson *et al*., 2022; Campos *et al*., 2023, 2024).

The current exploitation ratio (E_{cur}) for *P. subviridis* in this study indicates that the species is slightly over-exploited, based on the criteria established by Gulland (1971). He stated that when natural and fishing mortality rates are equal, the exploitation rate is 0.5; a rate below 0.5 indicates under-exploitation, while a rate above 0.5 indicates over-exploitation. Although E_{cur} is slightly above 0.5 in this study, it falls within the ranges reported for this species in other regions (Table 1). The lowest exploitation rate was observed in the coastal waters of Southern Bangladesh (Islam *et al*., 2023), while the highest rate was found in the Merbok Estuary, Malaysia (Mohd Rosli, 2012).

The recruitment pattern of *P. subviridis* demonstrated continuous recruitment, with a peak occurring in June, accounting for 18.68% of the total (Fig. 8). A similar recruitment pattern has been observed in certain Iraqi waters, such as the Shatt Al-Arab River (Mohamed and Abood, 2020) and the marine waters of the Arabian Gulf (Mohamed and Al-Hassani, 2021). Some researchers have reported two unequal peaks in the recruitment pattern of *P. subviridis* in other locations, such as the Merbok estuary in Malaysia (Mohd Rosli, 2012) and the East Hammar marsh in Iraq (Mohamed *et al*., 2013). Djumanto and Setyobudi (2015) observed that the recruitment patterns of male and female *P. subviridis* occur annually, with spawning peaks at the beginning and end of the dry season. Food availability and favourable weather conditions are the key factors influencing fish recruitment (Gebrekiros, 2016; Nissar *et al*., 2024).

The Virtual Population Analysis (VPA) is a tool used to provide biological advice for fishery management and to evaluate whether fish stocks are within safe biological limits. This ensures that productivity, which includes growth and recruitment, is not negatively affected by fishing activities (Lassen and Medley, 2001). In this study, it was determined that the highest natural mortality of *P. subviridis* occurs in fish measuring up to 14.0 cm in length (Fig. 9). Beyond this size, fishing mortality increases significantly, peaking at 19 cm, according to the VPA results. Similar findings were reported by Mohamed (2022) regarding *P. subviridis* in the Shatt Al-Arab River in Iraq. The most significant natural declines in population were observed among mid-length groups, especially among fish measuring 10-14 cm. Additionally, fishing mortality increased sharply for fish larger than 13 cm, peaking at a length of 17 cm. In contrast, Mohamed and Al-Hassani (2021) found that in Iraqi marine waters, natural losses of *P. subviridis* were highest among individuals measuring 12 to 18 cm. They reported that fishing mortality peaked at 1.14 for fish measuring 30 cm and reached 0.92 for those measuring 27 cm.

The analysis of the yield per recruit (Y'/R) and biomass per recruit (B'/R) indicated that the current exploitation rate of *P. subviridis* (E_{cur}= 0.58) is lower than both its optimal level ($E_{0.1}$= 0.609) and its maximum economic yield (E_{max}= 0.748). This suggests that the species is unexploited (Cadima, 2003). Several authors have reported similar results for *P. subviridis* stocks in various regions. For instance, Mohd Rosli (2012) found the values of E_{cur} and E_{max} for this species in the Merbok estuary, Malaysia to be 0.60 and 0.686, respectively. In East Hammar Marsh, Iraq, Mohamed *et al.* (2013) reported the following values: E_{cur}, $E_{0.1}$ and E_{max} were 0.43, 0.45, and 0.59, respectively. Rahman *et al*. (2016) reported the predicted E_{max} values of 0.530 for males and 0.521 for females, while the E_{cur} values were lower at 0.346 for males and 0.324 for females from Parangipettai Waters in India. Furthermore, Mohamed and Al-Hassani (2021) reported E_{cur}, $E_{0.1}$ and E_{max} values of 0.34, 0.76 and 0.93, respectively, in Iraqi marine waters of the Arabian Gulf.

Based on the findings of the current study, it can be concluded that the estimated length at first capture (L_c50) is lower than the length at first maturity (L_m50), which is 15.8 cm. This indicates that the bulk of *P. subviridis* individuals were captured before reaching maturity, suggesting that the captured species do not meet the criteria for effective management, $L_{c50} < L_{m50}$ (Udoh and Ukpatu, 2017; Panda *et al*., 2018). The capture of immature fish can disrupt the reproductive cycle, leading to population declines. This issue is significant not only for selective fisheries but also for conservation, ecology, and economics. Implementing sustainable practices, such as size limits and selective fishing gear, can help reduce these negative impacts and promote the long-term sustainability of fish stocks (Vasilakopoulos *et al*., 2011; Takashina, 2024).

Conclusion

The present study revealed that the lengths of individuals were within the range recorded for the species in other waters. $L\infty$ and K values were comparable to those reported from different regions. The recruitment of the species occurred throughout the year, with a single significant peak. The E_{obs} rate was lower than both the $E_{0.1}$ and E_{max} rates. Additionally, the length at first capture (L_c50) was lower than the length at first maturity (L_m50). This indicates that most individuals of *P. subviridis* were captured before reaching maturity. This suggests that the captured individuals do not reach their reproductive potential. Effective fisheries management requires using legal fishing gear to allow each fish at least one chance to reproduce, and protecting nursery grounds from illegal fishing to ensure long-term stock regeneration and resource availability.

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Conflict of interest

The authors declare that they have no conflict of interest.

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