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Abdul-Razak M. Mohamed and Ali H. Al-Hassani

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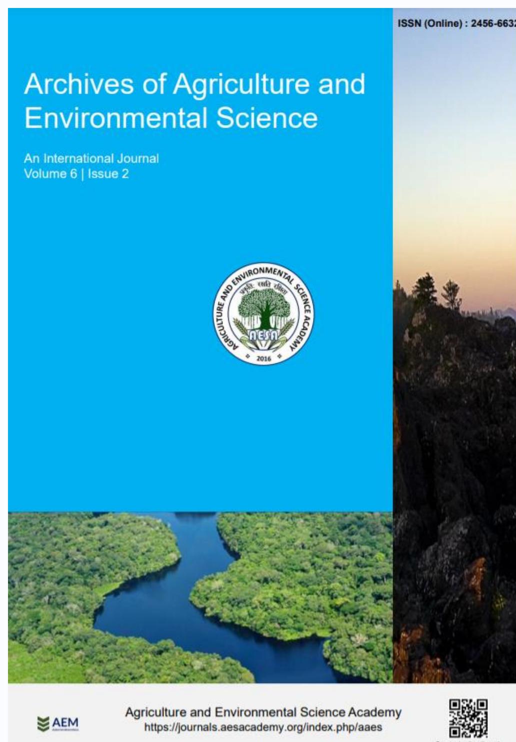
*Corresponding author's E-mail:
abdul19532001@yahoo.com



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ORIGINAL RESEARCH ARTICLE

Growth, mortality and stock assessment of greenback mullet, *Planiliza subviridis* from northwest Arabian Gulf, Iraq

Abdul-Razak M. Mohamed* **and Ali H. Al-Hassani**

Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, IRAQ
*Corresponding author's E-mail: abdul19532001@yahoo.com

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ABSTRACT

The growth, mortality and stock parameters of greenback mullet, *Planiliza subviridis* from Iraqi marine waters, northwest Arabian Gulf was assessed using FiSAT II software for length-frequency data collected from February 2020 to January 2021. *P. subviridis* is one of the species caught in large quantities as commercial by artisanal fishers. Fish samples were collected by the Shaheen steel-hulled dhow and from the artisanal fishermen. The total length and body weight relationship of fish was estimated as $W= 0.034L^{2.670}$, indicating negative allometric growth. Of 3350 specimens, growth and mortality parameters were evaluated. The asymptotic length ($L\infty$), growth rate (K) and growth performance index (Ø') were 33.8 cm, 0.30 and 2.535, respectively. The total mortality rate (Z), natural mortality rate (M), and fishing mortality rate (F) were 1.11, 0.74 and 0.38, respectively. The present exploitation rate ($E_{present}$) of *P. subviridis* computed as 0.34. Length at first capture (L_{50}) was 17.47 cm. Recruitment of *P. subviridis* was observed throughout the year, with a peak during July. The yield per recruit analysis indicates that the current exploitation rate was below the biological target reference points ($E_{0.1}$ and E_{max}), which refers to the stock of *P. subviridis* is underexploited. Virtual population analysis results showed that mid-lengths (16-22 cm) experienced the highest fishing mortality. The length at first capture (L_{50}) was higher than the length at first maturity (L_m) of the species. So, for management purposes, more yields could be obtained by increasing the fishing activities on this species for a substantial harvest.

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INTRODUCTION

The greenback mullet, *Planiliza subviridis* (Valenciennes, 1836), belong to the Mugilidae family, formerly placed in the genus *Liza*, but Durand *et al.* (2012) placed it in the genus *Planiliza*. It is a euryhaline species that are found to be schooling in shallow coastal waters, estuaries and freshwaters in the Indian and Pacific Oceans: the Arabian Gulf, the Red Sea and South Africa to the coasts of India, China, north to Japan and northern Australia (Thomson, 1984). The species is widely distributed in the Iraqi marine waters and enters the rivers and marshes of southern Iraq for feeding and locally known as "Beyah". It considers a commercially important species in these waters along with other mullet's species; *P. abu*, *P. klunzengeri*, *P. macrolepis*, *P. carinata*, *Osteomugil speigleri* and *O. cunnesius* (Mohamed and Jawad, 2021). The total landing of mullet's species by the artisanal fisheries in the Iraqi marine waters was about 1439 tons, composed about 12.7% of the total Iraqi marine landings and predominated the landings during 2019 (Mohamed and Abood, 2020a).

P. subviridis constituted 1.6%-2.9% of fish assemblage in the East Hammar marsh (Mohamed *et al.*, 2009; 2012) and 6.1% of fish structure in the Shatt Al-Arab River (Mohamed and Abood, 2017), 25% of fish structure in Al-Sweib River, Iraq (Abdullah *et al.*, 2018a) and 2.2% of fish assemblage in the south part of Main Outfall Drain, Basrah, Iraq (Abdullah *et al.*, 2018b). Jennings *et al*. (2000) stated that the assessment of fish population is essential to meet one of the main objectives of fishery science that of maximizing yield to fisheries while safeguarding the long-term viability of populations and ecosystem. Kebtieneh *et al.* (2016) stated that the basic purpose of stock assessment is to provide decision-makers with the information necessary to make rational choices on the optimum level of exploitation of aquatic living resources such as fish. There are a few studies have been done on the population dynamics of *P. subviridis* in various waters around the world, such as Mohd Rosli (2012) in Merbok estuary, Malaysia; Mohamed *et al*. (2013) in the East Hammar marsh, Iraq; Djumanto and Setyobudi (2015) in the estuary of Opak River-Yogyakarta, Indonesian; Rahman *et al.* (2016) from Parangipettai Waters, India and Mohamed and Abood (2020b) in the Shatt Al-Arab River, Iraq.

The objective of the present study was to assess the growth parameters, mortality rates, probability of capture, recruitment pattern, yield per recruit and virtual population analysis of *P. subviridis* in Iraqi marine waters, northwest Arabian Gulf to derive requisite information for the management and conservation of populations of this species in this region.

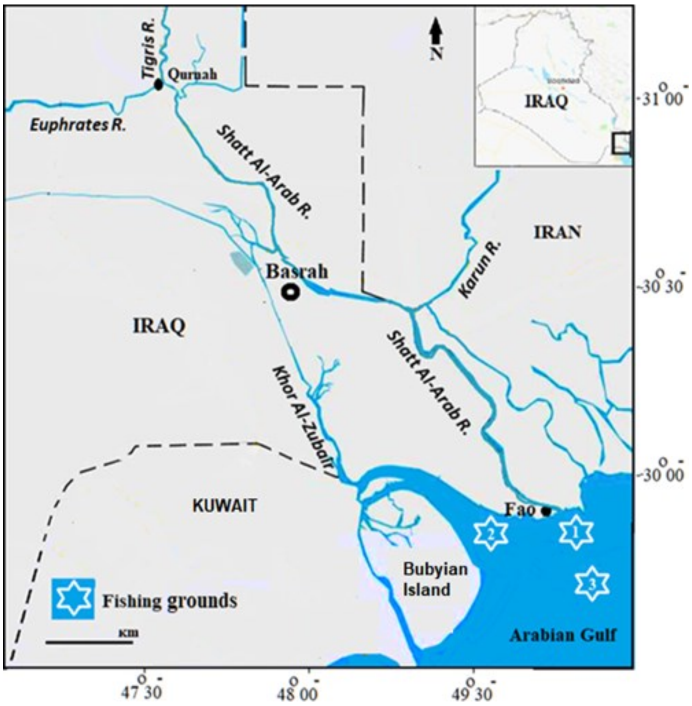

Figure 1. *Fishing grounds in Iraqi marine waters, northwest Arabian Gulf.*

MATERIALS AND METHODS

Collection of samples

The study was conducted in the Iraqi marine waters, the northwestern of the Arabian Gulf representing the estuarine part of the Gulf. The area is dominated by the large river delta of the rivers Euphrates, Tigris and Karun, merging into the Shatt Al-Arab that represent the main outflow in the Arabian Gulf (Pohl *et al*., 2014). Figure 1 illustrates the main fishing grounds for Iraqi marine fisheries, include the Shatt Al-Arab estuary, Khor Abdulla and Khor Al-Amaya (Mohamed *et al*., 2005). The fishermen operated with multifilament gears such as drift gill-nets, trawl nets, traps (gargoor), stake nets (hadra) and hook and line (Mohamed and Jawad, 2021). Al-Fao port considers the main centre of landings and auction of Iraqi marine resources locates on the tip of the northwest Arabian Gulf. Monthly samples of *P. subviridis* were obtained during the period from February 2020 to January 2021 (except April) from the Shaheen steel-hulled dhow (21 m length, 7 m wide and 2m draft with a horsepower of 150 horses) and from the artisanal fishermen at the main fish landings site in Al-Fao port.

Growth parameters

The total length (cm) measured to the largest possible number of *P. subviridis* in the field in order the estimated growth and population parameters. Subsamples of fish were immediately iced and transported to the laboratory for measuring length (to the nearest 0.1 cm) and weight (to the nearest 0.5 g) of each fish. The weight (W) relationship to the length (L) of *P. subviridis* was established using the power equation (Le Cren, 1951): $W= aL^b$, where a the intercept and b is the growth coefficient. To compare the difference of the growth coefficient (b) from 3, a t-test was used to test the significant difference (Ricker, 1975).

The length-frequency data of 3835 specimens of *P. subviridis* were pooled into groups with a 1.0 cm length interval. The resultant data were analyzed using the FiSAT II (FAO- ICLARM Stock Assessment Tools) software (Gayanilo *et al*., 2005).

The fitting of the best growth curve was based on the ELEFAN I module implemented in the FiSAT II software, which allows the fitted curve through the maximum number of peaks of the length-frequency distribution where we find the highest R_n value. The theoretical age at birth (t_o) was estimated independently, using the equation of Pauly (1983).

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

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

$$Ø' = \log_{10}K + 2 \log_{10}L\infty$$

Mortality rates

The total instantaneous mortality rate (Z) estimated using the length converted catch curve method of Pauly (1980) as implemented in FiSAT II. Natural mortality rate (M) was estimated using Pauly's empirical relationship (Pauly, 1980) considering the mean annual water temperature as 24.8°C (Al-Shamary *et al*., 2020).

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

Instantaneous fishing mortality (F) was estimated as F= Z−M, and the exploitation level (E) was obtained by the formula E= F/Z (Gulland, 1971).

The probability of capture was estimated using the procedure outlined in the FISAT II tool. By plotting the cumulative probability of capture against mid-length, a resultant curve was obtained, from which the lengths at capture at probabilities of 0.25 (L_{25}), 0.5 (L_{50}) and 0.75 (L_{75}) attained.

Recruitment pattern

The recruitment pattern was obtained following the procedure described in the FiSAT routine, which involves the backward projection of length frequencies onto the time axis based on growth parameters (Pauly 1983).

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

Relative yield per recruit (Y/R) and relative biomass per recruit (B/R) values were determined using the knife-edge option incorporated in the FiSAT II Tool. The input parameters were $L_c/L\infty$, M/K and E values. As a result, the exploitation rate at which the stock is 10% of its virgin stock ($E_{0.1}$) and the exploitation rate which produces maximum yield (E_{max}) were computed. The current rate of exploitation ($E_{current}$) value compared with the values of the biological referenced points ($E_{0.1}$ and E_{max}) to assess the status of the species stock (Cadima, 2003).

Virtual population analysis

The estimated length structured virtual population analysis (VPA) was carried out using the length convert curve procedure of Jones and van Zalinge (1981) in the FiSAT routine. The values of the L∞, K, M, F and the constants (a and b) of the length-weight relationship for the species were used as inputs. The results of VPA analysis were the biomass (tons), the yield (tons), total and fishing mortality and exploitation ratios.

RESULTS AND DISCUSSION

Length-frequency distribution

A total of 3350 length-frequency distribution data of *P. subviridis* was gathered from February 2020 to January 2021 and presented in Figure 2. Fish lengths ranged from 12.0 to 30.0 cm, and the major peak was at length 10.0 cm, forming 10.8% from the total caught. The population is dominated by middle-sized fish 16.0-22.0 cm constituted 61.6% of the total catch.

This length range of the individuals of *P. subviridis* in the present study found to be similar to those documented by Al-Daham and Wahab (2006) from Shatt Al-Basrah Canal, Iraq (14.5-31.0 cm) and Mohamed *et al*. (2013) from East Hammar marsh, Iraq (8.7-29.2cm), but was higher than those stated by Zolkhiflee (2016) from Pinang River Estuary, Malaysia (9.3-19.6 cm) and Mohamed and Abood (2020b) from Shatt Al-Arab River, Iraq (9.8-26.5 cm). However, Djumanto and Setyobudi (2015) noted higher lengths for the females of *P. subviridis* from the estuary of Opak River, Indonesia (7.2-35.9 cm). These differences may be related to environmental factors, food supply, population density, fishing pressure, and possibly using different fishing gears (Riedel *et al*., 2007; Wootton, 2011).

The length-weight relationship

A total of 324 specimens of *P. subviridis* were used to estimate the length-weight relationship and was illustrated in Figure 3. Their lengths varied from 12 to 30 cm, and their weights ranged between 36 and 352 g. The calculated length-weight equation was:

$$W= 0.034L^{2.670}, \quad r^2= 0.980$$

The t-test revealed that the regression was significantly different from 3 (t= 15.5, *P*<0.05), indicating positive allometric growth. The estimated growth coefficient (b) of *P. subviridis* in this study, indicating negative allometric growth in which the fish body weight becomes lighter for its corresponding length (Riedel *et al*., 2007). Similar growth coefficient values for the species were reported by Shadi *et al*. (2011) in Iranian waters, north of Arabian (b= 2.819), Mohd Rosli (2012) in Merbok estuary, Malaysia (2.823), Rahman *et al*. (2016) in the Parangipettai Waters, India (2.711 for males and 2.893 for females), Baloch *et al*. (2015) in Damb Harbour, Pakistan (2.801) and Zolkhiflee (2016) in the Pinang River, Malaysia (2.879 for males). In contrast, Zolkhiflee (2016) reported an isometric pattern (b= 3.028) for females' *P. subviridis* in the Pinang River, Malaysia. Differences in the value of growth coefficient (b) in the length-weight relationship could have been affected by several factors such as habitat, season, stage of maturity, sex, food availability, stomach fullness, health, stress and sampling methodology (Ricker, 1975; Froese, 2006; Cuadrado *et al*., 2019).

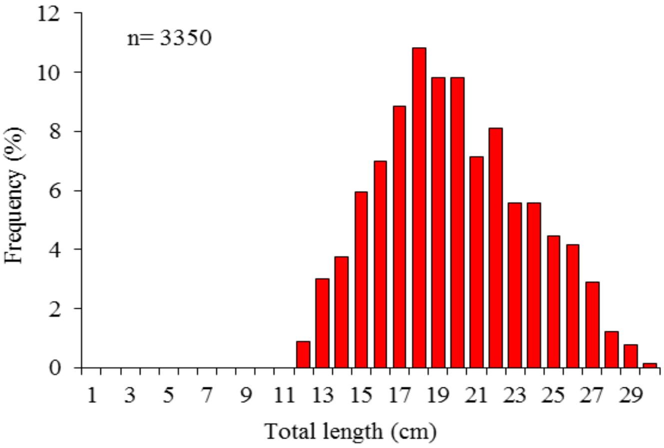

Figure 2. *The overall length-frequency distribution of P. subviridis.*

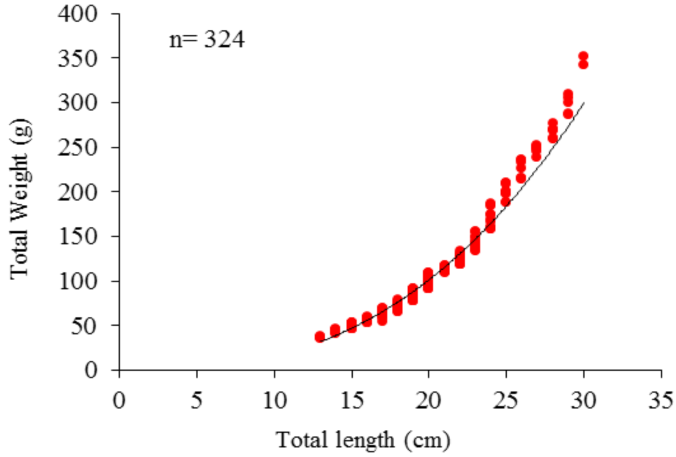

Figure 3. *The length-weight relationship of P. subviridis.*

Growth

The response surface (R_n) analysis in the ELEFAN I routine used to scan the best estimates of the growth parameters (L∞ and K) of *P. subviridis*. The goodness-of-fit was at R_n= 0.344 (Figure 2). The restructured length frequency of *P. subviridis* with superimposed growth curves is shown in Figure 4 and 5. The best growth constants (L∞ and K) value was estimated as 33.8 and 0.30, respectively, so the theoretical age at zero (t_0) was -0.774. The growth performance index (Ǿ) was estimated to be 2.535.

The asymptotic length (L∞) of *P. subviridis* in the present study was 33.8 cm, which similar to the value of 33.7 cm obtained by Mohamed *et al.* (2013) in the East Hammar marsh, Iraq, but was found to be higher than those stated by Djumanto and Setyobud (2015) in the estuary of Opak River, Indonesian (29.9 cm) and Rahman *et al.* (2016) in Parangipettai waters, India (26.8 cm for males and 27.8 cm for females). However, the highest values of L∞ for *P. subviridis* were 35.1 and 37.3 cm reported in the Merbok estuary, Malaysia (Mohd Rosli, 2012), and for the females in the estuary of Opak River, Indonesian (Djumanto and Setyobudi, 2015), respectively. The present growth index (Ø) of

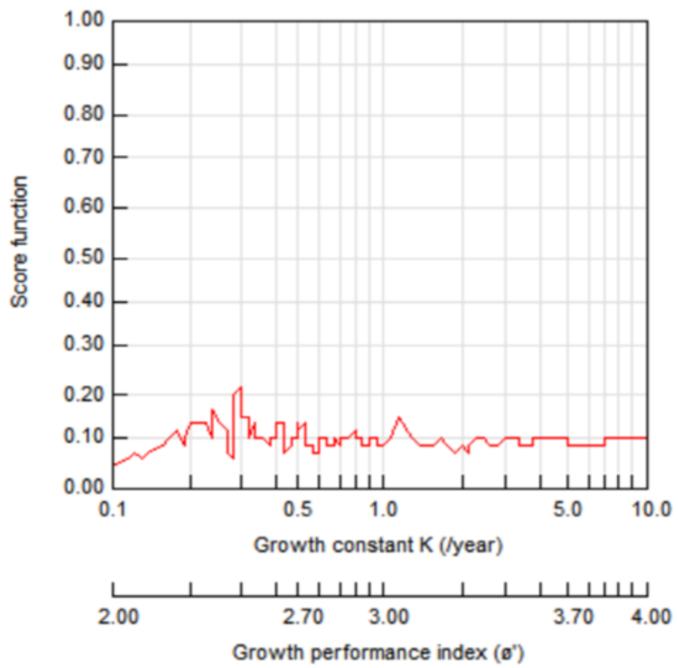

Figure 4. *K-scan routines of P. subviridis.*

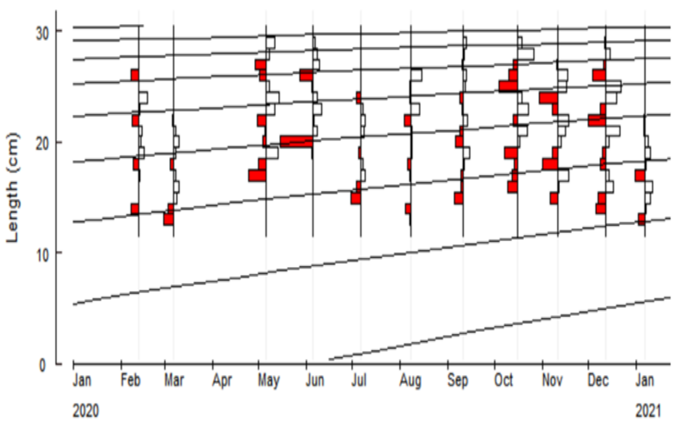

Figure 5. *Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for P. subviridis.*

P. subviridis was found to be equal to that reported for the species (Ø= 2.536) by Mohamed and Abood (2020) from the Shatt Al-Arab River and slightly less than reported for the species (Ø= 2.67) in the estuary of Opak River (Djumanto and Setyobudi, 2015). This variability in the growth of the same species in different geographic locations could be attributed to several factors, such as ecological conditions, habitat, availability of food, metabolic activity, reproductive activity, sizes of fish, method of sampling and fishing pressure (Wootton, 2011; Panda *et al.* 2018).

Mortality and exploitation rates

Using the length-converted catch curve executed in FiSAT II as shown in Figure 6, the annual mortality rate (Z), the natural mortality rate (M) and the rate of fishing mortality (F) assessed as 1.11, 0.74 and 0.38, respectively. The present exploitation rate ($E_{present}$) of *P. subviridis* computed as 0.34.

We found that the exploitation rates of *P. subviridis* in this study and various regions are below the optimum rate (0.5), such as 0.43 in East Hammar marsh (Mohamed *et al.*, 2013), 0.43 for males and 0.12 for females of *P. subviridis* in the estuary of Opak River, Indonesian (Djumanto and Setyobudi, 2015) and 0.35 for males, 0.32 for females of the species in Parangipettai waters, India (Rahman *et al.*, 2016) and 0.45 in the Shatt Al-Arab River (Mohamed and Abood, 2020b), except in the Merbok estuary, Malaysia where, it was 0.60 (Mohd Rosli, 2012). Gulland (1971) suggested the assumption that any stock is optimally exploited when the fishing mortality (F) is equal to the natural mortality (M), or E = (F/Z) = 0.5.

Probability of capture

The probability of capture of *P. subviridis* was analyzed and presented in Figure 7. The length at which 50% of the stock biomass is vulnerable to capture estimated at L_{50}= 17.47 cm. Correspondingly, the lengths at which 25% and 75% of the stock is captured were estimated as L_{25}= 15.81 cm and L_{75}= 19.12 cm. The length at first capture (L_{50}) was greater than estimates by Mohd Rosli (2012) in Merbok estuary, Malaysia (L_{50}= 11.2 cm) and Mohamed and Abood (2020b) in the Shatt Al-Arab River, Iraq (L_{50}= 12.84 cm). The variation in figures may be due to the presence of relatively large size fish species and the mesh size of fishing gears employed by fishermen in different waters.

Recruitment

The recruitment pattern showed that *P. klunzingeri* continuous recruitment with one peak in July (Figure 8). The recruitment varied from 0.12% in January to 19.53% in July. Some works found two peaks of unequal strength for the recruitment pattern of *P. subviridis* in some waters, such as in Merbok estuary, Malaysia (Mohd Rosli, 2012) and in East Hammar marsh (Mohamed *et al.*, 2013). Djumanto and Setyobudi (2015) stated that the recruitment in male *P. subviridis* occurred throughout the year, and there was no prominent recruitment peak, while female recruitment showed the peak in July in the estuary of Opak River, Indonesian.

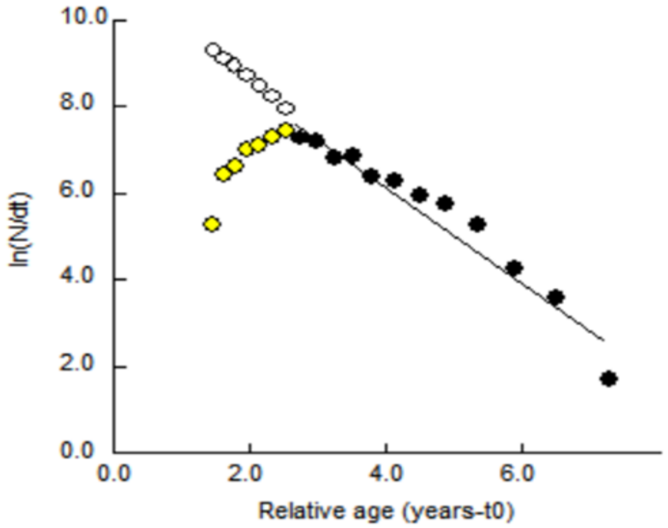

Figure 6. *Length converted catch curve for estimation of Z for P. subviridis.*

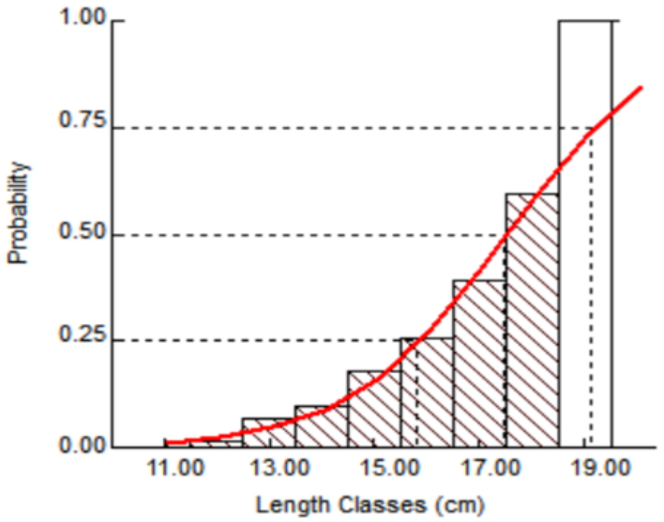

Figure 7. *Probability of capture for P. subviridis.*

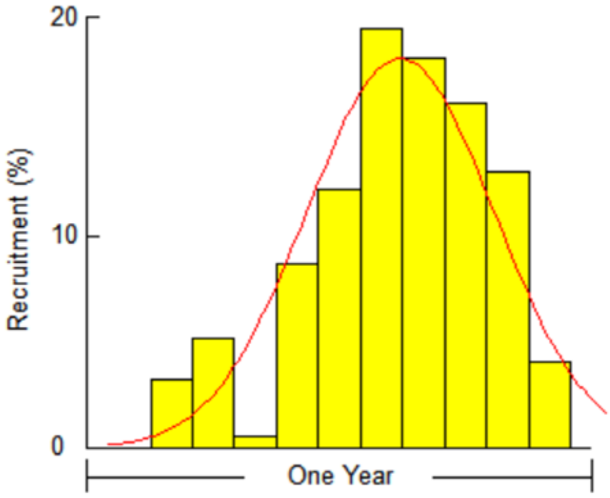

Figure 8. *Recruitment pattern of P. subviridis.*

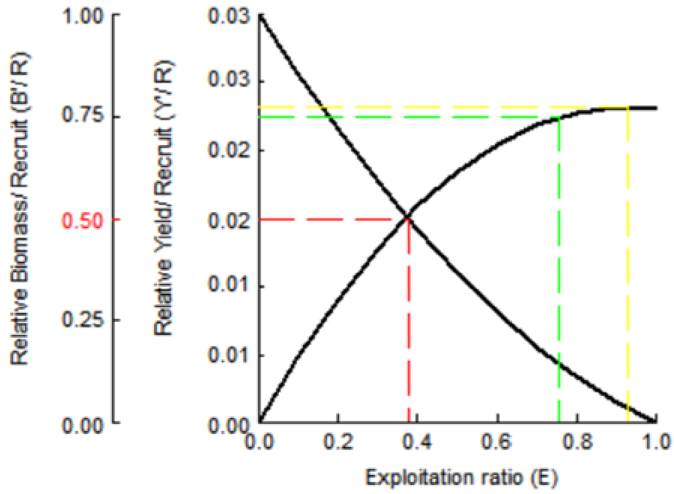

Figure 9. *Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for P. subviridis.*

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

The relative yield-per-recruit (Y/R) and biomass per-recruit (B/R) analyses performed here were based on the knife-edge selection routine in the Beverton and Holt Y/R model incorporated in FiSAT software as a function of M/K (2.465) and $L_c/L\infty$ (0.520), which derived from the previous analyses. The estimated values of the biological target reference points ($E_{0.1}$ and E_{max}) were 0.756 and 0.927, respectively (Figure 9). The current exploitation rate ($E_{current}$= 0.34) found to be lower than both biological target reference points for the species. The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were 0.014 and 0.546, respectively. The results revealed that the biological target reference points of *P. subviridis* were above the present exploitation rate, which denotes that the studied stock underexploited (Cadima, 2003). This finding has been noticed for *P. subviridis* stocks by several authors in different regions. Mohd Rosli (2012) reported that the values of $E_{present}$ and E_{max} for the species in Merbok estuary, Malaysia were 0.60 and 0.686, respectively. Mohamed *et al.* (2013) pointed out that the values of $E_{present}$, $E_{0.1}$ and E_{max} were 0.43, 0.45 and 0.59, respectively in East Hammar Marsh, Iraq. Moreover, Rahman *et al.* (2016) stated the predicted E_{max} values for male was 0.530 and for female 0.521, whereas the $E_{present}$ was on the lower side (0.346 for males and 0.3240 for females) for *P. subviridis* from Parangipettai Waters, India.

Virtual population analysis

Figure 10 demonstrated the results of virtual population analysis (VPA) of *P. subviridis* in the present study. The majority of fishing mortalities was recorded for the mid-lengths (16 cm to 22 cm), and the length group (18 cm) was more vulnerable to fishing. Natural losses were highest among individual within the length range of 12 to 18 cm. Surviving individuals in the stock exhibited a declining trend with an increased rate of fishing pressure, the highest number of survivors was observed at the length of 12 cm, and the lowest was at the length of 30 cm. The fishing mortality reached a maximum of 1.14 at 30 cm, followed by 0.92 at 27 cm.

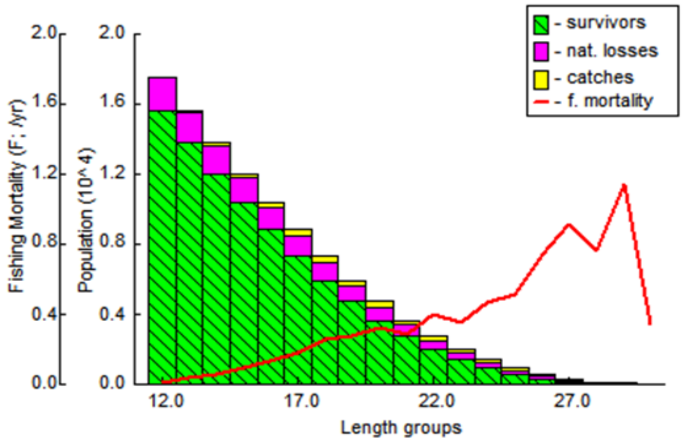

Figure 10. *Length-structured virtual population analysis of P. subviridis.*

The result of VPA indicated that the main loss in the stock of *P. subviridis* in the present study due to fishing mortality happened for lengths 16 cm to 22 cm. Moreover, the estimated length at first capture (L_{50}) of *P. subviridis* in the current study was 17.5 cm. However, the length at first maturity (L_m) of the species in southern Iraq found to be 13.7-14.2 cm (Al-Daham and Wahab, 2006). The occurrence of such a situation suggests that individuals of the species get the chance to join the stock before becoming vulnerable to capture by the available fishing gear. This would enable more females to participate in reproductive activity and allow the young recruits to grow and reproduce to ensure resource availability and sustainability (Udoh and Ukpatu, 2017).

Conclusion

The study revealed that the *P. subviridis* population showed a negative allometric growth pattern. The asymptotic length ($L\infty$) was within those reported from other waters. The estimated length at first capture (L_{50}) was higher than the length at the first sexual maturity (L_m) of the species. The recruitment pattern occurs throughout the year, with a peak in July. Fishing mortality was observed higher in the length range between 16 and 22 cm. The current exploitation rate was below the biological target reference points, which refers to the stock of *P. subviridis* is underexploited. So, for management purposes, more yields could be obtained by increasing the fishing activities on this species for a substantial harvest.

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