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Population dynamics of three mullets species (Mugilidae) from the Shatt Al-Arab River, Iraq

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Abstract: *The population dynamics of Planiliza abu, P. klunzengeri and P. subviridis in the Shatt Al-Arab River, Iraq were investigated using FiSAT II software. A total of 456 specimens of P. abu, 500 of P. klunzengeri and 600 of P. subviridis were collected for length-frequency analysis from November 2015 to October 2016. The asymptotic length (L∞) was computed as 21.2, 27.0 and 29.3 cm for P. abu, P. klunzengeri and P. subviridis, respectively. The growth coefficient (K) was estimated as 0.44, 0.49 and 0.40 for P. abu, P. klunzengeri and P. subviridis, respectively. The values of the growth performance index (Ø) obtained for the three species were 2.296, 2.624 and 2.536, respectively. The rates of total mortality (Z), fishing (F) and natural (M) for P. abu were 2.52, 1.08 and 1.44, respectively, for P. klunzengeri were 3.16, 1.09 and 2.07, respectively and for P. subviridis 1.68, 0.93 and 0.75, respectively. The recruitment of P. abu was of bimodal pattern, whereas only one main pulse of annual recruitment for P. klunzengeri and P. subviridis. The relative yield per recruit analysis revealed that the exploitation rates (E) for the three species were below than the biological target reference points (E_{max} and $E_{0.1}$), which denotes that the studied stocks were not in over-exploited condition. For management purposes, more yields could be obtained by increasing the fishing activities on these species, with some precautionary measures to avoid their overexploitation.*
Key Words: *Mullets, growth, mortality, yield-per-recruit, Shatt Al-Arab River*

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I. Introduction

The mullets belong to a family Mugilidae found worldwide in coastal temperate and tropical waters, and in some species spend part or even their whole life cycle in coastal lagoons, lakes and rivers (González-Castro and Ghasemzadeh, 2015). This family represented 304 available species and only 79 valid species in the world (Fricke *et al.,* 2020). There are five species of mullets inhabit the Iraqi waters (Mohamed *et al.*, 2016), namely abu mullet *Planliza abu* (Heckel, 1843), Klunzinger's mullet *P. klunzengeri* (Day, 1888), greenback mullet, *P. subviridis* (Valenciennes, 1836), keeled mullet *P. carinata* (Valenciennes, 1836) and silver mullet *Osteomugil speigleri* (Bleeker, 1858). Some species, like *P. subviridis* and *P. klunzengeri* are inhabiting coastal marine waters and enter the rivers and marshes of southern Iraq for feeding and locally known as Beyah, and one species, *P. abu* locally is known as Khishni inhabits in the rivers, lakes, drains, and marshes of Iraq (Mohamed *et al.*, 2018). These three species as well as *P. carinata* formerly placed in the genus *Liza* but Durand *et al.* (2012) placed in the genus *Planiliza*.

The contribution of mullet's species in the Iraqi marine waters increased from 12.3% (2239.6 tons) during 1990-1994 (Ali *et al*. 1998) to 22.1% (6651.0 tons) from the total landings during 2008-2018 (Mohamed, 2018).

There are only a few studies have been done on the population dynamics of *P. abu, P. klunzengeri* and *P. subviridis* in various waters around the world using FiSAT II (FAO-ICLARM Stock Assessment Tools) software (Dadzie *et al*., 2005; Hakimelahi *et al*., 2010; Mohd Rosli, 2012; Mohamed *et al*., 2013; Djumanto and Setyobudi, 2015; Mohamed *et al*., 2016; Rahman *et al.,* 2016).

In the present study, an attempt is made to investigate the growth parameters, mortality rates, probability of capture, recruitment patterns and stocks assessment for *P. abu, P. klunzengeri* and *P. subviridis* in the Shatt Al-Arab River, to evaluate the population parameters required for proposing plans for managing the fish stocks in Iraqi waters.

II. Materials and Methods

The Shatt Al-Arab River arises from the confluence of the Tigris and Euphrates rivers at Qurna town northern Basra Governorate and flows to the south eastern direction towards the Arabian Gulf (Fig. 1). The length of the river is about 204 km whereas the width varying from 250 m at the mouth to more than 1,500 m at the estuary. The tidal pattern in the Shatt Al-Arab River likes that of the upper part of the Gulf, and the dominant tide is of a semi-diurnal type with two high and two low waters occurring daily (Al-Ramadhan and Pastour, 1987). The major categories of land use in its catchments were agriculture, palms forests and human settlements.

The materials for this study were obtained from three sites on the Shatt Al-Arab River, near Al-Dair Bridge, Abu Al-Khasib district and north Fao town from November 2015 to October 2016. The fish caught using gill nets, cast net and electro-fishing (Mohamed and Abood, 2017).

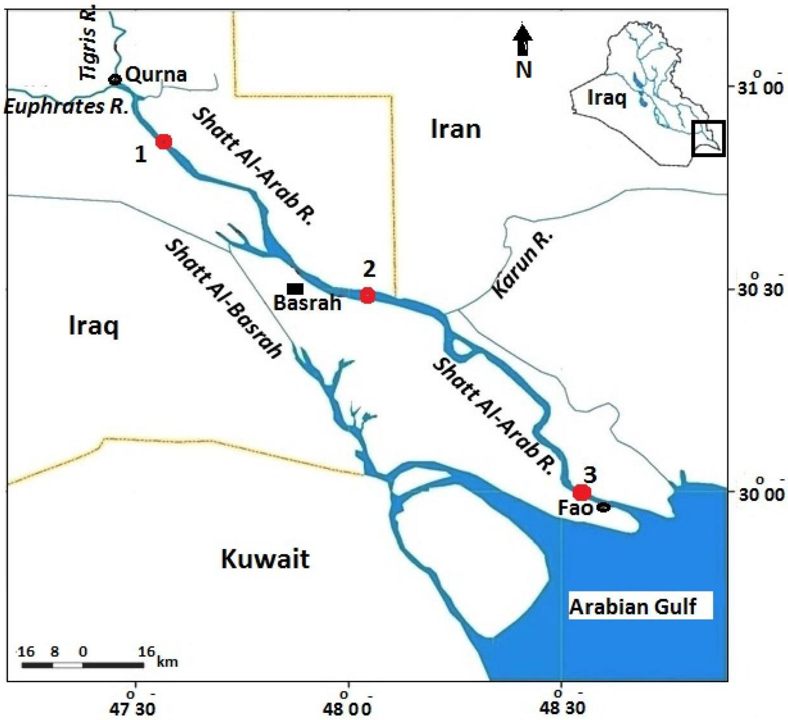

Fig. 1. Map of Shatt Al-Arab with locations of study sites.

The total length was measured to the nearest mm for 456 specimens of *P. abu*, 500 of *P. klunzengeri* and 600 of *P. subviridis*. The length measurements were pooled bimonthly period from different sites and subsequently grouped into 1.0 cm length classes for the construction of length-frequency distributions from November 2015 to October 2016.

Growth parameters of von Bertalanffy's equation ($L\infty$ and K) were calculated by the FAO-ICLARM Fish Stock Assessment Tools (FiSAT II, ver. 1.2.2.) software (Gayanilo *et al.* 2005) using the ELEFAN I routine, which uses the modal displacement of length classes time series to provide an index of growth rates for different age classes. The best growth curve was fitted, based on the "R_n value" non-parametric goodness of fit index. For the calculation of theoretical age at length zero (t_0) we used Pauly's empirical formula (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 computed according to the formula of Pauly and Munro (1984) as $Ø' = \log_{10}K + 2 \log_{10}L\infty$.

The length-converted catch curve method incorporated in FiSAT package estimated the instantaneous total mortality (Z), and the natural mortality (M) for each species calculated using Pauly's (1980) empirical equation relating M, t_0, $L\infty$, K and mean water temperature (T) where T= 24.6°C (Mohamed and Abood, 2017).

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

Fishing mortality (F) was derived from the difference between Z and M, and the exploitation ratio (E) from fishing mortality/total mortality. Estimation of probabilities of capture by detailed analysis of left ascending part of the catch curve using the estimation of $L\infty$ and K through the logistic curve in FiSAT package.

ELEFAN I routine of FiSAT routine was used to obtain recruitment patterns by backward projection onto time axis of the available length-frequency data through growth parameters (L∞ and K). The peaks and troughs of the graph obtained reflect the seasonality of recruitment.

The model of Beverton and Holt (1966), as modified by Pauly and Soriano (1986) was followed to predict the relative yield per recruit (Y′/R) of the three species, using the knife-edge analysisincorporated in FiSAT software. The data of $L_c/L\infty$ and M/K values were used to estimate $E_{0.1}$ (exploitation point at which the related increase in yield per recruit reached 1/10 of the related increase computed at a very devalued value of E), $E_{0.5}$ (the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit (B′′/R)) and E_{max} (exploitation point that gives maximum relative yield-per-recruit).The current exploitation rate (E) and the biological target reference points ($E_{0.1}$ and E_{max}) were used to indicate the stocks status (Cadima, 2003).

III. Results

Growth

Length frequency distributions of *P. abu, P. klunzengeri* and *P. subviridis* during the period from November 2015 to October 2016 are presented in Fig 2.The length of *P. abu* ranged from 6.4 to 19.7 cm, and the lengths of 9-12 cm constituted 79.7% of the species caught. The length of *P. klunzengeri* varied from 6 to 19 cm and the great majority was composed of the individuals from 9.6 to 23.0 cm comprising 88.5% of the species. The length of *P. subviridis* varied between 9.8 to 26.5 cm and those fish of 13-17 cm formed 72.4% of the total catch.

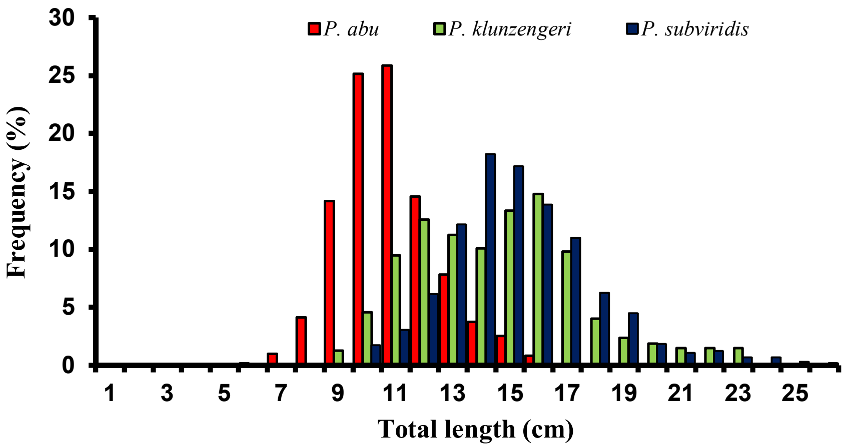

Fig. 2. The overall length frequencies of *P. abu, P. klunzengeri* and *P. subviridis*

Growth parameters of von Bertalanffy growth formula for each species from K-scan routine (Fig. 3) were observed by using the direct fit of length-frequency data in ELEFAN I and the response surface (R_n) for the curve (Fig. 4). Growth parameters for *P. abu* were L∞= 21.2cm, K= 0.44 and R_n= 0.21, and for *P. klunzengeri* were L∞= 27.0 cm, K= 0.49 and R_n= 0.30, while for *P. subviridis* were L∞= 29.3 cm, K= 0.40 and R_n= 0.24. From these results, the t_o values for *P. abu, P. klunzengeri* and *P. subviridis* were -0.416, -0.276 and -0.426, respectively, whereas the values of the growth performance index (Ø) obtained for the three species were 2.296, 2.624 and 2.536, respectively.Therefore, the von Bertalanffy growth equations for all species can be expressed as:

$L_t= 21.2\,(1-e^{-0.44\,(t+0.416)})$ for *P. abu*

$L_t= 27.0\,(1-e^{-0.49\,(t+0.276)})$ for *P. klunzengeri*

$L_t= 29.3\,(1-e^{-0.40\,(t+0.426)})$ for *P. subviridis*

Mortality

The total mortality coefficient (Z), the natural mortality coefficient (M) and the fishing mortality coefficient (F) for *P. abu* were estimated as 2.52, 1.08 and 1.44, respectively and for *P. klunzengeri* were 3.16, 1.09 and 2.07, respectively. The same parameters were estimated as 1.68, 0.93 and 0.75, respectively for *P. subviridis*. The present exploitation rates ($E_{present}$) for *P. abu* and *P. klunzengeri* were more than the optimum rate (0.5), whereas for *P. subviridis* was below the optimum rate. It was 0.57, 0.66 and 0.45 for *P. abu*, *P. klunzengeri* and *P. subviridis*, respectively.

The estimated probabilities of capture values for the three species are illustrated in figure 6. The values of L_{25}, L_{50} and L_{75} for *P. abu* were found to be 8.82, 9.40 and 9.98 cm, respectively, and for *P. klunzengeri* were 12.66, 13.97 and 15.27 cm, respectively, while, for *P. subviridis* were 11.85, 12.84 and 13.82, respectively.

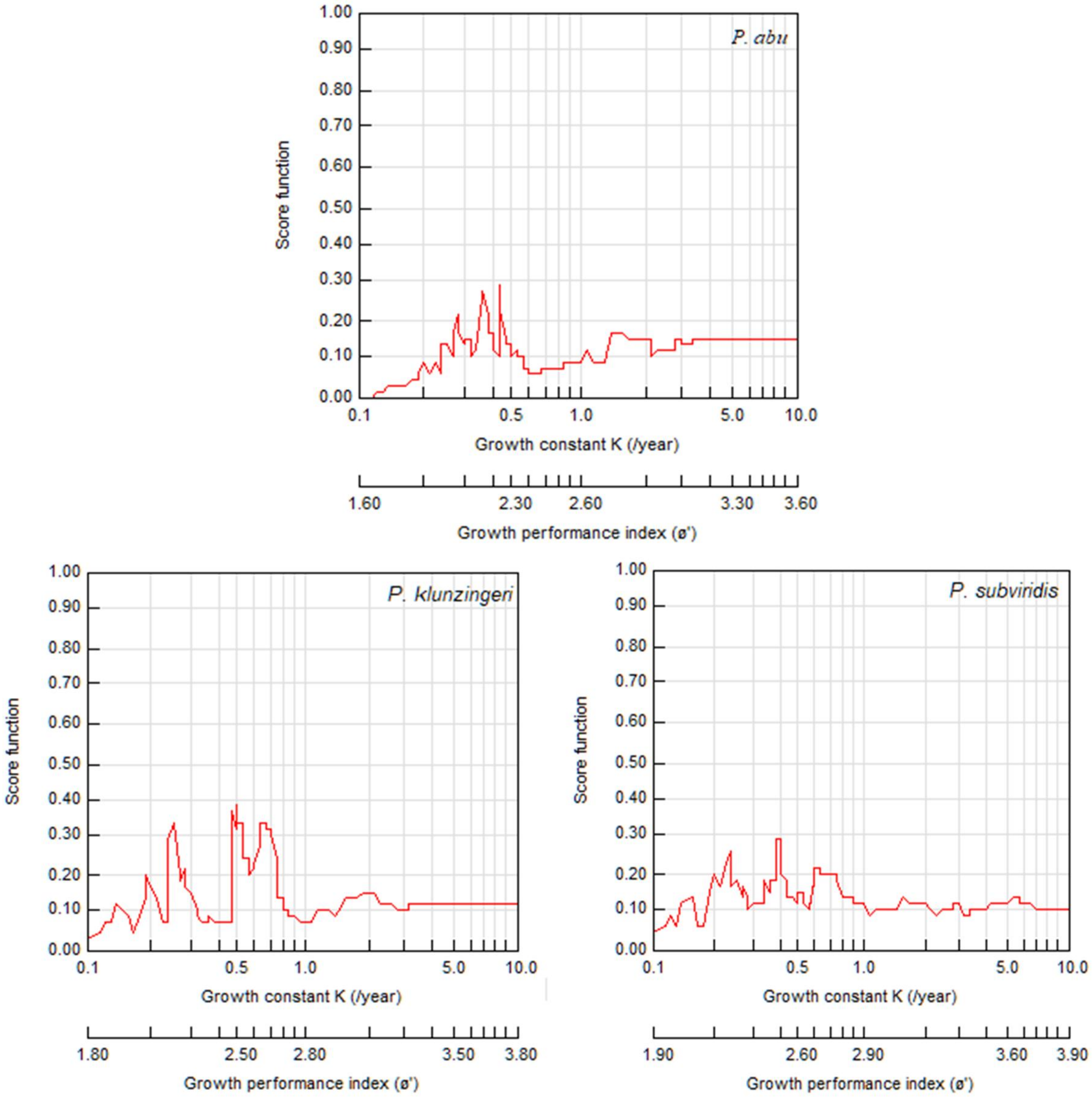

Fig. 3. K-scan routines of *P. abu, P. klunzengeri* and *P. subviridis*

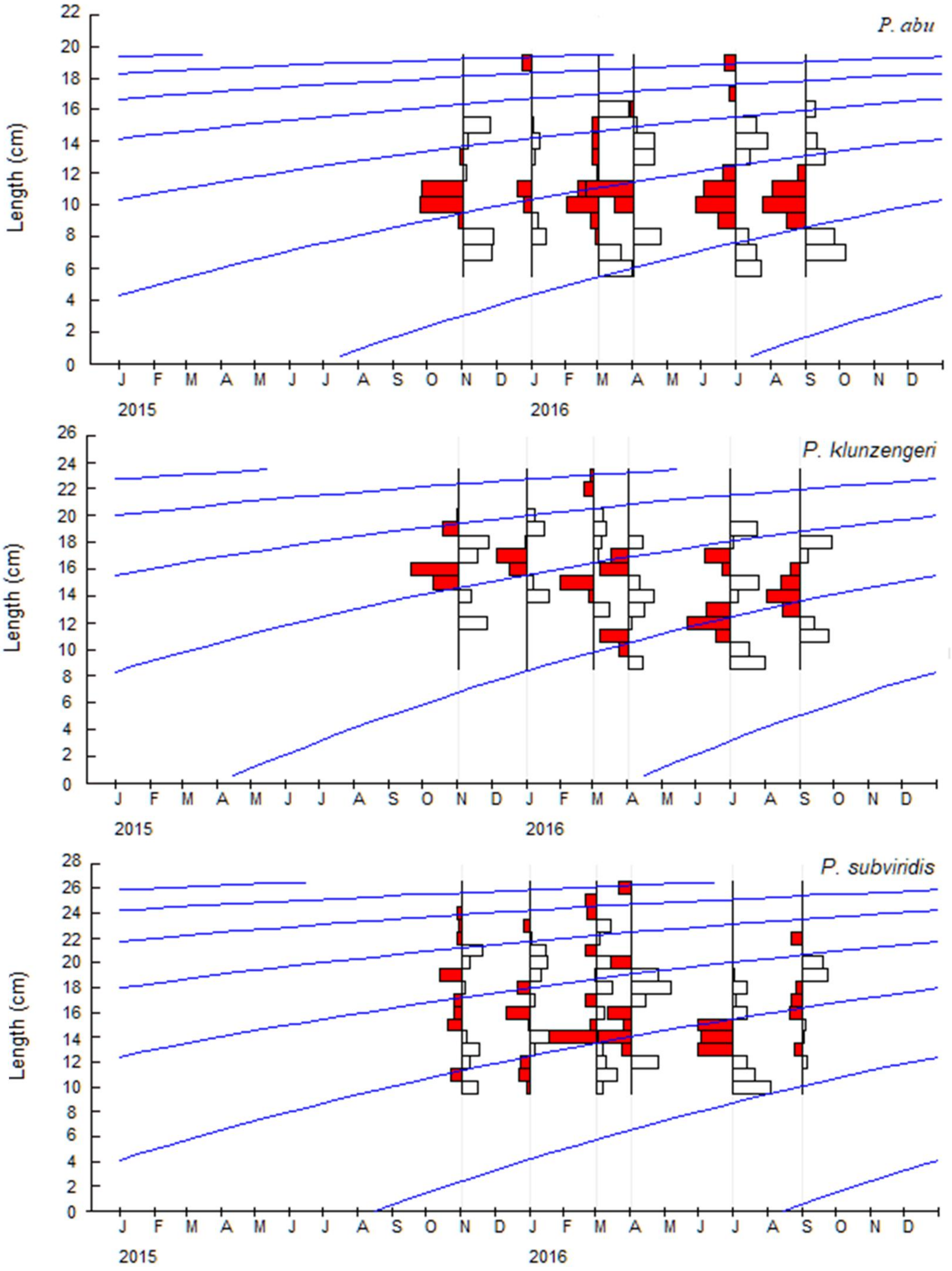

Fig. 4. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *P. abu, P. klunzengeri* and *P. subviridis*

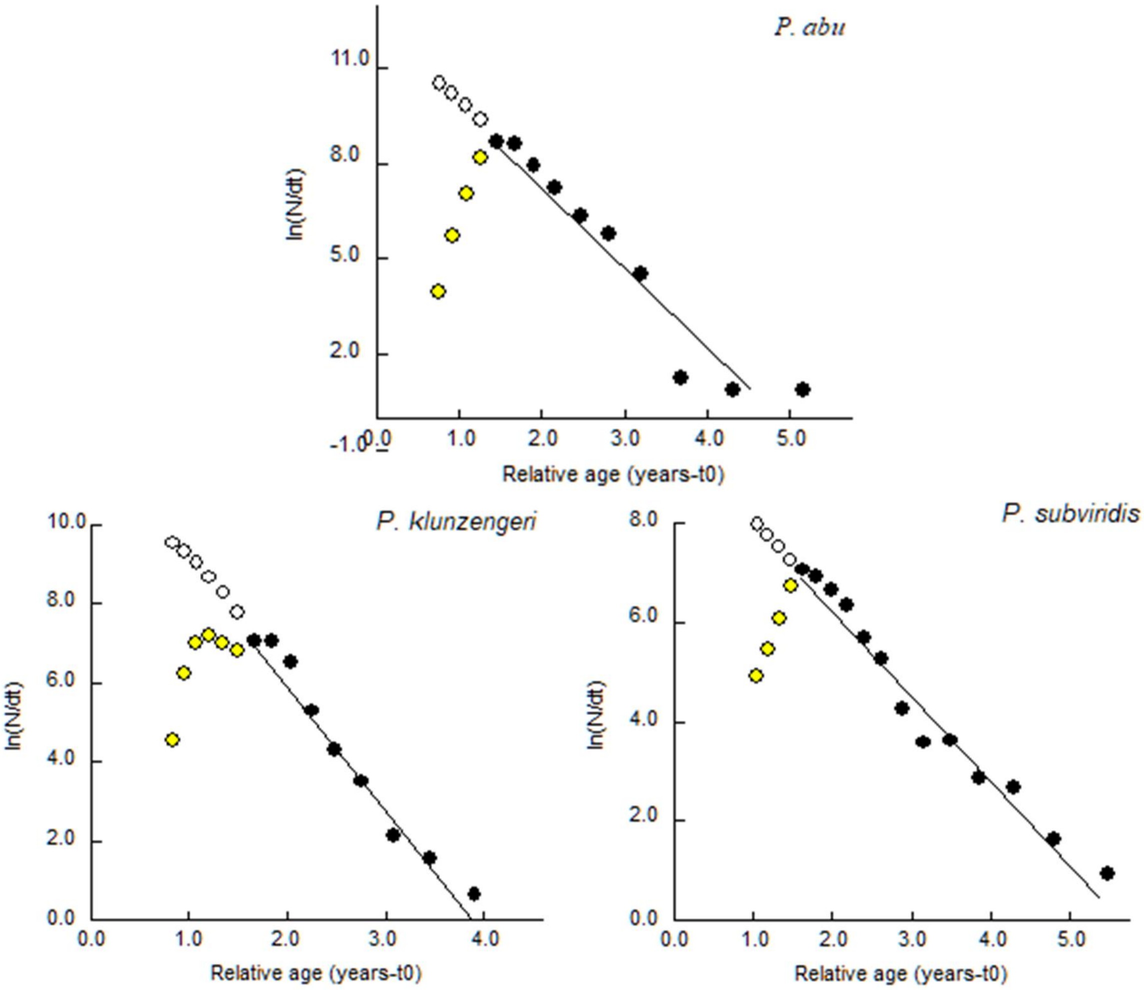

Fig. 5. Length converted catch curves for *P. abu, P. klunzengeri* and *P. subviridis*

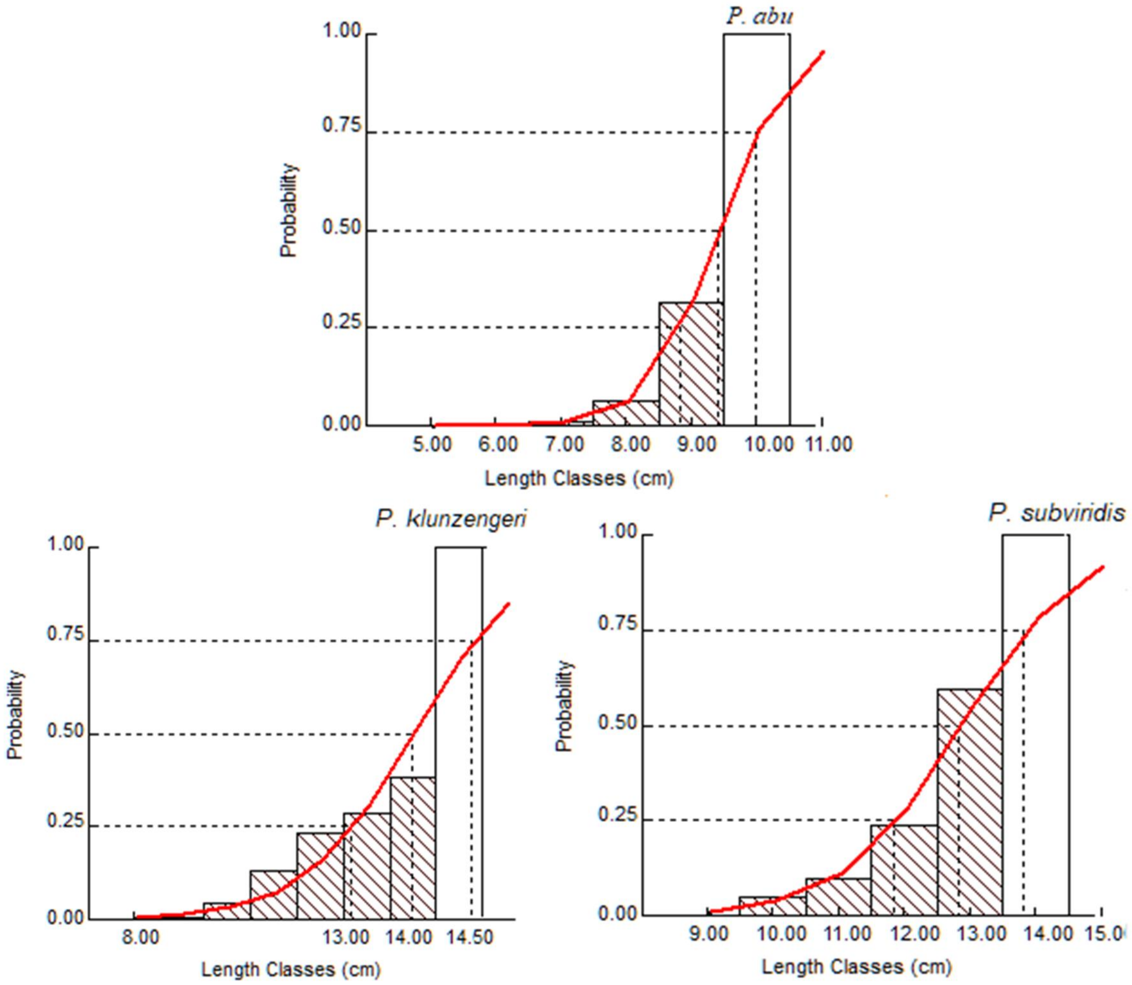

Fig. 6. Probability of capture for *P. abu, P. klunzengeri* and *P. subviridis*

Recruitment

The recruitment of *P. abu* was of a bimodal pattern. The modes were of unequal strength pulses, the minor contributed 10.4% of the total recruits with a peak in April and the major formed 17.6% with a peak in July (Fig. 7), whereas only one main pulse of annual recruitment for *P. klunzengeri* and *P. subviridis* were in June, constituted for 20.42% and 20.25%, respectively.

Stock assessment

Relative yield-per-recruit analysis using the knife-edge option of FiSAT gave E_{max}= 0.74, $E_{0.1}$= 0.62, and $E_{0.5}$= 0.35 for *P. abu*, E_{max}= 0.85, $E_{0.1}$= 0.72, and $E_{0.5}$= 0.37 for *P. klunzengeri* and E_{max}= 0.72, $E_{0.1}$= 0.61, and $E_{0.5}$= 0.35 for *P. subviridis* (Fig. 8). It is clear that the present exploitation rates ($E_{present}$) for the three species were lower than the biological target reference points (E_{max} and $E_{0.1}$) for all species.

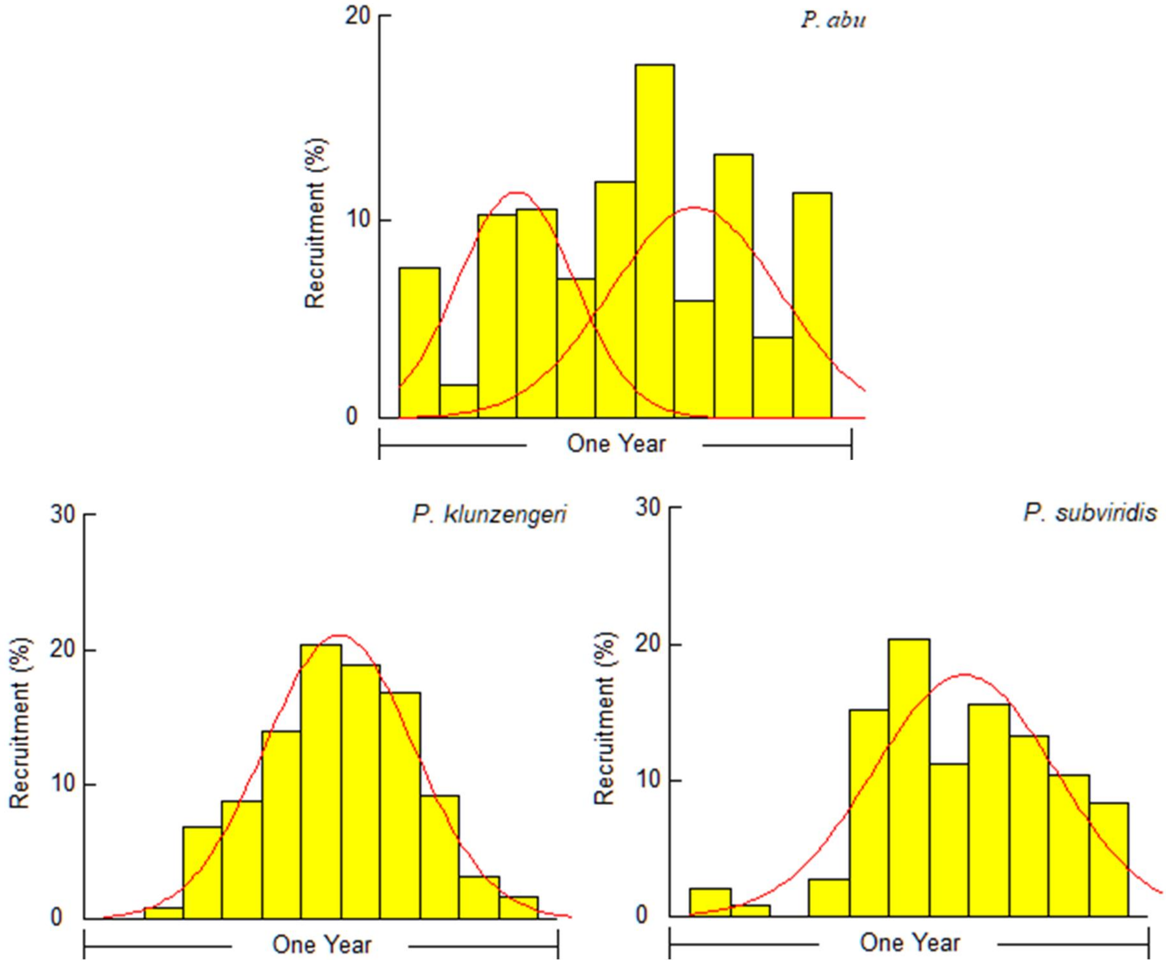

Fig. 7. Recruitment patterns of *P. abu, P. klunzengeri* and *P. subviridis*

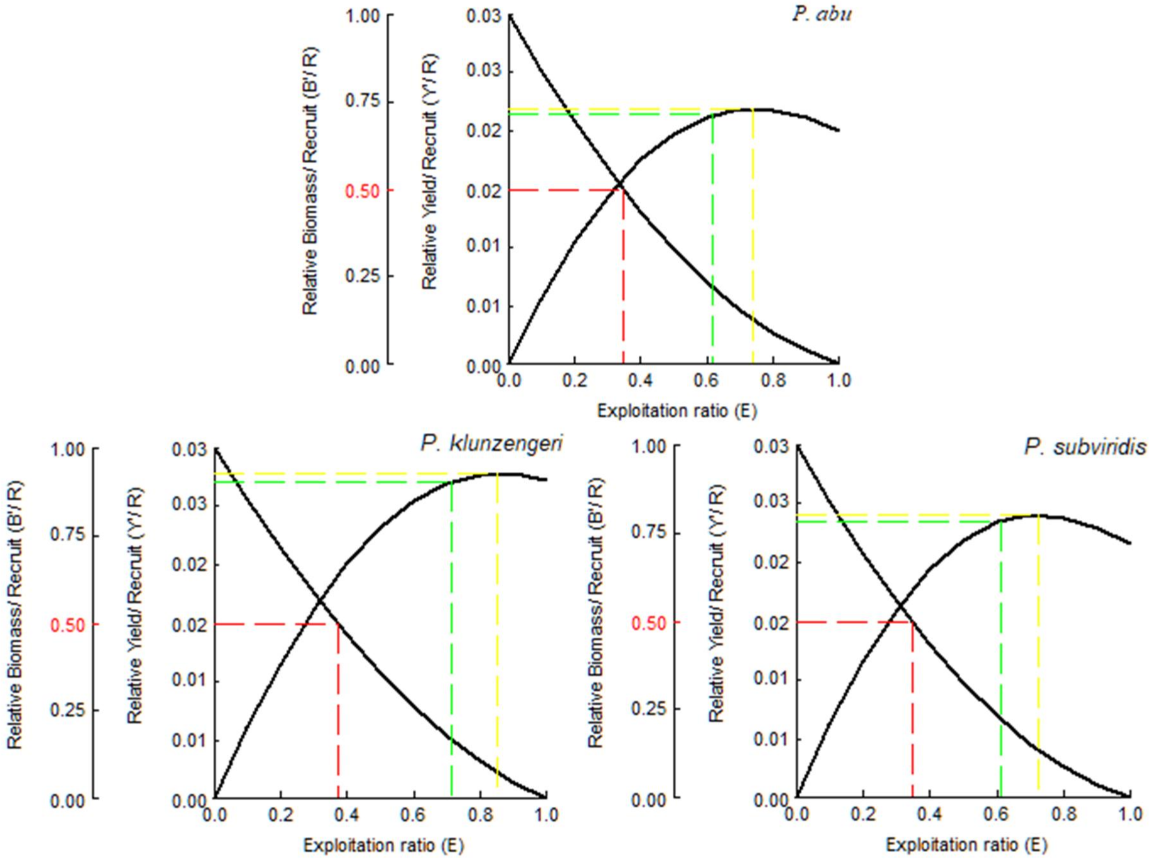

Fig. 8. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for *P. abu, P. klunzengeri* and *P. subviridis*

IV. Discussion

The study revealed that the lengths of individuals of *P. abu* were more or less similar to those reported for the samespecies from other waters in the region, such as 11.1-22.2 cm in the Atatürk Dam Lake, Turkey (Doğu *et al.*, 2013), 2.0-22.0, 4.0-20.0 and 3.0-19.0 cm in East Hammar, Huwazah and Chybaish marshes, respectively (Mohamed, 2014), 1.4-21.3 cm in East Hammar marsh (Mohamed *et al.*, 2016) and 4.0-23.1 cm in Ceyhan River basin, Turkey (Birecikligil *et al*., 2017). Also, the length range of *P. klunzengeri* in the present study was within the lengths for the species recorded from other waters, such as 2.0-21.0 cm in the Kuwait Bay (Dadzie *et al.,* 2005) and 12.1-17.8 cm in the Iranian waters of the Arabian Gulf and Oman Sea (Hakimelahi *et al*., 2010).While the lengths of *P. subviridis* in the present study (9.8-26.5 cm) was found to be almost similar to those recorded by Mohamed *et al.* (1998) from the Iraqi marine waters (5.6-25.6 cm), Al-Daham and Wahab (2006) from Shatt Al-Basrah Canal (14.5-31.0 cm) and Mohamed *et al*., 2013) from East Hammar marsh (8.7-29.2cm). However, the size of *P. subviridis* in the present study was higher than those reported by Samad and Abbas (1999) from Sandspit backwaters along Karachi coast, Pakistan (11.5-20.2 cm) and Zolkhiflee (2016) from Pinang River Estuary, Malaysia (9.3-19.6 cm). Conversely, Djumanto and Setyobudi (2015) recorded higher lengths for the females of *P. subviridis* from the estuary of Opak River, Indonesia (7.2-35.9 cm). This may be related to several factors such as water condition, food supply, population density, fishing pressure and possibly using different gears (Nikolsky, 1963).

The growth model of von Bertalanffy was applied to describe the theoretical growth of *P. abu, P. klunzengeri* and *P. subviridis* in the Shatt Al-Arab River by applying the FiSAT II software. The estimated growth parameters for *P. abu* were $L\infty$= 21.2 cm and K= 0.44, they were more or less similar to those reported for the same species from the southern marshes. Mohamed (2014) found that the values of $L\infty$ and K for the species were 23.2 cm and 0.37 in East Hammar, 21.1 cm and 0.44 in Huwazah and 20.0 cm and 0.41 in Chybaish marshes during 2005-2006. However, Mohamed *et al.* (2016) pointed out that the values of $L\infty$ and K for *P. abu* in East Hammar during 2009-2010 were 24.6 cm and 0.44, respectively, whereas Birecikligil *et al.* (2017) reported higher value of $L\infty$ (27.87 cm) for *P. abu* in Ceyhan River basin, Turkey. Also, the growth performance index (Ø) of *P. abu* in the present study (2.30) was similar to those reported for the species by Mohamed (2014) in the southern marshes but lower than that stated by Birecikligil *et al.* (2017) in Ceyhan River basin, Turkey.The asymptotic length (L∞) and the growth performance index (Ø) of *P. klunzengeri* in the present study were higher than those mentioned by Dadzie *et al.* (2005) from the Kuwait Bay, Kuwait (L∞= 24.8 cm, Ø= 2.45) and Hakimelahi *et al.* (2010) from the Iranian waters of the Arabian Gulf and Oman Sea (L∞= 22.9 cm, Ø= 2.39). The L∞ of *P. subviridis* in the present study was 29.3 cm. A similar result was obtained by Djumanto and Setyobud (2015) for the males of the species in the estuary of Opak River, Indonesian (L∞= 29.9 cm), whereas, Rahman *et al.* (2016) stated that the value of L∞ varied between 26.8 cm for males to 27.8 cm for females of *P. subviridis* from Parangipettai waters, India.The highest values of L∞ for *P. subviridis* were 35.1, 33.7 and 37.3 cm reported in the Merbok estuary, Malaysia (Mohd Rosli, 2012), in the East Hammar marsh, Iraq (Mohamed *et al.,* 2013) and for the females in the estuary of Opak River, Indonesian (Djumanto and Setyobudi, 2015), respectively. The present growth index (Ø) of *P. subviridis* was slightly less than that 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 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 (Nikolsky, 1963; Panda *et al.* 2018).

The results of the present exploitation rate for *P. abu* in this study was moderate overexploitation, which was similar to those reported for the same species from the southern marshes, such as 0.58 and 0.56 in East Hammar and Chybaish marshes, respectively (Mohamed, 2014) and 0.68 in East Hammar marsh (Mohamed *et al*., 2016), however, it was under the optimum level of exploitation (E= 0.38) in the Huwazah marsh (Mohamed, 2014). Birecikligil *et al.* (2017) stated that the exploitation rate of *P. abu* in Ceyhan River basin, Turkey was 0.17.The population of *P. klunzengeri* in the Shatt Al-Arab River was overexploitation. Similar observations were made earlier by other workers, such as 0.75 in the Kuwait Bay, Kuwait (Dadzie *et al.,* 2005) and 0.52 in the Iranian waters of the Arabian Gulf and Oman Sea (Hakimelahi *et al.*, 2010). It was found that the exploitation rates of *P. subviridis* in this study and various regions are below than 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 and 0.32 for females of the species in Parangipettai waters, India (Rahman *et al.,* 2016), except in the Merbok estuary, Malaysia where, it was 0.60 (Mohd Rosli, 2012). Gulland (1971) suggested that in an optimal exploited stock, fishing mortality should be about equal to natural mortality, resulting in an exploitation rate of 0.5, whereas less than 0.5 refers to under exploitation and greater than 0.5 refers to overexploitation.

The recruitment pattern of *P. abu* in the present study shows two recruitment periods, the first occurred in April while the second and major recruitment occurred in July. Also, Mohamed *et al.* (2016) noted that *P. abu* in the East Hammar marsh has two recruitment periods to the fishing ground occurred in March (25.3%) and in August (74.7%).The recruitment patterns of the stocks of *P. klunzengeri* and *P. subviridis* in this study suggest that there was only one main pulse of annual recruitment in June for both species. The recruitment of *P. klunzengeri* was found to have two recruitment peaks, one in May and the other in September in the Kuwait Bay (Dadzie *et al.,* 2005). Some works found two peaks of unequal strength for the recruitment pattern of *P. subviridis* in some waters, such as in East Hammar marsh (Mohamed *et al.*, 2013), in Merbok estuary, Malaysia (Mohd Rosli, 2012). Djumanto and Setyobudi (2015) reported that the recruitment in male *P. subviridis* occurred throughout the year and there was no prominent recruitment peak, while in female recruitment showed the peak in July in the estuary of Opak River, Indonesian.

It is obvious from the relative yield per recruit analysis that the present exploitation rates ($E_{present}$) for *P. abu, P. klunzengeri* and *P. subviridis* in the Shatt Al-Arab River were well below than the biological target reference points (E_{max} and $E_{0.1}$) for all species, indicating that these species were not overexploited. Similar findings have been observed in the stocks of *P. subviridis* in different waters, such as in Merbok estuary, Malaysia (Mohd Rosli, 2012), in the East Hammar marsh (Mohamed *et al.,* 2013), in the estuary of Opak River, Indonesian (Djumanto and Setyobudi, 2015) and Parangipettai waters, India (Rahman *et al*., 2016).Conversely, other studies found that the stock of *P. klunzengeri* in the Kuwait Bay (Dadzie *et al.*, 2005) was overexploited and also the stock of *P. abu* in the East Hammar marsh (Mohamed *et al*., 2016).

V. Conclusion

It could be concluded that the studied stocks in the Shatt Al-Arab River were not in overexploited condition and for management purposes, more yields could be obtained by increasing the fishing activities on these species, such as increasing the number of fishing boats for substantial harvest, with some precautionary measures to avoid their overexploitation, especially for *P. abu* and *P. klunzengeri* stocks

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