Stock expectations and virtual population analysis of three mullets species in the Shatt Al-Arab River, Iraq

ABSTRACT

A total of 456 individuals of *Planiliza abu*, 500 *P. klunzengeri* and 600 P. subviridis were involved in analyzing the length-frequencies of fish for knowledge the stock expectations and virtual population analysis of these species in the Shatt Al-Arab River from November 2015 to October 2016 using the FiSAT II program. The results showed that the growth patterns of the three species were allometric. The values of L∞ for the three species were 21.2, 27.0 and 29.3 cm, respectively. The rates of total mortality (Z), fishing (F), natural (M) and exploitation (E) for *P. abu* were 2.69, 1.09, 1.60 and 0.59, *klunzengeri* 2.49, 1.08, 1.41 and 0.57 and *P. subviridis* 1.51, 0.84, 0.68 and 0.45, respectively. The present exploitation rates (E) for all species are lower than the biological target reference points expressing a case of under-exploitation of the species. Virtual population analysis (VPA) showed that the maximum fishing mortality for the three species occurred in the mid-lengths, with maximum values at the length of 15 cm for *P. abu* and 17 cm for *P. klunzengeri* and *P. subviridis*. The mullets species catches have not met the criteria for good management ($L_{c50} < L_{m50}$), indicating that the fish may be vulnerable to capture before they mature. Accordingly, the present study proposes that the officials in fishery management can get more yields through increasing the fishing activities on these species but must be matching the mesh sizes with the fishing recommendation to assure resource availability and sustainability.

Keywords: Mullets, stock predictions, virtual population analysis, Shatt Al-Arab River, Iraq.

1. 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 [1]. This family represented 304 available species and only 80 valid species in the world [2]. Five species of mullets inhabit the Iraqi waters [3], 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 [4]. These three species as well as *P. carinata* formerly placed in the genus *Liza* but Durand *et al.* [5] were placed them in the genus *Planiliza*.

The mullets species have predominated the total landings of Iraqi marine fisheries during 2019, accounting for about 1439 t (12.7%), followed by threadfin bream, 10.8% and river shad, 9.1% [6].

Sparre and Venema [7] and Baharti [8] stated that the virtual population analysis (VPA) is a modelling technique commonly used in fisheries science for reconstructing the historical fish numbers at age or length using the information on the deaths of individuals in each year, and the deaths are usually partitioned into catch by fisheries and natural mortality, to calculate the population that must have been in the water to produce this catch.

There are a few studies have been done on the stock assessment of *P. abu, P. klunzengeri* and *P. subviridis* in various waters around the world [9-15]. However, there is no study on the virtual population analysis of mullets fish, except the works of Al-Hassani and Mohamed [16] and Mohamed and Al-Hassani [17] on the stock assessment and virtual population analysis of *P. klunzengeri* and *P. subviridis* in Iraqi marine waters using FiSAT II (FAO-ICLARM Stock Assessment Tools) software.

Therefore, the present work covers growth, stock expectations and virtual population analysis of the *P. abu*, *P. klunzengeri* and *P. subviridis* populations in the Shatt Al-Arab River to provide information for proper management of these species.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted on the Shatt Al-Arab River at Basrah province, Iraq from November 2015 to October 2016. The river originates from the confluence of the Tigris and Euphrates rivers at Qurna and flows in the southeastern direction towards the Arabian Gulf (Fig. 1). The river is about 204 km long, whereas the width varies from 250 m at the mouth to more than 1,500 m at the estuary. During the last years, the Shatt Al-Arab River has been suffered from the deterioration of the water quality due to a series of anthropogenic activities such as agricultural runoff wastes and untreated wastewater, invasion of fish species and seawater intrusion as a result of drastically reduced water quantity and quality related to the decline in rates of the flow from the Tigris, Euphrates and Karun Rivers [18, 19]. Water temperatures during the time of this study varied from 13.3 to 34.7 °C with a mean value of 24.6 °C, salinity ranging from 1.0 to 9.7 ‰ and the discharge rate in the north of the river fluctuated from 40.9 to 59.8 m^3/s [20]. The tidal pattern of the Shatt Al-Arab River is like that of the upper part of the Gulf, and the dominant tide is of a semi-diurnal type with two high and two low water occurring daily. The catchment land of the river is used for agriculture, palms forests and human settlements.

2.2 Fish sampling

A total of 1,556 individuals of fish including 456 *P. abu,* 500 *P. klunzengeri* and 600 *P. subviridis*, were collected in this study from three sites in the river, the first site is located near Al-Dair Bridge, the second site is located at Abu Al-Khasib district and the third site is located north Fao town (Fig. 1). The sampling was performed with the help of local fishermen using gill nets, cast nets and electro-fishing [20]. Collected fish were kept in a cooler box and immediately transported to the laboratory.

2.3 Data analysis

At the laboratory, the total length of fish was individually measured to the nearest 0.1 cm using the measuring board and weighed using the electronic weighing balance to the nearest 0.1g. The monthly samples of length measurements for all species were pooled bimonthly periods from different sites and then grouped into 1-cm intervals to construct the length-frequency distributions. The data were analyzed using FiSAT II software (FAO-ICLARM Stock Assessment Tools, ver. 1.2.2) [21].

The formula of Le Cren [22], $W = a L^b$, was used to estimate the relationship between weight (W) and total length (L) of the fish. The linear regression of the log-transformed equation used in this analysis was as follows: $\text{Log } W = \text{Log } a + b \text{ Log } L$, where a= intercept and b= slope of the length-weight relationship. Furthermore, the b-value for each species was tested by t-test to verify if it was significantly different from isometric growth [23].

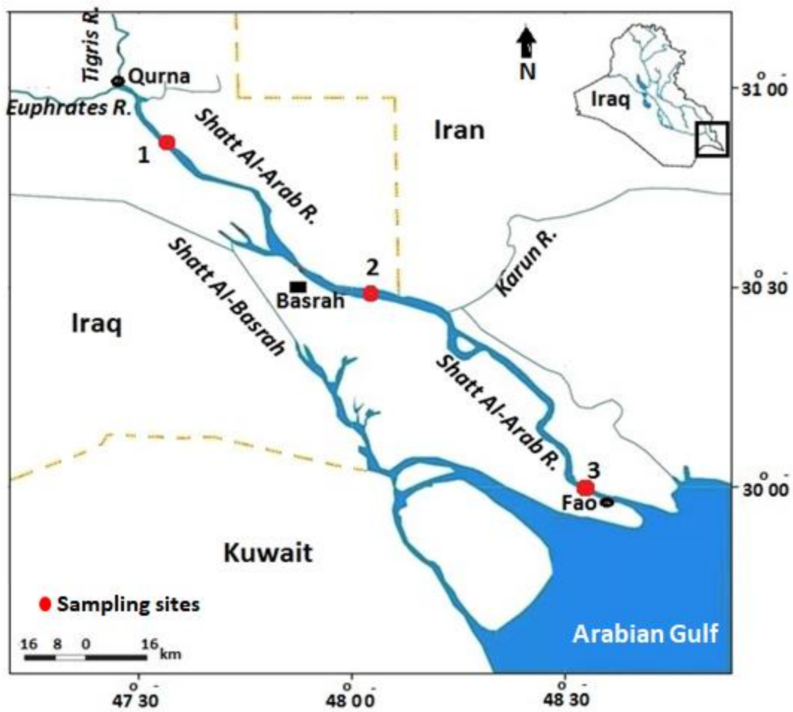

Fig. 1. Map of Garmat Ali river with locations of study sites.

The growth parameters L∞ and K were estimated using the ELEFAN-I routine of the FiSAT II software, which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. With the help of the goodness of fit value (R_n), the asymptotic length (L∞) and growth constant (K) were estimated [24, 7].

The instantaneous total annual mortality rate (Z) was estimated using the length-converted catch curve method incorporated in the FiSAT package using the input parameters L∞ and K, and selecting the best points on the straight line of the right arm of the curve. The natural mortality (M) was estimated following the approach of Pauly [25], as follows:

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

where, L∞ in cm, K in year−1 and T, the mean annual water temperature, 24.6 °C [20]. The fishing mortality (F) estimated by subtracting M from *Z* and exploitation rate (E= F/Z) was computed to assess the status of the fishery.

The relative yield-per-recruit (Y'/R) and relative biomass per recruit (B/R)' were carried out using the model of Beverton and Holt [26] as modified by Pauly and Soriano [27], and the data of L_c/L∞ and M/K values as described in the FiSAT package to estimate the biological target reference points, $E_{0.1}$ and E_{max} [28].

The length-frequency data also were used to carry out virtual population analysis (VPA) for each species using a routine modified from Jones and van Zalinge [29] and incorporated in the FiSAT package to reconstruct the population from size-wise total catch data in the length-frequency samples raised to the total catch [21]. The input parameters used were L∞, K, M, F and constants of length-weight relationship (a and b) were used as inputs to VPA analysis for each species.

The initial step is to estimate the terminal population (N_t) given the inputs, from:

$$N_t = C_t \cdot (M + F_t)/F_t,$$

where C_t is the terminal catch (i.e., the catch taken from the largest length class).
Then, starting from N_t, successive values of F are estimated, by iteratively solving:

$$C_i = N_{i+\Delta t} \cdot (F_i/Z_i) \cdot (\exp(Z_i \cdot \Delta t_i)-1),$$

where $\Delta t_i = (t_i+1 - t_i)$, and $t_i = t_o - (1/K) \cdot \ln(1-(L_i/L_\infty))$, and where population sizes (N_i) are computed from:

$$N_i = N_{i+\Delta t} \cdot \exp(Z_i)$$

The last two equations are used alternatively, until the population sizes and fishing mortality for all length groups have been computed (Gayanilo *et al*., 2005). An F-array representing the fishing mortality for each length group, the reconstructed population (in numbers), and the mean stock biomass by length class were made using FiSAT II. The results of the VPA analysis were the biomass (tons), the yield (tons), total and fishing mortality and exploitation ratios.

3. Results

3.1 Growth

The descriptive statistics of the length-weight data for 456 *P. abu*, 500 *P. klunzengeri* and 600 *P. subviridis* in the Shatt Al-Arab River from November 2015 to October 2016 are given in Table 1. The lengths and weights of the species were 6.4 to 19.7 cm and 3.7 to 86.9 g, respectively for *P. abu*, 7.5 to 26.3 cm and 6.0 to 356.0 g, respectively for *P. klunzengeri* and 7.0 to 25.0 cm and 8.0 to 325.0 g, respectively for of *P. subviridis*. The t-test revealed that the regression slopes (b) in the length-weight relationships for all species were significantly different from value 3 (t= 3.85, $p<0.05$ for *P. abu,* t= 4.93, $p<0.05$ and t= 6.89, $p<0.05$ for *P. subviridis*) indicated negative allometric growth for all species.

Table 1. The ranges for length and weight of *P. abu*, *P. klunzengeri* and *P. subviridis*.

Species	N	Length range (cm)	Weight range (g)	Length-weight relationship		
				a	b	r^2
P. abu	456	6.4-19.7	3.7-86.9	0.020	2.810	0.973
P. klunzengeri	500	6.0-19.0	3.4-78.7	0.026	2.722	0.993
P. subviridis	600	9.6-26.5	5.2-244.6	0.034	2.710	0.981

Table 2 gives the outputs of the ELEFAN I and length-converted catch curve routines in the FiSAT II package for the three species. The growth curves of all species superimposed over the restructured length-frequency distributions through the ELEFAN I routine are presented in Figure 2. Growth parameters were L_∞= 21.2 cm and K= 0.44 for *P. abu*, L_∞= 27.0 cm and K= 0.49 for *P. klunzengeri* and L_∞= 29.3 cm and K= 0.40 for *P. subviridis* (Table 2).

Table 2. Estimates of parameters of growth, mortality and exploitation of *P. abu*, *P. klunzengeri* and *P. subviridis*.

Population parameters	*P. abu*	*P. klunzengeri*	*P. subviridis*
Asymptotic length (L_∞, cm)	21.2	27.0	29.3
Growth coefficient (K)	0.44	0.49	0.40
The goodness of fit (R_n)	0.21	0.30	0.24
The theoretical age at length zero (t_0)	-0.416	-0.276	-0.426
The growth performance index (Ø)	2.296	2.624	2.536
Total mortality rate (Z)	2.52	3.16	1.68
Natural mortality rate (M)	1.08	1.09	0.93
Fishing mortality rate (F)	1.44	2.07	0.75
Present exploitation rate ($E_{present}$)	0.57	0.66	0.45
Biological target reference point ($E_{0.1}$)	0.62	0.72	0.61
Biological target reference point (E_{max})	0.74	0.85	0.72

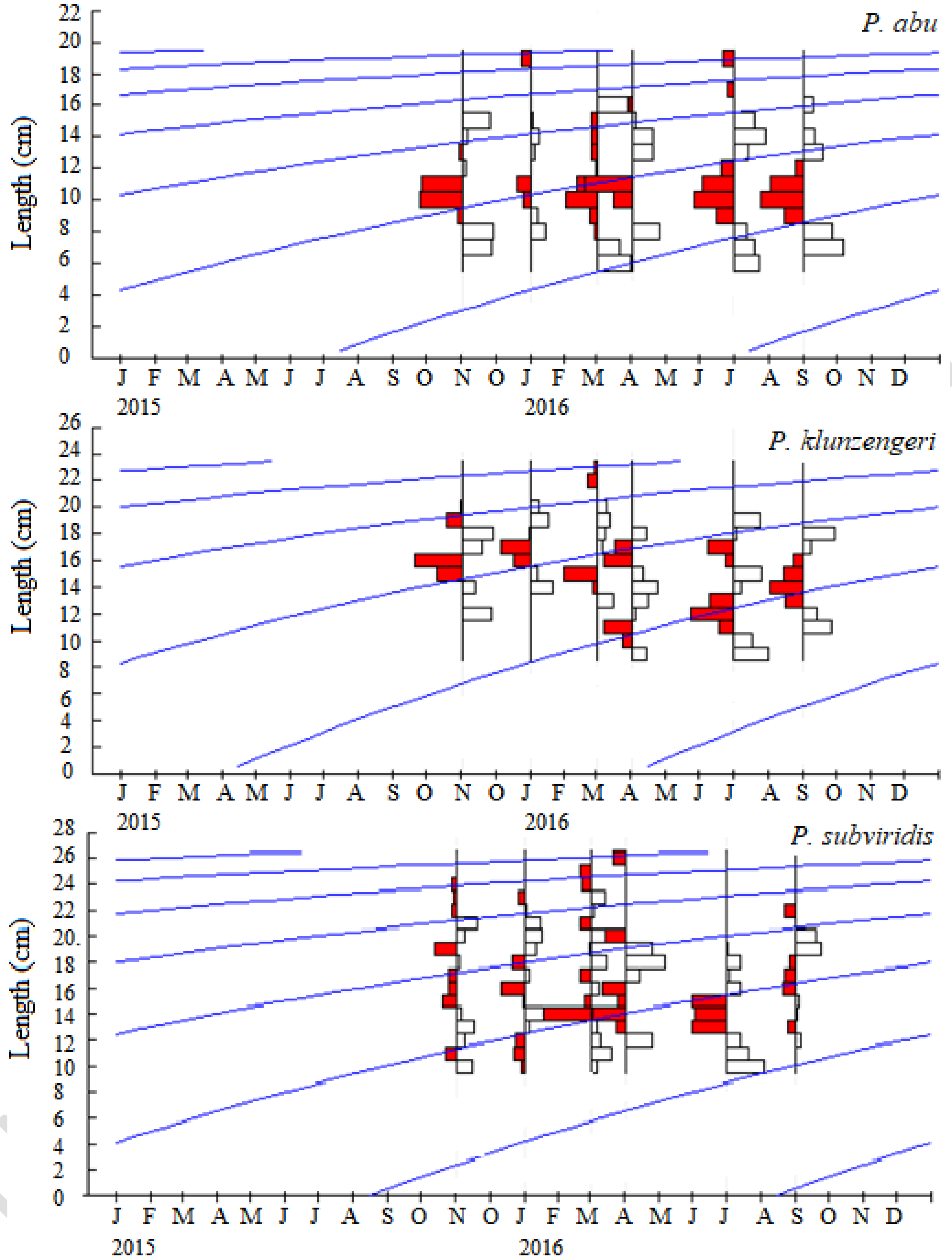

Fig. 2. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *P. abu, P. klunzengeri* and *P. subviridis*

3.2 Stock predictions

In this study, the total mortality rates (Z) of *P. abu*, *P. klunzengeri* and *P. subviridis* were 2.52, 3.16 and 1.68, respectively, while the instantaneous rates of natural mortality were 1.08, 1.09 and 0.93 for the three species, respectively. In addition, their respective fishing mortality rates were calculated as 1.44, 2.07 and 0.75. The exploitation rates (E) for *P. abu, P. klunzengeri* and *P. subviridis* estimated were found to be 0.57, 0.66 and 0.45, respectively. Moreover, from the relative yield-per-recruit analysis, the estimated values of the biological target reference points ($E_{0.1}$ and E_{max}) for *P. abu* were

0.503 and 0.591, for *P. klunzengeri* were 0.668 and 0.791, while for *P. subviridis* were 0.751 and 0.938, respectively. Therefore, the present exploitation rates (E) were lower than the biological target reference points for the three species.

3.3 Virtual population analysis

The outputs of length-structured virtual population analysis of *P. abu* are presented in Table 3. There were greater harvests (catch and biomass) for mid-length ranging from 9-13 cm for *P. abu*, with the maximum steady-state biomass of this species (0.01 t) occurring during the length groups 9-10 cm. The recruitments of P. abu into the fishery was estimated as 6006 then after the population decrease with the increased length groups. The fishing mortality rate increased steadily between the mid-lengths (10-16 cm) for *P. abu*, with a maximum fishing mortality rate (1.670/y) at mid-length 15 cm. The average value of fishing mortality of *P. abu* was 0.861, which was lower than the value estimated by catch-curve (1.44/y).

Table 3. The outputs from the virtual population analysis of *P. abu.*

Mid-Length	Catch (in numbers)	Population (N)	Fishing mortality (F)	Steady-state Biomass (tons)
6	3	6005.9	0.0036	0
7	18	5107.24	0.024	0
8	74	4279.72	0.111	0
9	254	3485.89	0.4493	0.01
10	451	2621.31	1.043	0.01
11	464	1703.31	1.6272	0
12	261	931.35	1.5397	0
13	140	487.27	1.439	0
14	67	242.2	1.2336	0
15	45	116.55	1.6698	0
16	15	42.44	1.2982	0
17	1	14.96	0.1694	0
18	0	7.58	0	0
19	2	3.5	1.44	0

Table 4 demonstrates the results of the virtual population analysis (VPA) of *P. klunzengeri.* It is clear from the table that the catch of the species occurred from size 9 cm and peaked at 16 cm. The recruitments of *P. klunzengeri* into the fishery was estimated as 3494 then after the population decrease with the increased length groups. The most exploited length groups to the fishery were 15-22 cm. However, the length group 17 cm of *P. klunzengeri* was more vulnerable to fishing (3.388/y). The average value of fishing mortality of the species was 1.455/y, which was lower than the value estimated from the catch-curve (2.07/y). The maximum steady-state biomass of *P. klunzengeri* (0.01 t) happened during length groups 11-15 cm.

The results of length-structured virtual population analysis of *P. subviridis* in the Shatt Al-Arab River are presented in Table 5. Most harvests of the species happened in mid-lengths of 13-17 cm, with the maximum steady-state biomass (t) of this species (0.01 t) occurring in the length groups 10-19 cm. The recruitment of the species into the fishery was estimated as 3122 then after the population decrease with increased length groups. The fishing mortality rate increased steadily during the mid-lengths (10-17 cm) for the species, with a maximum fishing mortality rate (1.132/y) at 17 cm. The average value of fishing mortality of *P. subviridis* was 0.631, which was lower than the value estimated by catch-curve (0.75/y).

The outputs of the virtual population analysis of *P. abu*, *P. klunzengeri* and *P. subviridis* in this study about the survivability, natural losses and fishing mortality are illustrated in figure 3. The survivability and natural losses of the fish populations decreased with an increase in length and fishing mortality for all species. Also, the fishing mortality values of the three species were not constant, the maximum values of fishing mortality were 1.670 for *P. abu* at length 15 cm, 3.388 for *P. klunzengeri* at length 17

Table 4. The outputs from the virtual population analysis of *P. klunzengeri.*

Mid-Length	Catch (in numbers)	Population (N)	Fishing mortality (F)	Steady-state Biomass (tons)
9	11	3494.03	0.0296	0
10	63	3077.41	0.1839	0
11	140	2640.9	0.4579	0.01
12	188	2167.61	0.7189	0.01
13	166	1694.56	0.7668	0.01
14	146	1292.58	0.8332	0.01
15	197	955.59	1.4978	0.01
16	219	615.22	2.6621	0
17	139	306.55	3.3879	0
18	46	122.82	2.3854	0
19	19	55.8	1.9078	0
20	10	25.95	2.0045	0
21	3	10.51	1.2074	0
22	2	4.8	1.7086	0
23	1	1.53	2.07	0

Table 5. The outputs from the virtual population analysis of *P. subviridis.*

Mid-Length	Catch (in numbers)	Population (N)	Fishing mortality (F)	Steady-state Biomass (tons)
10	18	3122.01	0.0474	0.01
11	32	2750.67	0.0912	0.01
12	64	2392.41	0.2006	0.01
13	127	2031.7	0.4522	0.01
14	190	1643.48	0.8128	0.01
15	179	1236.08	0.9734	0.01
16	145	886.07	1.0414	0.01
17	115	611.58	1.132	0.01
18	65	402.1	0.8868	0.01
19	47	268.94	0.8902	0.01
20	19	172.84	0.4917	0
21	11	117.9	0.3742	0
22	13	79.56	0.6136	0
23	7	46.85	0.4919	0
24	7	26.62	0.8168	0
25	3	11.65	0.6804	0
26	2	4.55	0.73	0

cm and 1.132 for *P. subviridis* at length 17 cm, after which a gradual decline, with some fluctuations in fishing mortality values for all species.

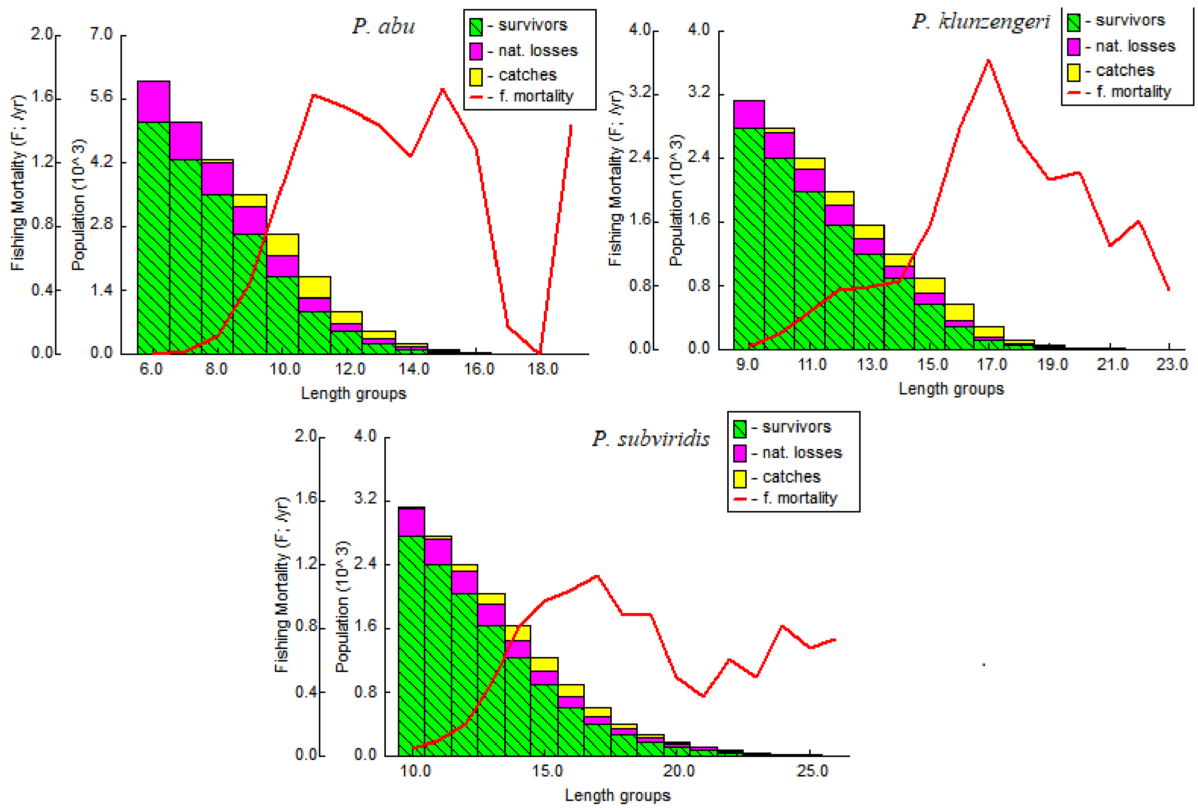

Fig. 3. Length-structured virtual population analysis of *P. abu*, *P. klunzengeri* and *P. subviridis.*

4. DISCUSSION AND CONCLUSION

In the present study, the three mullets species showed negative allometric growth (b<3), i.e. this type of growth indicates that the fish becomes lighter for its corresponding length [30]. A similar growth pattern was also observed for *P. abu* in the Atatürk Lake, Turkey (b= 2.080-2.870) by Doğu, *et al.* [31] and in the restored southern marshes, Iraq (b= 2.662-2.910) by Mohamed [13], for *P. klunzengeri* in the Iranian waters of the Arabian Gulf and Oman Sea (b= 2.719) by Hakimelahi *et al*. [10] and *P. subviridis* in Iranian waters, north of Arabian (b= 2.819) by Shadi *et al*. [32], in Merbok estuary, Malaysia (2.823) by Mohd Rosli [12], in the Parangipettai waters, India (2.711 for males and 2.893 for females) by Rahman *et al.* [15], in Damb Harbour, Pakistan (2.801) by Baloch *et al.* [33] and the Pinang River, Malaysia (2.879 for males) by Zolkhiflee [34]. In contrast, some authors reported isometric growth for *P. abu* in some waters [35, 36] and for females' *P. subviridis* in the Pinang River, Malaysia [34]. However, Bilici [37] stated that the growth of *P. abu* in the Tigris River before the construction of the Ilisu and Cizre dams, Turkey was positive allometric growth b= 3.129). The difference in growth patterns is affected by several factors, including differences in geographical location, fish sizes, season, sex, stage of fish maturity, food availability, stomach fullness, health, stress and sampling methodology [23, 38-40].

The ultimate growth of *P. abu* in the present study (L_∞= 21.2 cm) was similar to those reported for the same species from the southern marshes, such as 21.1 cm in Huwazah and 20.0 cm in Chybaish [13], whereas was better than those recorded for the species in some waters such as 19.6 cm in the Tigris River, Turkey [41] and 19.5-20.3 cm in the Orontes River, Turkey [35]. It was lower than the values reported for the species in some water such as 24.6 cm in the Atatürk Lake, Turkey [31], 23.2 cm in the East Hammar marsh, Iraq [13] and 23.4 cm in the AL-Diwaniya River, Iraq [42]. However, Birecikligil *et al.* [34] reported a higher value of L_∞ (27.87 cm) for *P. abu* in the Ceyhan River basin, Turkey. The asymptotic length (L_∞) of *P. klunzengeri* in the present study L_∞= 27.0 cm) was higher than those mentioned by Dadzie *et al.* [9] from the Kuwait Bay, Kuwait (L_∞= 24.8 cm) and Hakimelahi *et al.* [10] from the Iranian waters of the Arabian Gulf and Oman Sea (L_∞= 22.9 cm). Conversely, Al-

Hassani and Mohamed [16] reported a higher value of L_∞ (29.8 cm) for *P. klunzengeri* in the Iraqi marine waters. The L_∞ of *P. subviridis* in the present study was 29.3 cm, which was similar to the value obtained by Djumanto and Setyobud [14] for the males of the species in the estuary of Opak River, Indonesian (L_∞= 29.9 cm), while was higher than those documented by Rahman *et al.* [15] in Parangipettai waters, India (26.8 cm for males and 27.8 cm for females). Conversely, the L_∞ of *P. subviridis* in the present study was lower than those stated by Mohamed *et al.* [43] in the Iraqi marine waters (30.8 cm), Djumanto and Setyobud [14] in the estuary of Opak River, Indonesian (29.9 cm), Rahman *et al.* [15] in Parangipettai waters, India (26.8 cm for males and 27.8 cm for females) and Mohamed and Al-Hassani [17] in the Iraqi marine waters (33.8 cm). Several authors have been discussed the differences in the growth of the same species in different geographic locations and referred to several factors, including differences in habitat, environmental conditions, availability of food, metabolic activity, reproductive activity, the genetic constitution of the individual, sizes of fish, fishing pressure and sampling method [7, 44-46].

Jennings *et al.* [47] 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 ecosystems. The 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 [13] and 0.68 in East Hammar marsh [48]. However, it was under the optimum level of exploitation (E= 0.38) in the Huwazah marsh [13]. Birecikligil *et al.* [36] stated that the exploitation rate of *P. abu* in the 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 [9] and 0.52 in the Iranian waters of the Arabian Gulf and Oman Sea [10]. However, the exploitation rate (E) of the *P. klunzengeri* population in Iraqi marine waters was under exploitation, E= 0.3 [16]. Also, it was 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 [49], 0.43 for males and 0.12 for females of *P. subviridis* in the estuary of Opak River, Indonesian [14] and 0.35 for males and 0.32 for females of the species in Parangipettai waters, India [15] and 0.34 in the Iraqi marine waters [17], excluding in the Merbok estuary, Malaysia, E= 0.60 [12]. Gulland [50] suggested the assumption that any stock becomes optimally exploited when the fishing mortality (F) is equal to the natural mortality (M).

The biological reference points are the performance indicator of the fish stock, it often takes various stock dynamics parameters, such as growth, recruitment and mortality, and reflects them to a single index [51, 28]. In the present study, the exploitation rates ($E_{present}$) of the three species were lower than their biological target reference points ($E_{0.1}$ and E_{max}), which indicates that the stocks of these species are underexploited in the study river. A similar finding has been noticed for *P. klunzengeri* stock in the Iraqi marine waters by Al-Hassani and Mohamed [16] who found that the value of $E_{present}$ (0.30) was below both $E_{0.1}$ (0.77) and E_{max} (0.90). Conversely, Dadzie *et al*. [9] stated that the current exploitation rate (E= 0.75) of *P. klunzengeri* was above $E_{0.1}$ (0.239) and E_{max} (0.373) in Kuwait Bay, Arabian Gulf. Also, several authors found similar results for *P. subviridis* as the value of $E_{present}$ was below than both $E_{0.1}$ and E_{max}, such as Mohd Rosli [12] reported that the values of $E_{present}$ and E_{max} for *P. subviridis* in Merbok estuary, Malaysia were 0.60 and 0.686, respectively, Mohamed *et al.* [49] pointed out that the values of $E_{present}$, $E_{0.1}$ and E_{max} were 0.43, 0.45 and 0.59, respectively for *P. subviridis* in East Hammar Marsh, Iraq, Rahman *et al.* [15] 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, and Mohamed and Al-Hassani [17] found that the value of $E_{present}$ (0.34) was below than both $E_{0.1}$ (0.76) and E_{max} (0.93) for the species in the Iraqi marine waters.

Shepherd and Pope [52] referred that the virtual population analysis (VPA) is virtual in the sense that the population size is not observed or measured directly but is inferred or back-calculated to have been a certain size in the past to support the observed fish catches and an assumed death rate owing to non-fishery related causes. The virtual population analysis (VPA) revealed that the maximum fishing mortality for the three species occurred in the mid-lengths, with maximum values at the length of 15 cm for *P. abu* and 17 cm for *P. klunzengeri* and *P. subviridis*. More, the estimated values for the length at first capture (L_{c50}) of the three species in the same river were found to be 9.40 cm for *P. abu*, 13.97 cm for *P. klunzengeri* and 12.84 cm for *P. subviridis* [52]. The first sexual maturation is an important point in the animal's life history and must be taken into account for successful fish management [54]. There are some studies about the lengths at first maturity (L_{m50}) for these species in other waters, the L_{m50} of *P. abu* in the Orontes River was 11.49-11.82 cm [35], while of *P. klunzengeri* was 13.0-15.0 cm in the Arabian Gulf [55, 56] and of *P. subviridis* was 13.7-14.2 cm in the Shatt Al-Basrah Canal [57] and 13.1-14.5 cm in the Parangipettai waters [58]. When comparing the L_{m50} values with the L_{c50} values, the results that mullets species catches have not met the criteria for good management ($L_{c50} < L_{m50}$), i.e. they may be vulnerable to capture by the available fishing gear before they mature, so that every individual would get at least one chance to breed in their lifetime, which would help renew the stock over the long term [59,46].

The overall purpose of fisheries science is to provide decision-makers with advice on the relative merits of alternative management, and this advice may include predictions of the reaction of stock and fishers to varying levels of fishing effort and, conventionally, include an estimate of the level of fishing effort required to obtain the maximum yield that may be taken from stock on a sustainable basis [60]. Accordingly, the present study proposes that the officials in fishery management can get more yields through increasing the fishing activities on these species but must be matching the mesh sizes with the fishing recommendation to allow the escape of young recruits to grow and reproduce to assure resource availability and sustainability.

The *P. abu*, *P. klunzengeri* and *P. subviridis* in the Shatt Al-Arab River, Iraq exhibited negative allometric growth patterns. $L\infty$ values of the three species were 21.2, 27.0 and 29.3 cm, respectively. The exploitation rates (E) for *P. abu, P. klunzengeri* and *P. subviridis* were 0.57, 0.66 and 0.45, respectively, and were lower than their biological target reference points ($E_{0.1}$ and E_{max}), which indicates that the stocks of these species are underexploited in the study river. The values of L_{c50} were lower than the values of L_{m50} for all species, which indicated heavy harvesting of small individuals in the river, and this is not a healthy sign for sustainable stock management.

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