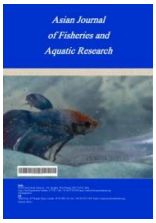

Asian Journal of Fisheries and Aquatic Research

13(4): 25-36, 2021; Article no.AJFAR.71648
ISSN: 2582-3760

Aspects of Stock Assessment of Klunzinger's Mullet, *Planiliza klunzengeri* (Day, 1888) from Northwest Arabian Gulf, Iraq

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2021/v13i430272
Editor(s):
(1) Dr. Pınar Oguzhan Yildiz, Ataturk University, Fisheries, Turkey.
Reviewers:
(1) Diovani Piscor, Universidade Estadual de Mato Grosso do Sul, Brazil.
(2) Raphael da Silva Costa, University of São Paulo (USP), Brazil.
Complete Peer review History: https://www.sdiarticle4.com/review-history/71648

Original Research Article

Received 17 May 2021
Accepted 23 July 2021
Published 27 July 2021

ABSTRACT

The stock assessment of Klunzinger's mullet, *Planiliza klunzengeri* was conducted, to estimate its some aspects viz. growth, mortality, recruitment, yield-per-recruit and virtual population analysis in Iraqi marine waters, northwest Arabian Gulf, Iraq, from February 2020 and January 2021. The population parameters were analyzed by the FiSAT software using monthly length-frequency data collected by the Shaheen dhow and from the artisanal fishermen at the fish landing site in Al-Fao city to derive information required for their management. A total of 3319 individuals of *P. klunzingeri* ranged from 11.0 to 27.0 cm have been collected. Length-weight relationship was calculated as $W= 0.026L^{2.716}$. The asymptotic length ($L\infty$), growth rate (K) and the growth performance index (Ø') were 29.8 cm, 0.34 and 2.48, respectively. The rates of annual instantaneous of total mortality (Z), fishing mortality (F), natural mortality (M) and present exploitation (Epresent) were 1.19, 0.84, 0.36 and 0.30, respectively. The recruitment pattern of *P. klunzingeri* was continuous throughout the year, with one peak during May. The results of virtual population analysis revealed that the majority of *P. klunzingeri* were harvested between 14 cm and 19 cm. The length at first capture (L_{50}) in the current study was higher than the length at first maturity (L_m) of the species in the region. The $E_{present}$ was below the biological target reference points ($E_{0.1}$= 0.770 and E_{max}= 0.903), referred to the stock of *P. klunzingeri* is underexploited.

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Therefore, the harvest level should increase to its maximum sustainable yield level by increasing fishing effort level with monitoring surveys and evaluate the risk associated with fishing effort increases as fishing precautionary approaches.

Keywords: Planiliza klunzingeri; growth and mortality; virtual population analysis; yield-per-recruit; Arabian Gulf.

1. INTRODUCTION

The Klunzinger's mullet *Planiliza klunzingeri* (Day, 1888) belong to the Mugilidae family, which comprises 79 species belonging to 26 genera in the world [1]. Of this total, six species of mullets were reported from the Iraqi waters [2], namely Abu mullet *Planiliza abu* (Heckel, 1843), Klunzinger's mullet *P. klunzingeri* (Day, 1888), Greenback mullet *P. subviridis* (Valenciennes, 1836), Largescale mullet *P. macrolepis* (Smith, 1846), Keeled mullet *P. carinata* (Valenciennes, 1836), Silver mullet *Osteomugil speigleri* (Bleeker, 1858) and Longarm mullet *O. cunnesius* (Valenciennes, 1836).

The *P. klunzingeri*, formerly known as *Liza carinata* [3], also formerly placed in the genus *Liza* but Durand *et al.* [4] placed it in the genus *Planiliza*. It is native to the Indian Ocean, the Arabian Sea, Gulf of Oman and Arabian Gulf [5]. It inhabits coastal marine waters and enters the rivers and marshes of southern Iraq for feeding and locally known as “Beyah”. The species constituted 3.7% of fish assemblage in the East Hammar marsh during 2009-2010 [6], 3.7% of fish assembly in the Garmat Ali River during 2007-2008 [7], and 10.6% of fish structure in the Shatt Al-Arab River during 2015-2016 [8]. The total landing of mullet’s species in the artisanal fisheries in the Iraqi marine waters includes the study species was about 1439 tons, composed about 12.7% of the total Iraqi marine landings and predominated the landings during 2019 [9].

Kebtieneh *et al.* [10] 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. Few studies have been done on the population dynamics of *P. klunzengeri* in some waters using FiSAT II software (FAO-ICLARM Stock Assessment Tools). Dadzie *et al*. [11] has discussed the growth, mortality, recruitment and exploitation of *P. klunzingeri* in the Kuwait Bay, Arabian Gulf, and stated that the current exploitation rate was above the optimum, the maximum and the economic yield indices. Hakimelahi *et al*. [12,13] have also studied the population dynamics of *P. klunzingeri* in the Iranian waters of the Arabian Gulf and Oman Sea and suggested that the species was moderately exploited. The growth parameters, mortality rates, probability of capture, recruitment patterns and stocks assessment for *P. klunzengeri* in the Shatt Al-Arab River were assessed by Mohamed and Abood [14].

The present study was undertaken to generate information on the stock status such as growth parameters, mortality rates, probability of capture, recruitment pattern, yield per recruit and virtual population analysis of *P. klunzengeri* in Iraqi marine waters, northwest Arabian Gulf to derive requisite information for the sustainable management of the species.

2. MATERIALS AND METHODS

2.1 Fish Sampling

The fish *P. klunzengeri* random samples were obtained from Iraqi marine waters, northwest Arabian Gulf from February 2020 to January 2021, except April, representing the virtual population of these fishes. Fig. 1 illustrates the main fishing grounds for Iraqi marine fisheries, include the Shatt Al-Arab estuary, Khor Abdulla and Khor Al-Amaya [15]. A total of 3319 individuals of the fish were collected from the Shaheen steel-hulled dhow (21 m length, 7 m wide and 2m draft with a horsepower of 150 horses), and the artisanal fishermen at the main fish landings site in Al-Fao port, 100 km south of Basrah city. The fishermen operated with multifilament gears such as drift gillnets, trawl nets, traps (gargoor), stake nets (hadra) and hook and line [2]. The total lengths of fish were measured in the field to the estimation of growth and population parameters. Subsamples of fish were immediately iced and transported to the laboratory for measuring length (to the nearest 1.0 mm) and weight (to the nearest 0.5 g) of each fish.

2.2 Methodology

To estimate the relationship between total length (L) and total weight (W), the power function: W=

$a*L^b$ was fitted to the data [16], where a the intercept and b is the growth coefficient. The value of (b) tested to see if it was statistically different from 3.

The length data were grouped into 1 cm length classes, sequentially arranged according to a time series of 11 months, and stored in the FiSAT II package [17]. The asymptotic length ($L\infty$) and growth coefficient (K) parameters were estimated using ELEFAN-I routing, which incorporated into the FiSAT software. To estimate the reliability of the K value, a K-scan routine was conducted. The estimate of theoretical age at length zero (t_0) was obtained by using the empirical equation of Pauly [18]:

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

The growth performance index (Ø') of the *P. klunzingeri* population was calculated based on the $L\infty$ and K estimates according to Pauly and Munro [19] from the following equation:

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

Total mortality rate (*Z*) was estimated by length converted catch curve method of Pauly [20] in the FiSAT II program using the input parameters $L\infty$ and K. Natural mortality rate (M) was estimated using Pauly's empirical relationship [20] considering the mean annual water temperature as 24.8°C [21]:

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

From these mortality parameters, fishing mortality (F= Z-M) and exploitation rate (E= F/Z) of *P. klunzingeri* were estimated.

A selectivity curve was generated using linear regression fitted to the ascending data points from a plot of the probability of capture against length to derive values of the lengths at capture at probabilities of 0.25 (L_{25}), 0.5 (L_{50}) and 0.75 (L_{75}). The recruitment pattern obtained by backward projection on the long axis of a set of length-frequency data [18] as described in the FiSAT software.

The analysis of yield per recruit was determined using the knife-edge analysis of the Beverton and Holt [22] model as modified by Pauly and Soriano [23] of the FiSAT software. The input parameters were $L_c/L\infty$, M/K and E values. The results gave estimates of biological referenced points ($E_{0.1}$ and E_{max}), where $E_{0.1}$ is the exploitation rate at which the marginal increase of relative yield-per-recruit is 1/10th of its value at E=0 and E_{max} is the exploitation rate which produces maximum yield. The current rate of exploitation ($E_{current}$) value compared with the values of $E_{0.1}$ and E_{max} to assess the status of the species stock [24].

Length structured virtual population analysis (VPA) was used to calculate the biomass (tons), the yield (tons), total and fishing mortality and exploitation ratios following the length convert curve procedure of Jones and van Zalinge [25] fitted in FiSAT II. The values of $L\infty$, K, M and F, and a and b of the allometric length-weight relationship for the species were used as inputs to VPA analysis.

3. RESULTS

3.1 Length-Frequency Distribution

The overall length-frequency distribution of 3319 individuals of *P. klunzingeri* collected from February 2020 to January 2021 is presented in Fig. 2. The smallest size of the species recorded was 11.0cm while the largest size was 27.0 cm. The most frequent length group was 17 cm composed about 11.0% of the total catch. The population is dominated by middle-sized fish 14.0-19.0 cm constituting 63.1% of the total catch.

3.2 The Length-Weight Relationship

The total length of 305 individuals of *P. klunzingeri* varied from 10 to 35.5 cm while the total weight ranged between 18 and 650 g (Fig. 3), and the resultant equation was:

$$W= 0.026L^{2.716}, \quad r^2= 0.992$$

The total length-weight relationship of the species indicated that this relationship is highly significant ($p<0.05$) with a high r^2 value (0.992) which indicate an increase in length with an increase in weight. The exponent (b= 2.716) was significantly different from value 3 (t= 20.09, $P<0.05$), indicating that growth in this species is negatively allometric.

3.3 Growth

The ELEFAN I routine in FiSAT II software was used to scan the goodness of fit, R_n (Fig. 4) for the best estimates of the asymptotic length ($L\infty$)

and the growth constant (K), based on the restructured form of the length-frequency data for *P. klunzingeri* (Fig. 5). The obtained growth parameters were: L∞= 29.8 cm and K= 0.34, while the goodness of fit was at R_n= 0.198. The theoretical age at zero calculated at t_0= -0.621. The assessed value of (Ø) for the species was 2.48.

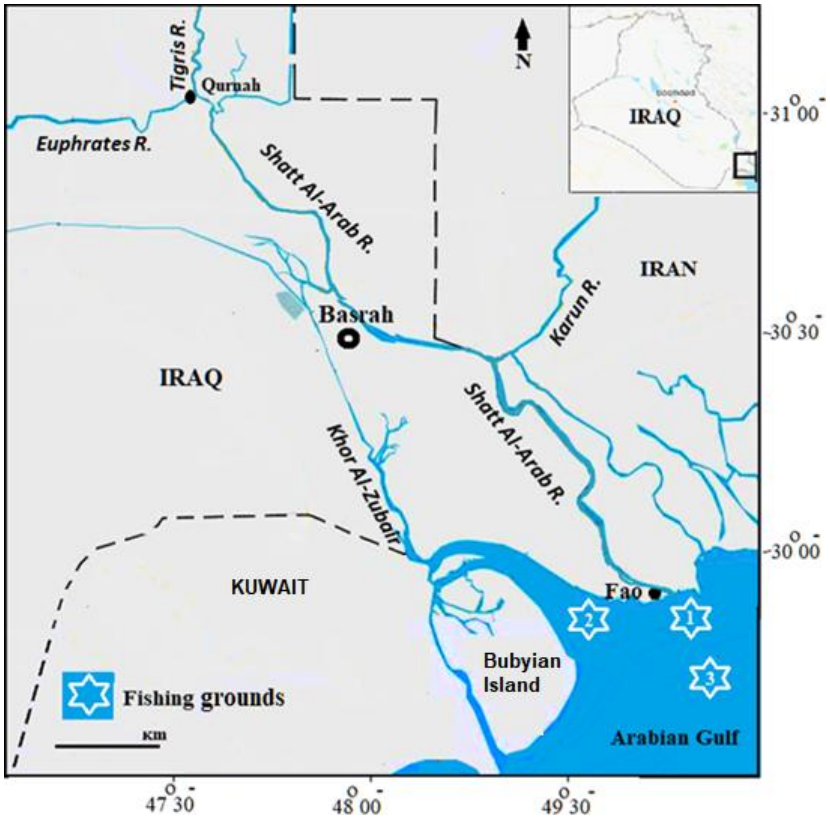

Fig. 1. Fishing grounds in Iraqi marine waters, northwest Arabian Gulf (15)

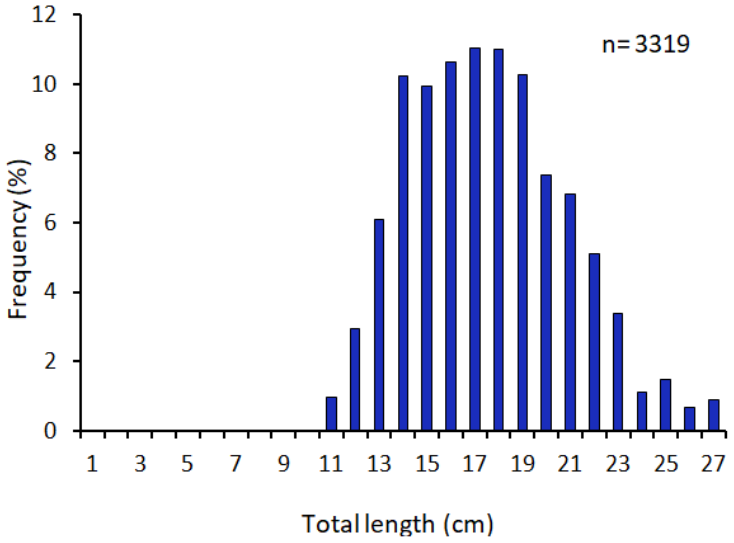

Fig. 2. Overall length-frequency distribution of *P. klunzengeri*

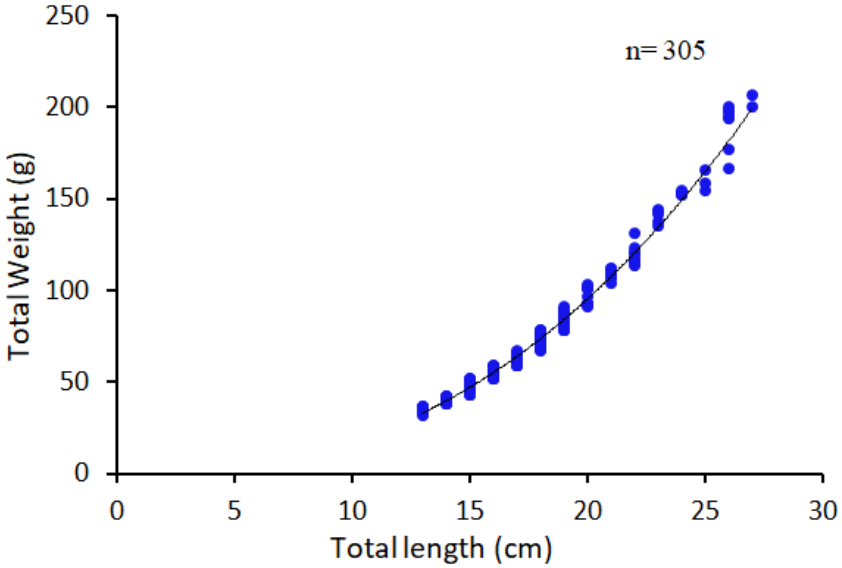

Fig. 3. The length-weight relationship of *P. klunzingeri*

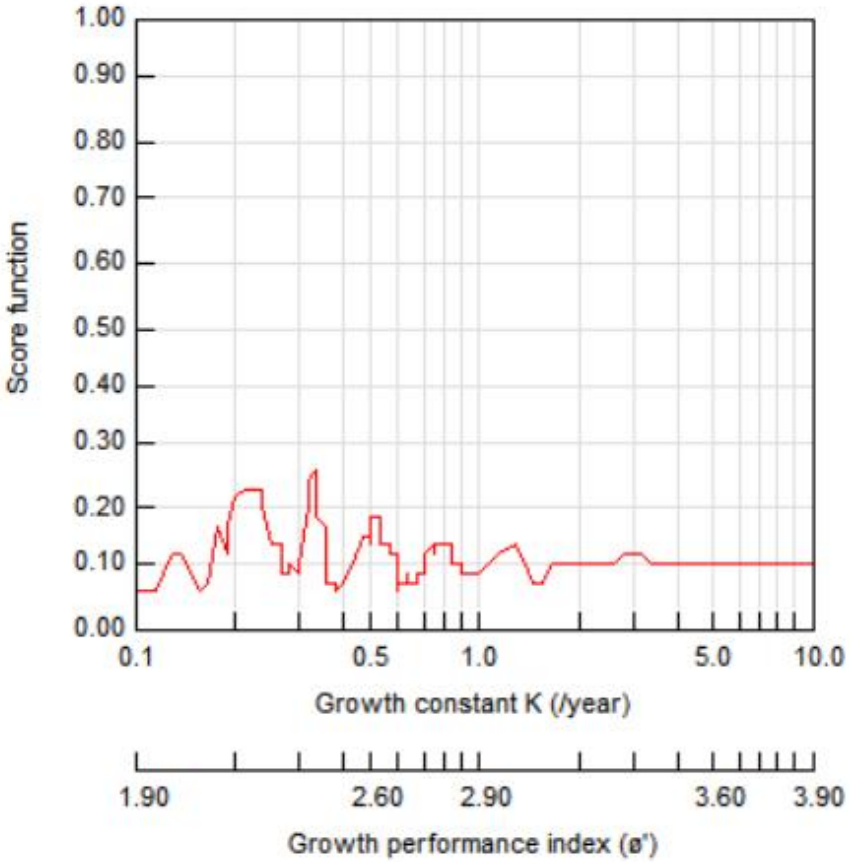

Fig. 4. K-scan routines of *P. klunzengeri.*

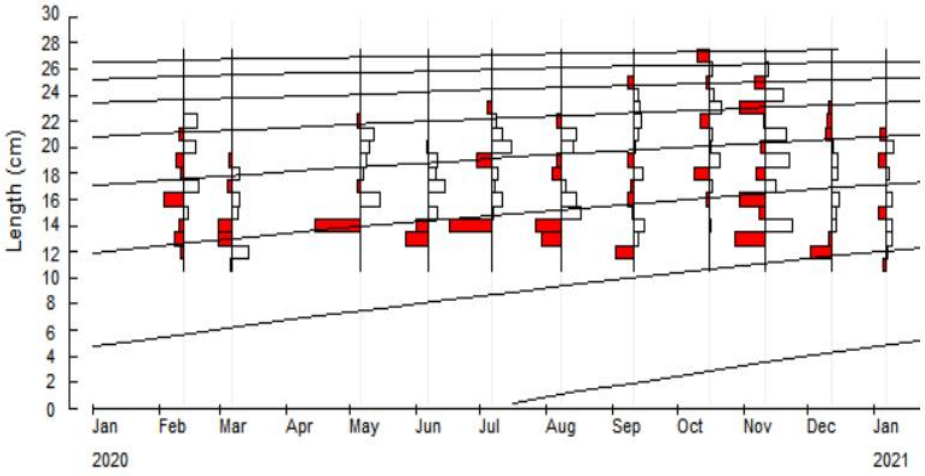

Fig. 5. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *P. klunzingeri*.

3.4 Mortality and Exploitation Rates

The estimated value of the annual mortality rate (Z) of *P. klunzingeri* was obtained using a length-converted catch curve method in FiSAT software. The darkened circles in Fig. 6 represent the points used in estimation (Z), where it was 1.19 with a 95% confidential interval(0.97-1.22; r^2= 0.973). The natural mortality rate (M) was determined by Pauly empirical equation in FiSAT software and was 0.84, while the rate of fishing mortality (F) was at Z-M= 0.36. The present exploitation rate ($E_{present}$) computed from F/Z= 0.30.

3.5 Probability of Capture

The selection curve generated by the ascending part of the length-converted catch curve for *P. klunzingeri* in FiSAT software is shown in Fig. 7. From the curve, the mean length at first capture (L_{50}) was extrapolated as 15.20 cm, whereas the values of L_{25} and L_{75} were 13.86 and 16.55 cm.

3.6 Recruitment

The recruitment pattern of *P. klunzingeri* was continuous throughout the year with one peak during May (Fig. 8). It is clear from the figure that the per cent recruitment varied from 2.12% in November to 22.24% in May.

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

The results of relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) of *P. klunzingeri* using the knife-edge selection routine in the Beverton and Holt Y/R method incorporated in FiSAT software are presented in Fig. 9. The values of M/K (2.471) and Lc/L∞ (0.510) as derived from the previous analyses were used to produce values of the maximum economic yield target (MEY) on the green line ($E_{0.1}$= 0.770) and the maximum sustainable yield (MSY) on the yellow line (E_{max}= 0.903). The current exploitation rate ($E_{current}$= 0.30) was 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 0.018 and 0.423, respectively.

3.8 Virtual Population Analysis

The virtual population analysis (VPA) results are presented in Table 1 and Fig. 10. The results revealed that the majority of *P. klunzingeri* were harvested between 14 cm and 19 cm. The 17 cm length group was more vulnerable to fishing, followed by 18 cm and 16 cm length groups. Surviving individuals in the stock exhibited a declining trend with an increased rate of fishing pressure. The highest number of survivors (23364) in the stock was observed in the length range of 11 cm, whereas the lowest number of survivors (100) was observed for individuals at a length range of 27 cm. The highest peak of fishing mortality (F= 0.36) occurred at length 27 cm, followed by F= 0.31 on individuals at the length of 21.0 cm. Steady-state biomass increased with mid-length, from 16cm to 18cm (0.1 ton), then fell to 0.02 ton for mid-length 27 cm.

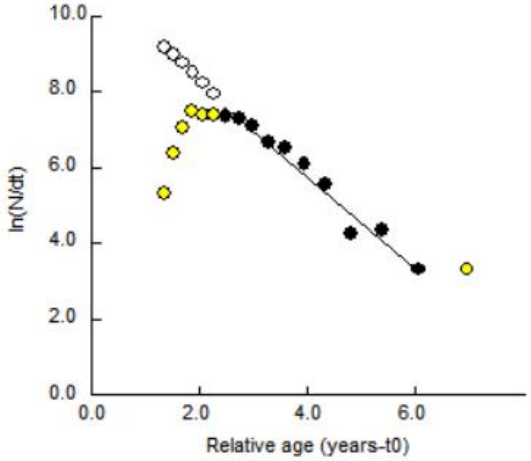

Fig. 6. Length converted catch curve for estimation of Z for *P. klunzingeri*

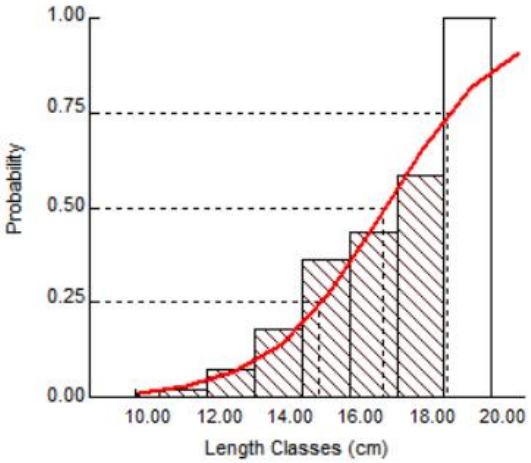

Fig. 7. Probability of capture for *P. klunzingeri*.

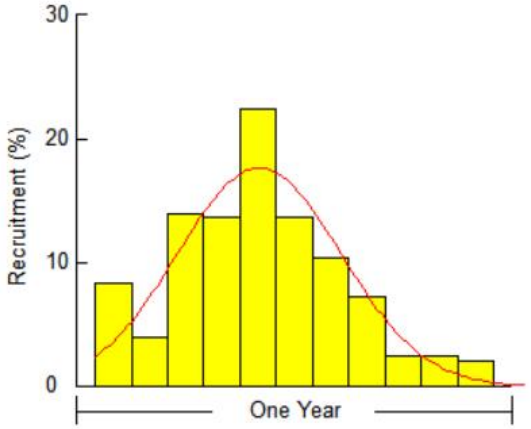

Fig. 8. Recruitment pattern of *P. klunzingeri*.

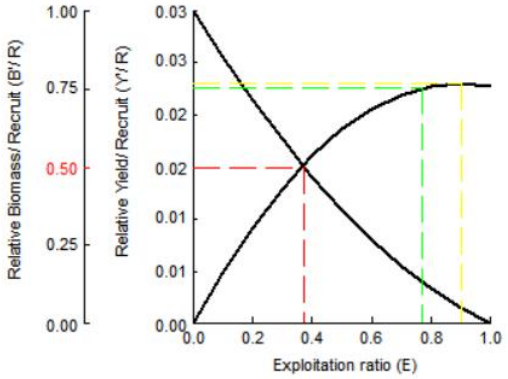

Fig. 9. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for *P. klunzingeri.*

Table 1. FiSAT II output of virtual population analysis of *P. klunzengeri* in present study

Length (cm)	Catch (numbers)	Virtual Population (N)	Fishing mortality (F)	Steady-state Biomass (tons)
11.0	32.00	23364	0.0093	0.06
12.0	98.00	20456	0.0311	0.07
13.0	202.00	17713	0.0705	0.08
14.0	340.00	15102	0.1322	0.09
15.0	330.00	12602	0.1450	0.09
16.0	353.00	10360	0.1778	0.10
17.0	366.00	8339	0.2150	0.10
18.0	365.00	6543	0.2556	0.10
19.0	341.00	4979	0.2921	0.09
20.0	245.00	3657	0.2620	0.08
21.0	227.00	2627	0.3112	0.07
22.0	169.00	1787	0.3087	0.06
23.0	113.00	1158	0.2845	0.05
24.0	37.00	711	0.1296	0.04
25.0	49.00	435	0.2517	0.03
26.0	22.00	222	0.1847	0.02
27.0	30.00	100	0.3600	0.02
Mean			0.2012	

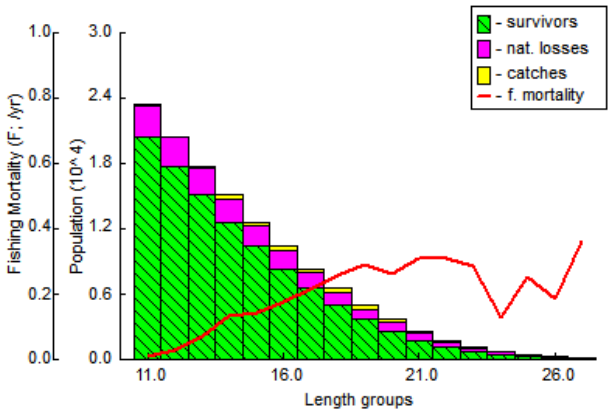

Fig. 10. Length-structured virtual population analysis of *P. klunzengeri*

4. DISCUSSION AND CONCLUSION

Jenning *et al*. [26] stated that the assessment of fish populations is essential to address one of the main objectives of fishery science, which is maximizing yield while safeguarding the long-term viability of populations and ecosystem. The size of *P. klunzengeri* in the present study ranged from 11.0 to 27.0 cm in which the higher limit was larger than those obtained for this species by other authors such as Dadzie *et al.* [11] in the Kuwait Bay, Arabian Gulf (2.0-21.0 cm), Hakimelahi *et al*. [12] in the Iranian waters of the Arabian Gulf and Oman Sea (12.1-17.8 cm), and Mohamed and Abood [14] in the Shatt Al-Arab River, Iraq (9.6-23.0 cm). This variation in the size of fish may be related to water condition, food supply, population density, fishing pressure, and possibly using different fishing gears.

The value of (b) in the length-weight relationship of *P. klunzengeri* (2.719) showed negatively allometric, i.e. the fish becomes lighter for its corresponding length [27]. Similar growth was also observed in the study of Hakimelahi *et al*. [12] for the species in the Iranian waters of the Arabian Gulf and Oman Sea (b= 2.823). Several factors such as habitat, season, stage of fish maturity, sex, food availability, stomach fullness, health, stress and sampling methodology can influence the constants of the length-weight relationship in fish [28-30].

In the present study, the asymptotic length ($L\infty$= 29.8 cm) and the growth performance index (Ø= 2.48) of *P. klunzingeri* were higher than those mentioned by Dadzie *et al.* [11] from the Kuwait Bay, Arabian Gulf ($L\infty$= 24.8 cm, Ø= 2.45), Hakimelahi *et al.* [12] from the Iranian waters of the Arabian Gulf and Oman Sea ($L\infty$= 22.9 cm, Ø= 2.39), and Mohamed and Abood [14] in the Shatt Al-Arab River, Iraq ($L\infty$= 27.0 cm), but lower than the value of Ø reported for the species in the Shatt Al-Arab River (Ø= 2.624). The variability in the growth of the same species in different waters could be attributed to several factors, such as; ecological conditions, availability of food, metabolic activity, reproductive activity, sizes of fish, method of sampling and fishing pressure [31-33].

Table 2 compares the rates of the total mortality (Z), natural mortality (M), fishing mortality (F) and the current exploitation ($E_{current}$) of *P. klunzingeri* obtained in this study with those obtained from other studies by applying the FiSAT II software. It is clear from the table that the exploitation rates (E) of the species population in the present study was under exploitation (0.30), whereas in other waters were overexploited. The highest values of mortality and exploitation rates of the species in these waters were obtained by Dadzie *et al.* [11] in the Kuwait Bay, Arabian Gulf, who reported that total mortality (Z) and $E_{current}$ were reported 4.64 and 0.75, respectively. Moreover, Mohamed and Abood [14] stated that the values of Z and $E_{current}$ were 3.16 and 0.66, respectively in the Shatt Al-Arab River, Iraq. Pauly [20] stated that the optimum categorization of exploitation rate for healthy fish stocks was taken as 0.5 with values lower or greater than E= 0.5 interpreted as underexploited or overexploited stock, respectively.

The recruitment pattern showed that *P. klunzengeri* in the present study recruited in the fishery throughout the year with one peak during May. A similar trend was also observed in the study of Mohamed and Abood [14] for the same species in the Shatt Al-Arab River, Iraq. However, Dadzie *et al*. [11] found two peaks of unequal strength for the recruitment pattern of *P. klunzengeri* in Kuwait Bay, one in May and the other in September.

Results from the analysis of relative yield-per-recruit and relative biomass-per-recruit of *P. klunzingeri* indicate that the actual exploitation rates (E) for the species was below the biological target reference points, the economic yield target ($E_{0.1}$) and the maximum sustainable yield (E_{max}), which denotes that the studied stock underexploited [24]. A similar finding has been noticed for *P. klunzengeri* stock in the Shatt Al-Arab River by

Table 2. Comparison of mortality and exploitation rates of *P. klunzingeri* in different studies

Author	Z	M	F	$E_{current}$	Waters
Dadzie et al. [11]	4.64	1.16	3.48	0.75	Kuwait Bay, Arabian Gulf
Hakimelahi et al. [12]	2.31	1.09	1.22	0.52	Iranian waters of the Arabian Gulf and Oman Sea
Mohamed and Abood [14]	3.16	1.09	2.07	0.66	Shatt Al-Arab River, Iraq
Present study	1.19	0.84	0.36	0.30	Northwestern Arabian Gulf, Iraq

Mohamed and Abood [14] who reported that the value of the actual exploitation rate (E= 0.66) was below the biological target reference points ($E_{0.1}$= 0.72 and E_{max}= 0.85). Conversely, Dadzie *et al*. [11] 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.

From the study, the result of the virtual population analysis (VPA) revealed that the majority of P. klunzingeri individuals were harvested at sizes ranging from 14 to 19 cm. Also, the estimated length at first capture (L50) of P. klunzingeri in the current study was 15.2 cm. It has been documented that the length at first maturity (Lm) of the same species in the northwest Arabian Gulf was 13-15 cm [34, 35]. 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 as reported by Udoh and Ukpatu [36] for Nematopalaemon hastatus in Okoro River estuary, Nigeria.

It could be concluded the exploitation rate of P. klunzingeri in the present study was far below the economic yield target and the maximum sustainable yield, indicating that this species is not overexploited. Therefore, the harvest level should increase to its maximum sustainable yield level by increasing fishing effort level with monitoring surveys and evaluate the risk associated with fishing effort increases as fishing precautionary approaches.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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