



E-ISSN: 2347-5129

P-ISSN: 2394-0506

(ICV-Poland) Impact Value: 5.62

(GIF) Impact Factor: 0.549

IJFAS 2021; 9(4): 15-22

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www.fisheriesjournal.com

Received: 09-04-2021

Accepted: 13-05-2021

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International Journal of Fisheries and Aquatic Studies

Population dynamics of Arabian yellow fin sea bream, *Acanthopagrus arabicus* Iwatsuki, 2013 from Iraqi marine waters, Arabian Gulf

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DOI: <https://doi.org/10.22271/fish.2021.v9.i4a.2517>

Abstract

In this study, the population dynamics of the Arabian yellow fin sea bream, *Acanthopagrus arabicus* in the Iraqi marine waters, Arabian Gulf were assessed, to contributing towards the development of management plans for its sustainable exploitation. *A. arabicus* 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 from February 2020 to January 2021. The length-weight relationship was described as $W = 0.030L^{2.867}$, indicating a negative allometric growth pattern. Of 3484 individuals ranging in total length from 13.0 to 41.0 cm were used to evaluate the growth and mortality parameters. The asymptotic length (L_{∞}), growth rate (K) and growth performance index (ϕ') were 44.6 cm, 0.34 and 2.830, respectively. The total mortality (Z) was calculated as 1.17, while the natural and fishing mortality rates were 0.75 and 0.42, respectively, and the current exploitation rate (E_{present}) was 0.36. Length at first capture (L_{50}) was 21.9 cm. The recruitment pattern occurs throughout the year, with two recruitment peaks. The yield per recruit analysis indicates that the current exploitation rate was below the economic yield target and the maximum sustainable yield, indicating that this stock underexploited. Virtual population analysis results showed that the mid-lengths (16-22 cm) experienced the highest fishing mortality. So, for management purposes, more yields could be obtained by increasing the fishing activities on this species for a substantial harvest.

Keywords: *Acanthopagrus arabicus*, growth and mortality, yield-per-recruit, VPA, Arabian Gulf

1. Introduction

Sparidae is found in shallow temperate and tropical waters of the Atlantic, Indian and Pacific oceans and represented by 39 valid genera and 438 valid species [1]. Sparid fish are an important component of the artisanal fisheries in the Iraqi marine waters. The total landing of sparid's species during 2019 was about 1439 tons which constitute 12.7% of the total Iraqi marine landings [2]. They are represented with 11 valid species in Iraq [3].

Arabian yellow fin sea bream, *Acanthopagrus arabicus* Iwatsuki, 2013 is a family member widely distributed in the northwestern Indian Ocean: Arabian Gulf and Oman east to Pakistan and India [4-6]. *A. arabicus* was named *A. latus* for a long time until Iwatsuki [4] reviewed the taxonomic position of *Acanthopagrus*, and this species group has been separated into 5 valid species based on morphological and molecular characteristics. Accordingly, the distribution of western yellow fin sea bream, *A. latus* was restricted to the east Asia Shelf.

The individuals of *A. arabicus* inhabit the Iraqi marine waters, and their juveniles enter the rivers and marshes of southern Iraq for feeding and locally known as "Shank". The species constituted 1.7% of fish assemblage in Garmat Ali River [7], 0.6% of fish assemblage in the East Hammar marsh [8], 4.2% of fish assemblage in the Shatt Al-Arab River [9] and 2.2% of fish structure in the south part of Main Outfall Drain, Basrah, Iraq [10].

There are a few studies have been done on the population dynamics of *A. arabicus* in some waters using ELEFAN or FiSAT II software such as Morgan [11] Lee and Al-Baz [12] and Mathews and Samuel [13] in Kuwait waters, Arabian Gulf; Resen *et al.* [14] in Iraqi waters, Arabian Gulf; Vahabnezhad *et al.* [15] in Iranian waters, Arabian Gulf, and Mustafa *et al.* [16] in the Sundarbans Ecosystem of Bangladesh.

In this study, we explore the use of the FiSAT II software [17] to estimate growth parameters, mortality rates, probability of capture, recruitment pattern, yield per recruit and virtual

population analysis of *A. arabicus* in Iraqi marine waters to provide management advice for their sustainable exploitation in the fishery.

2. Materials and Methods

This study focused on the Iraqi marine waters, the northwestern of the Arabian Gulf. The region is dominated by the large river delta of the rivers Euphrates, Tigris and Karun, merging into the Shatt Al-Arab represent the main outflow in the Arabian Gulf^[18]. The main fishing grounds for Iraqi marine fisheries (Fig. 1) include the Shatt Al-Arab estuary, Khor Abdulla and Khor Al-Amaya^[19]. Fishing was done by several types of fishing gears such as drift gillnets, trawl nets, traps (gargoor), stake nets (hadra) and hook and line^[20].

From February 2020 to January 2021 (except April), we obtained monthly samples of *A. arabicus* 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.

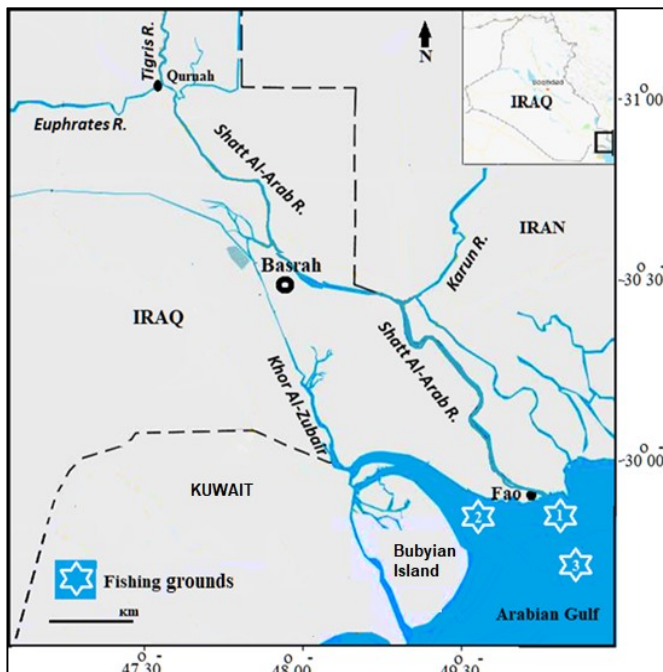


Fig. 1: Fishing grounds in Iraqi marine waters, northwest Arabian Gulf

In the field, the total length (cm) of the largest possible number of *A. arabicus* were measured to 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 power equation ($W = aL^b$) was applied to describe the relationship between the total length (L) and the total weight (W), and a and b are constants^[21]. The slope (b) was tested to see if it was statistically different from 3.

The total length (cm) of 5000 individuals of *A. arabicus* was measured and pooled into groups with a 1.0 cm length interval and constituted the database for growth and mortality analysis. Monthly length-frequency data was analyzed using the FiSAT II (FAO- ICLARM Stock

Assessment Tools) software^[17]. The growth parameters asymptotic length (L_{∞}) and growth coefficient (K) were estimated using the ELEFAN I module incorporated into the FiSAT II software. K scan routine conducted to assess a reliable estimate of the K values. The theoretical age at birth (t_0) was estimated independently, using the equation of Pauly^[22]:

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

The estimated L_{∞} and K were used to calculated the growth performance index using the formula of Pauly and Munro^[23]:

$$(\phi) = 2\log L_{\infty} + \log K$$

From estimates of the growth parameters (L_{∞} and K), the instantaneous rate of total mortality (Z) was estimated using a length-converted catch equation^[24] as implemented in FiSAT II. The instantaneous natural mortality rate (M) was estimated from Pauly's empirical formula^[24] using mean surface water temperature (T) of 28°C^[25]:

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

The instantaneous fishing mortality (F) was estimated as $F = Z - M$, and the exploitation rate (E) was obtained by the formula $E = F/Z$ ^[26].

The ascending left arm of the length converted catch curve incorporated in FiSAT II was used to estimate the probability of length at first capture (L_{50}) in addition to the lengths of capture at probabilities of L_{25} and L_{75} . The recruitment pattern of the stock was determined by backward projection on the long axis of the set of available length-frequency data and input growth parameters as described in FiSAT.

Analysis of yield per recruit was conducted based on the Beverton and Holt^[27] model, as modified by Pauly and Soriano^[28] using the knife-edge option incorporated in the FiSAT II Tool. The values of L_c/L_{∞} , M/K and E were used as input parameters to compute the economic yield target ($E_{0.1}$) and the maximum sustainable yield (E_{max}) as the biological referenced points^[29].

The length-frequency data used to carry out virtual population analysis (VPA) using the length convert curve procedure of Jones and van Zalinge^[30] 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 to VPA analysis. The results of VPA analysis were the biomass (tons), the yield (tons), total and fishing mortality and exploitation ratios.

3. Results

3.1. Length-frequency distribution

The overall length-frequency distribution of *A. arabicus* is illustrated in Figure 2. The sample composed of 3484 individuals ranging in total length from 13.0 to 41.0 cm. The most frequent length group percentages were 7.26, 6.31 and 5.86%, corresponding to length groups 24, 28 and 19 cm. The dominant individuals that ranged from 19 to 29 cm formed 62.7% of the total catch.

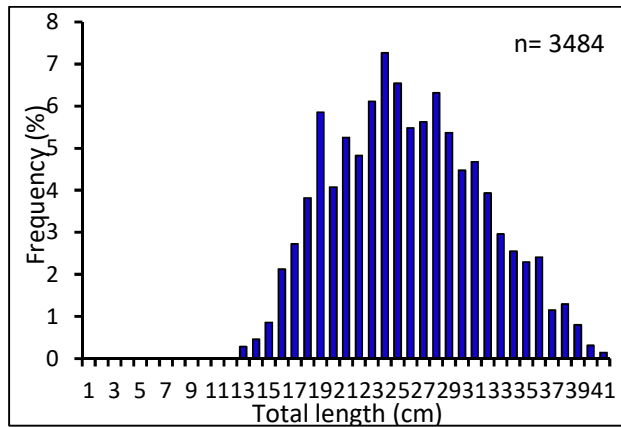


Fig. 2: The overall length-frequency distribution of *A. arabicus*.

3.2. The length-weight relationship

The length-weight relationship for *A. arabicus* is shown in Figure 3, and the total length ranged between 14 and 41 cm while the total weight varied from 53 and 1161 g. The obtained equation was:

$$W = 0.030L^{2.867}, \quad r^2 = 0.992$$

The value of (b) deviated significantly from the value 3 ($t = 9.2, P < 0.05$), indicating negative allometric growth.

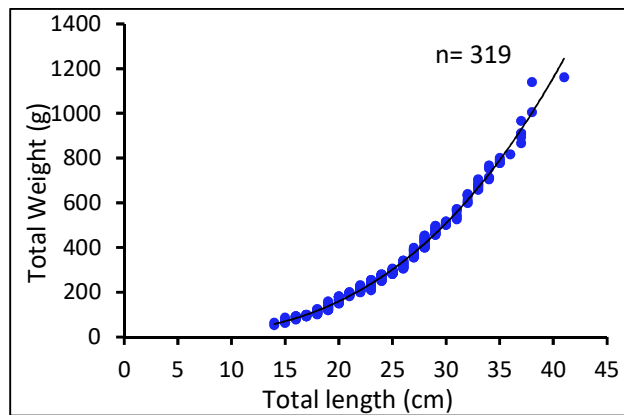


Fig. 3: The length-weight relationship of *A. arabicus*.

3.3. Growth

The ELEFAN I routine used to scan for the best estimates of the asymptotic length (L_∞) and the growth constant (K). The response surface (R_n) analysis in the ELEFAN I was used to scanning the best estimates, and the goodness-of-fit was at $R_n = 0.163$ (Fig. 2). The restructured length frequency of *A.*

arabicus with superimposed growth curves is shown in Figure 3. The best growth constants (L_∞ and K) value were estimated as 44.6 and 0.34, respectively, so the theoretical age at zero (t_0) was -0.481. The growth performance index (ϕ') was estimated to be 2.830.

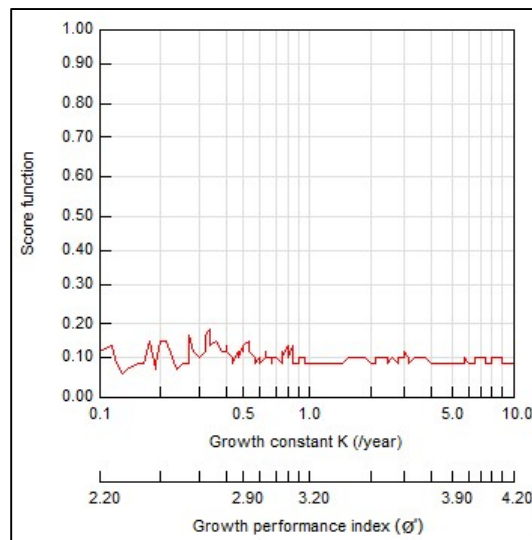


Fig. 4: K-scan routines of *A. arabicus*.

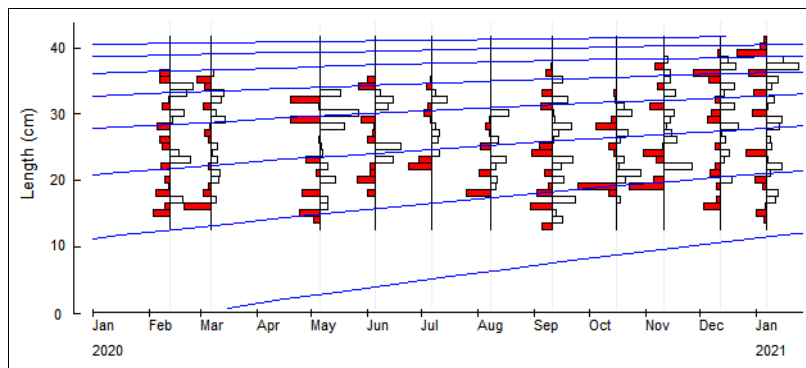


Fig 5: Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *A. arabicus*

3.4 Mortality and exploitation rates

The length-converted catch curve method used to assess the total mortality (Z) of *A. arabicus*, where total mortality was $Z = 1.17$ (Fig. 5). The natural mortality rate (M) and the rate of

fishing mortality (F) assessed as 0.75 and 0.42, respectively. The present exploitation rate (E_{present}) of the species computed as 0.36.

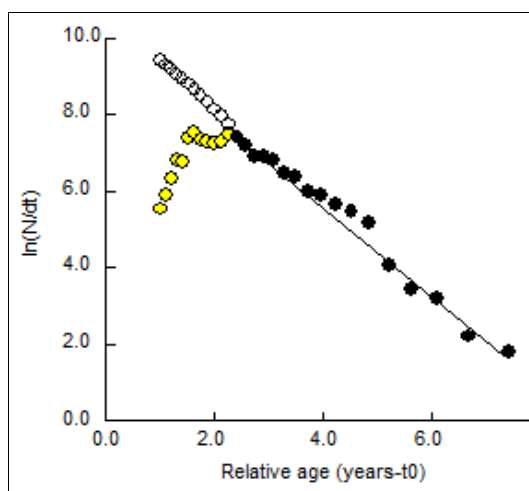


Fig 6: Length converted catch curve for estimation of Z for *A. arabicus*

3.5 Probability of capture

Figure 7 shows the probabilities of the capture of each size class obtained by backward extrapolation of the straight portion of the right descending part of the catch curve in FiSAT software. The length at which 50% of the stock biomass is vulnerable to capture estimated at $L_{50} = 21.9$ cm. Correspondingly, the lengths at which 25% and 75% of the stock is captured were estimated as $L_{25} = 19.18$ cm and $L_{75} = 24.61$ cm.

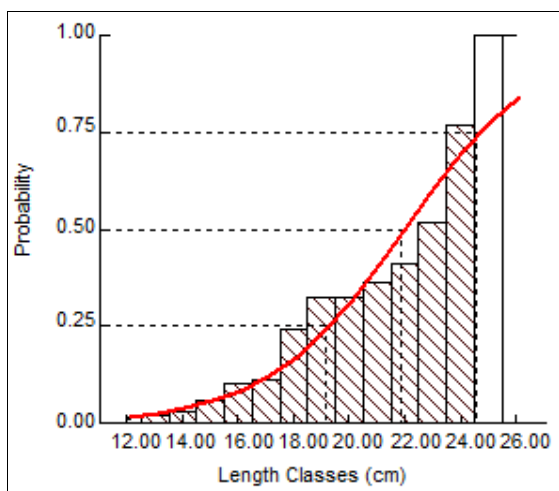


Fig 7: Probability of capture for *A. arabicus*

3.6 Recruitment

The recruitment pattern (Fig. 8) shows that *A. arabicus* was recruited in the fishery throughout the year with two prominent peaks of different magnitudes. The peak of the major one occurred in March (20.64%), while the peak of the minor one happened in August (12.26%).

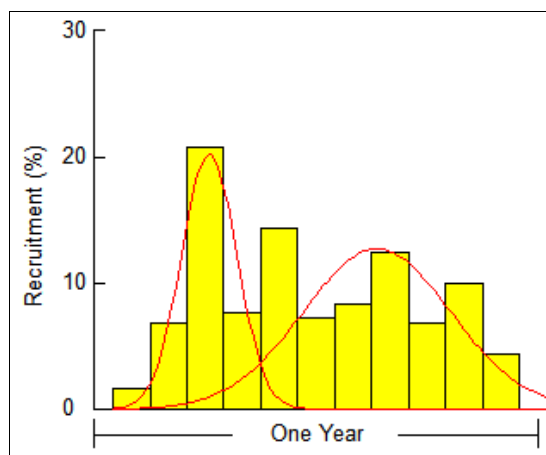


Fig 8: Recruitment pattern of *A. arabicus*

3.7 Yield per recruit (Y'/R) and biomass per recruit (B'/R)

The relative yield-per-recruit (Y'/R) of *A. arabicus* was determined as a function of M/K (2.205) and L_c/L_∞ (0.490)

through the knife-edge selection routine of FiSAT II. The estimated values of the biological target reference points ($E_{0.1}$ and E_{max}) were 0.652 and 0.810, respectively (Fig. 9). The current exploitation rate ($E_{current} = 0.36$) found to be lower than both biological target reference points for the species.

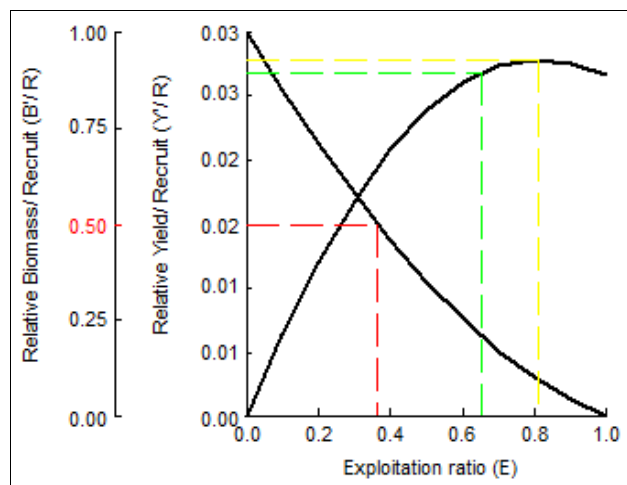


Fig 9: Relative yield per recruit (Y/R) and biomass per recruit (B/R) analyses of *A. arabicus*

3.8 Virtual population analysis

Figure 10 and Table 1 demonstrated the results of the virtual population analysis (VPA) of *A. arabicus* in the present study. The majority of individuals were harvested for the mid-lengths between 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 13 to 19 cm. Surviving individuals in the stock exhibited a declining trend with an increased rate of fishing pressure, the highest number of survivors (16733) was observed at the length of 13 cm, and the lowest (14) was at the length of 41 cm. The highest peak of fishing mortality ($F = 0.85$) occurred at length 36 cm. Steady-state biomass increased with mid-length, from

23 cm to 27 cm (0.2 ton), then fell to 0.02 ton for mid-length 41 cm (Table 1).

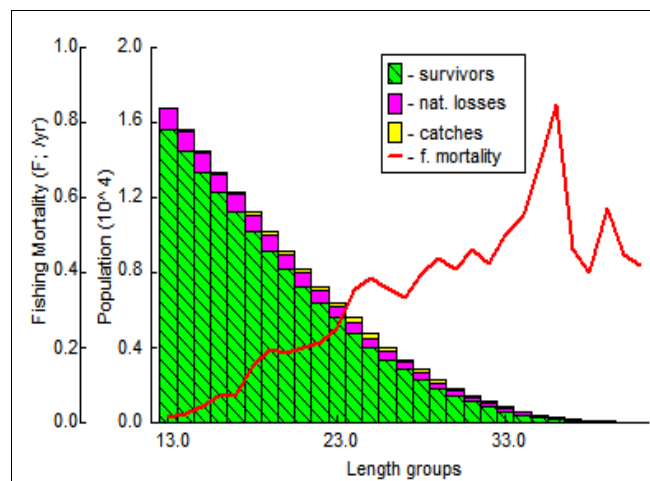


Fig 10: Length-structured virtual population analysis of *A. arabicus*

4. Discussion

Kebtieneh *et al.* [31] 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. The analysis of the length composition in this study revealed that the individuals of *A. arabicus* have an average total length ranging from 13.0 to 41.0 cm. This size of fish found to be similar to those documented for the species by Resen *et al.* [14] from Iraqi waters, Arabian Gulf (13.0-43.0 cm) but was higher than those stated by Riaz *et al.* [32] on the Karachi coast, Pakistan (16.5-35.4 cm). However, Mohamed *et al.* [33] recorded higher lengths for *A. arabicus* from Iraqi waters, Arabian Gulf (14.0-40.0 cm as standard length). These differences may be related to various factors, including water temperature, food availability, population density, fishing pressure and fishing gears [34, 35].

Table 1: FiSAT II output of virtual population analysis of *A. arabicus*

Mid-length (cm)	Catch (In numbers)	Population (N)	Fishing mortality (F)	Steady-state biomass (tons)
13.0	24.00	16733.29	0.0160	0.07
14.0	35.00	15581.77	0.0242	0.08
15.0	57.00	14464.20	0.0412	0.10
16.0	94.00	13370.47	0.0713	0.11
17.0	92.00	12287.48	0.0734	0.13
18.0	179.00	11255.17	0.1511	0.14
19.0	217.00	10187.69	0.1956	0.15
20.0	191.00	9138.75	0.1847	0.17
21.0	190.00	8172.30	0.1978	0.18
22.0	189.00	7261.72	0.2127	0.19
23.0	204.00	6406.44	0.2501	0.20
24.0	260.00	5590.67	0.3520	0.20
25.0	253.00	4776.63	0.3838	0.20
26.0	210.00	4029.19	0.3593	0.20
27.0	173.00	3380.81	0.3347	0.20
28.0	178.00	2820.17	0.3934	0.19
29.0	171.00	2302.84	0.4395	0.18
30.0	135.00	1840.05	0.4082	0.17
31.0	128.00	1457.00	0.4616	0.16
32.0	97.00	1121.02	0.4236	0.14
33.0	93.00	852.27	0.5020	0.13
34.0	80.00	620.33	0.5536	0.11
35.0	74.00	431.94	0.6912	0.09
36.0	62.00	277.65	0.8466	0.06

37.0	23.00	160.72	0.4628	0.05
38.0	14.00	100.45	0.3990	0.04
39.0	13.00	60.14	0.5695	0.02
40.0	6.00	30.02	0.4461	0.02
41.0	5.00	13.93	0.4200	0.02

The growth coefficient of *A. arabicus* in the present study ($b = 2.931$) shows negative allometric growth. The values for 'b' less than 3.0 indicates that the fish become heavier for a particular length as it increases in size [36]. Similar growth coefficient values for the species were reported by Mathews and Samuel [13] in Kuwait waters, Arabian Gulf ($b = 2.780$), Riaz *et al.* [32] in the Karachi coast, Pakistan ($b = 2.733$) and Vahabnezhad *et al.* [15] in Iranian waters, Arabian Gulf ($b = 2.570$). The growth coefficient of fish differs not only in different species but also the same within species depending on sex, maturity stage, feeding intensity, health condition, season, stress and sampling methodology [35, 37].

In the present study, the asymptotic length (L_{∞}) of *A. arabicus* was 44.6 cm, which was higher than those stated by Morgan [11] in Kuwait waters, Arabian Gulf ($L_{\infty} = 43.0$ cm), Mathews and Samuel [13] in Kuwait waters, Arabian Gulf ($L_{\infty} = 44.5$ cm) and Mustafa *et al.* [16] in the Sundarbans Ecosystem, Bangladesh ($L_{\infty} = 33.6$ cm), nevertheless, it was lower than those stated by Resen *et al.* [14] in north-west Arabian Gulf ($L_{\infty} = 48.7$ cm) and Vahabnezhad *et al.* [15] in Iranian waters, Arabian Gulf ($L_{\infty} = 50.4$ cm as fork length). By the way, Mustafa *et al.* [16] stated that the Sundarbans ecosystem is the nursery ground for *A. arabicus* in Bangladesh. The growth performance index (\dot{O}) in this study was estimated to be 2.830, which was within the values observed in other populations of *A. arabicus*, like Vahabnezhad *et al.* [15] in Iranian waters, Arabian Gulf ($\dot{O} = 2.76$) and Mustafa *et al.* [16] in the Sundarbans Ecosystem of Bangladesh ($\dot{O} = 2.982$). The differences observed with values from other researchers may depend on several factors, including the environmental conditions, habitat, availability of food, metabolic activity, reproductive activity, the genetic constitution of the individual, fishing pressure and sampling method [38, 39].

Gulland [26] suggested that when the natural mortality and fishing mortality are equal, the exploitation rate is equal to 0.5, while less than 0.5 refers to under exploitation and greater than 0.5 refers to overexploitation. So, the obtained value of exploitation rate (E) in the present study (0.34) was lower than the optimum level reflecting the low level of fishing pressure on this species. Similar findings for the exploitation rates of *A. arabicus* in other waters, such as 0.45 in Kuwait waters, Arabian Gulf [11], 0.41 in Iraqi waters, Arabian Gulf [14], 0.45 in Iranian waters, Arabian Gulf [15] and 0.38 in the Sundarbans Ecosystem of Bangladesh [16].

The recruitment pattern of *A. arabicus* in the present study was continuous throughout the year, with two recruitment peaks. The major peak occurred in March and the minor one in July. Resen *et al.* [14] also observed two recruitment of the species in the Iraqi waters, Arabian Gulf, the major peak occurring in May and the minor in September. Mustafa *et al.* [16] found one seasonal pulse for *A. arabicus* in the Sundarbans Ecosystem of Bangladesh, extended from May to October, with the peak in July. Fiorentino *et al.* [40] stated that the recruitment pattern has concerned with the spawning time. From the present study, the analysis of relative yield-per-recruit and relative biomass-per-recruit of *A. arabicus* indicated that the present exploitation rate ($E_{\text{present}} = 0.34$) of the species was below the biological target reference points

(the economic yield target, $E_{0.1}$ and the maximum sustainable yield, E_{max}) and exploitation ratio of 0.5 and 0.4, respectively [26, 41], which denotes that the studied stock underexploited [29].

Similar findings have been reported for *A. arabicus* stocks by the other authors. Resen *et al.* [14] found that the value of E_{present} (0.41) was below the value of E_{max} (0.53) for the species in the Iraqi waters, Arabian Gulf. Vahabnezhad *et al.* [15] found that the values of E_{present} , $E_{0.1}$ and E_{max} in Iranian waters, Arabian Gulf were 0.45, 0.46 and 0.58, respectively. Also, the values of E_{present} , $E_{0.1}$ and E_{max} in the Sundarbans Ecosystem of Bangladesh were 0.38, 0.42 and 0.51, respectively [16].

The result of virtual population analysis (VPA) revealed that the main loss in the stock of *A. arabicus* by the fishing process in the present study occurred for the mid-lengths between 18 cm to 31 cm, and the highest peak of fishing mortality ($F = 0.85$) occurred at length 36 cm. However, the current length at first capture (L_{50}) of *A. arabicus* was 21.9 cm, which is not too far from the length at first maturity (L_m) of the species in the Kuwaiti waters (23.7 cm), as documented by Lee and Al-Baz [12]. 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 [42]. Lee and Al-Baz [12] stated that both simultaneous increases in the size at first capture and the fishing effort for *A. arabicus* stock in Kuwait waters would give some benefit for the yield per recruit. Therefore, for management purposes, more yields could be obtained by increasing the fishing activities on this species for a substantial harvest, with some precautionary measures to avoid overexploitation.

5. Conclusion

According to the results of the study, the *A. arabicus* individuals showed a negative allometric growth pattern. The asymptotic length (L_{∞}) was within those reported from other waters. The recruitment pattern occurs throughout the year, with two recruitment peaks. The current exploitation rate is lower than the economic yield target and the maximum sustainable yield, indicating that this stock underexploited. Besides, there is fishing mortality towards mid fish sizes. 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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