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Fisheries studies and stock evaluation of shrimp scad, *Alepes djedaba* (Teleostei: Carangidae) caught from Arabian Gulf

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PEER REVIEW

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Comments
This paper focuses some useful data (findings) including the length composition, growth parameters, mortality rates, Y/R and B/R of *A. djedaba* in the Arabian Gulf off Saudi Arabia using monthly samples. The manuscript presents all these items in scientific way.
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ABSTRACT

Objective: To evaluate the stock of *Alepes djedaba* (*A. djedaba*) by describing the length composition, growth parameters, mortality rates of *A. djedaba* captured in Arabian Gulf off Saudi Arabia and adopting yield per recruit and biomass per recruit models.
Methods: A random sample of 490 fish representing a moderate range of total lengths (16.5–32.4 cm) and weights (60–410 g) were sampled in Arabian Gulf off Dammam, Saudi Arabia during the period from August 2008 to July 2009. LFD5 software was used for estimation of growth parameters. Total mortality was calculated using the length converted catch curve. Natural mortality was estimated using Pauly and David´s formula. Fishing mortality was computed by subtracting natural mortality from total mortality. Per recruit analysis was made using Beverton and Holt model.
Results: Length–frequency analysis revealed four peaks and the length range from 22 cm to 27 cm dominated the catch, constituting about 71% of the catch. Values of the von Bertalanffy growth parameters were computed using LFD5 software as follows: the asymptotic length (L_∞)=41.71 cm, curvature parameter (K)= 0.36 year^{-1}, and hypothetic age at zero length (t_0) = –0.76 year. The total mortality (Z) was estimated as 2.07 year^{-1}, and natural mortality was 0.8 year^{-1}. Fishing mortality F=1.27 year^{-1} , which was higher than $F_{0.1}$ (0.3 year^{-1}), $F_{SB(50)}$ (0.59 year^{-1}) and $F_{SB(40)}$ (0.86 year^{-1}). At the current levels of fishing and natural mortality, the biomass per recruit is 34% of the virgin biomass.
Conclusions: These may indicate an overexploitation state of the fisheries of *A. djedaba* in Arabian Gulf .

KEYWORDS
Length frequency, Growth parameters, Mortality rates, Per recruit analysis, Shrimp scad

1. Introduction

The shrimp scad, *Alepes djedaba* (*A. djedaba*) (also known as the slender yellowtail kingfish), is a species of widespread tropical marine fish of the jack family, Carangidae. The species is commonly found on inshore reefs and sandy substrates. It has the common body profile of a scad, and may be difficult to differentiate from others in the genus *Alepes*. It is one of the larger scads, growing to 40 cm but often is encountered at much smaller sizes[1]. It is a species of moderate commercial interest in most countries where it is often considered too small to be worthwhile and is often caught on hook and line tackles and in seines as bycatch[2]. In Indian fisheries, the shrimp scad was found to be the most common carangid fish in the catch of purse seines, however, it is rarely taken by trawls or gill nets[3]. It is also often taken by subsistence fisheries using various traditional gears such as inter–tidal fixed stake traps[4].

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Around the Asian and Indonesian coasts, larger numbers are taken than anywhere else in its range and it is considered a good eating fish[5]. In Arabian Gulf fishery of Saudi Arabia, shrimp scad is commonly caught by fish traps, gill nets and hand lines.

No much data or studies could be found on such species. Few studies concerned the length distribution[6–9], age and growth[10,11], length weight relationship[5,9,12], mortality[10,13]. Other studies were made on taxonomy and naming[14–16], distribution and habitat[17–20] and biology and fishery[2–6,12]. The first objective of the current work is to give a recent study and basic information on the length frequency and some population parameters, age, growth and total morality rate of *A. djedaba* in Gulf water off Saudi Arabia.

Yield per recruit (Y/R) and biomass per recruit (B/R) models are important in giving advices for management, particularly as they relate to minimum size controls[21]. This is because they depend on the exploitation pattern (fishing mortality) or fishing regime, natural mortality and the mesh size of the fishing gear, which is reflected by the age at first capture. For a given exploitation pattern, rate of growth and natural mortality, an equilibrium value of Y/R can be calculated for each level of fishing mortality. These models are the most convening stock assessment methods in the absence or uncertainty of long term catch data[22–25]. Also in the absence of other biological data pertinent to the application of age based models especially for the bycatch species[26]. Managers require estimates of the catch levels that provide long–term yield as well as those at which the risk of stock depletion is unacceptably high[26]. Among these estimates the biological reference points such as $F_{0.1}$, $F_{SB50\%}$ and $F_{SB40\%}$ would help for the evaluation of the status of fish stocks and management of its fisheries[23,27–29]. Thus, another objective of the present work is to use Y/R and B/R models to determine the biological reference points, $F_{0.1}$, $F_{SB(50)}$ and $F_{SB(40)}$ for evaluation and better management of the fishery of *A. djedaba*, as one of the moderate economically important species in the Saudi Arabia fishery.

2. Materials and methods

2.1. Length frequency analysis

A random sample of shrimp scad, *A. djedaba* ranged in the length from 16.5 cm to 32.4 cm (total length) and in weight from 60 g to 410 g (gutted weight) were monthly collected from Arabian Gulf off Dammam, Saudi Arabia by longlines, from August 2008 to July 2009. Lengths were classified into 0.5 cm interval classes ranging from 16.0–16.5 cm to 32.0–32.5 cm. These data were stored in LFD5 software for further analysis[30].

2.2. Growth

The classified length–frequency were used to estimate the growth parameters, the asymptotic length (L_∞), curvature parameter (K) and hypothetic age at zero length (t_0) using LFD5 software[30] following ELEFAN procedures[31]. Length at ages and correspondent changes in length were estimated using von Bertalanffy Growth equation[32]. These were used to draw the growth and increment curves graph.

2.3. Mortality rates

The value of total mortality (Z) was estimated by applying the length converted catch curve developed by Pauly[33]:

$$L_n \frac{C(t,t+\triangle t)}{\triangle t} = c - Z(t+\triangle t/2)$$

Where, C is the catch and t is the age computed by the inverse von Bertalanffy growth formula: $t=(t_0+1/k)\times L_n(1-L_t/L_\infty)$ [34].

Natural mortality (M) was estimated by using the growth parameters and the mean environmental temperature using Pauly and David's formula[35] for tropical species.

$$Log_{10} M=-0.0066-0.279\ Log_{10} L_\infty+0.6543\ Log_{10} K+0.4634\ Log_{10} T$$

Where, L_∞ and K are growth parameters and T is the mean annual water temperature (T in Arabian Gulf is about 25 °C according to Hazek[36]. The annual instantaneous fishing mortality coefficient (F) was calculated by subtracting the natural mortality coefficient (M) from the total mortality coefficient (Z) derived from age based catch curves (F=Z–M).

2.4. Per recruit models

Y/R and B/R were determined as a function of the exploitation rate. The estimated Y/R is based on the model of Beverton and Holt[37], as modified by Pauly[38].

$$Y/R=F/K\times A\times W_\infty[1/z-3U/(z+1)+3U^2/(z+2)-U^3/(z+3)]$$

Where, $A=(L_\infty-L_c/L_\infty-L_r)M/K$, $U=1-(L_c/L_\infty)W_\infty$(797.5 g)=the asymptotic weight (this was obtained by applying the length weight relationship deduced by Osman and Abdulhadi[12] and using L_∞ value of the present study), L_c=length at first capture, L_r(16.25 cm)=length at first recruitment (the smallest length in all samples), L_∞=asymptotic length, K=von Bertalanffy growth coefficient, z=Z/K, M=natural mortality coefficient, F=Fishing mortality, L_c=length at first capture was calculated using the following equation: $L_c=L-K(L_\infty-L)/Z$[39].

Where L is the average length of the entire catch=23.99 cm.

B/R was estimated from the following equation:

$$B/R=(Y/R)/F=1/K\times A\times W_\infty[1/(z)-3U/(z+1)+3U^2/(z+2)-U^3/(z+3)]$$

The virgin B/R is the B/R when fishing mortality (F) equals zero.

2.5. The biological reference point

The biological reference point, $F_{0.1}$ (the value of F at marginal increase in Y/R is 10% of its value at F=0) was calculated according to Gulland and Boerema[40], as described by Cadima[41].

$$dV/dF=dY/dF-0.1B_0 = 0 \text{ or } dY/dF=0.1B_0$$

Where $V=Y-0.1B_0$, dY is the change in the Y/R, dF is the change in the F and B_0 is the B/R when F=0. Therefore, the value of F at which $dY/dF=0.1B_0$ represents the value of $F_{0.1}$. $F_{0.1}$ can then be calculated by maximizing the function $V=Y-0.1\times B_0\times F$. It is noted that V is at a maximum value when $F=F_{0.1}$.

3. Results

3.1. Length composition

The length frequency distribution of *A. djedaba* is given in Figure 1. Fish length ranged from 16.5–32.5 cm with mean length of 24 cm. Fish between 22 and 27cm constituted about 71% of the catch, followed by the fish less than 22 cm which constituted 18.4%. Fish larger than 27 cm constituted only less than 10.6% of the total catch.

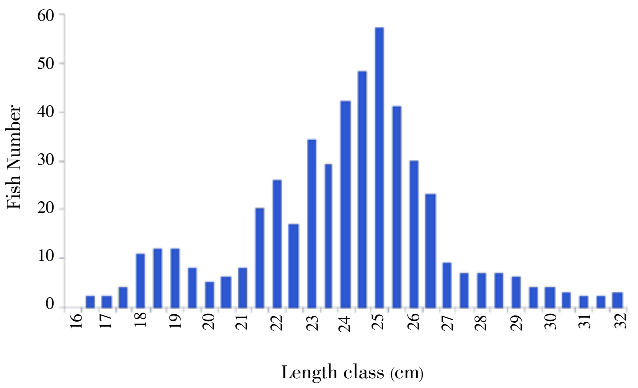

Figure 1. Length frequency distribution of *A. djedaba* captured from Arabian Gulf off Saudi Arabia.

3.2. Growth

The estimated values of growth parameters were $L_\infty=40.71$ cm, $K=0.36$ year^{-1} and $t_0=-0.76$ year.

The estimated lengths at ages and their correspondent increments are calculated and represented in Figure 2. In this figure, it appears that the maximum growth rate was achieved when the fish reach one year in the age followed by continuous decrease while the fish getting older.

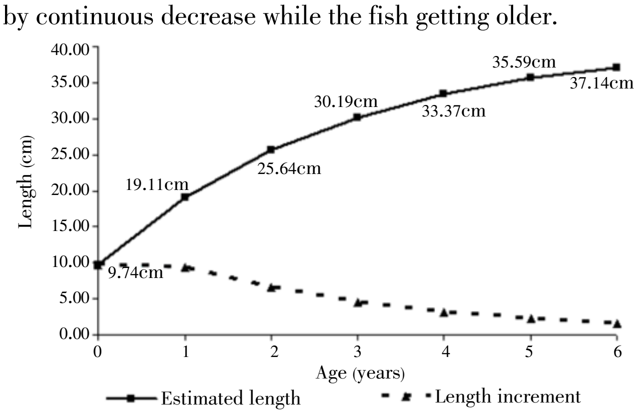

Figure 2. The estimated length (cm) and increment at age (year) of *A. djedaba* captured from Arabian Gulf off Saudi Arabia.

3.3. Mortality rates

Figure 3 represents the length converted catch curve from which total mortality (Z) was estimated as 2.07 year^{-1}. Natural mortality (M) was estimated independently as M=0.8 year^{-1} and fishing mortality F=1.27 year^{-1}.

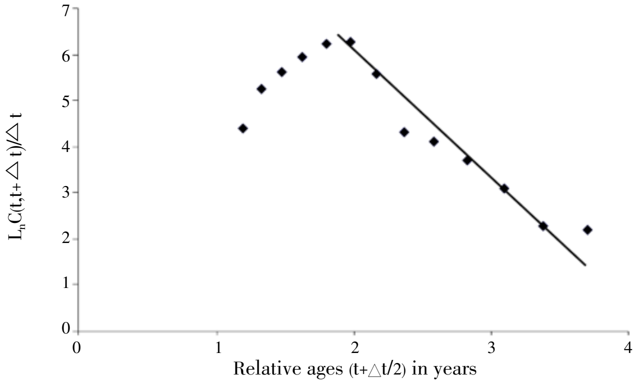

Figure 3. Linearized catch curve for estimation of total mortality rate of *A. djedaba* captured from Arabian Gulf off Saudi Arabia.

3.4. The change in Y/R and B/R

Figure 4 shows that Y/R increase with increasing the fishing mortality. After the current level (1.27 year^{-1}) of fishing mortality, the Y/R increases slower than before.

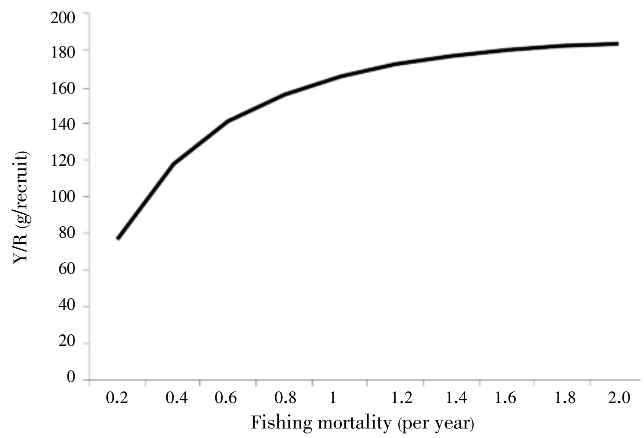

Figure 4. Y/R of *A. djedaba* as a function of fishing mortality.

Figure 5 shows that B/R decreases with the increase in fishing mortality. At the current levels of fishing mortality, B/R is equal to about 34% of the unexploited level.

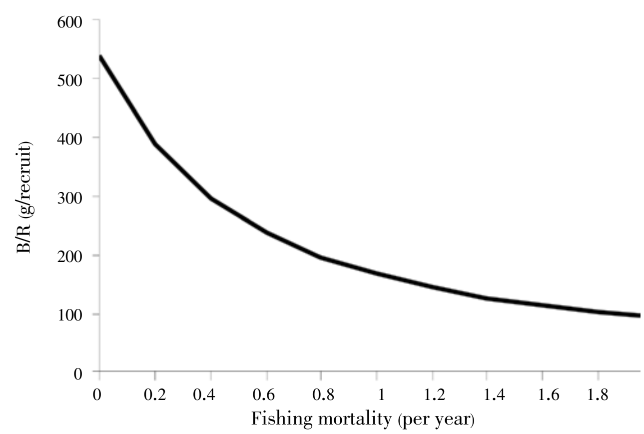

Figure 5. B/R of *A. djedaba* as a function of fishing mortality.

3.5. Biological reference points

Figure 6 shows that the current level of fishing mortality is higher than $F_{0.1}$ (0.8 year^{-1}), $F_{SB(50)}$ (0.59 year^{-1}), $F_{SB(40)}$ (0.86 year^{-1}).

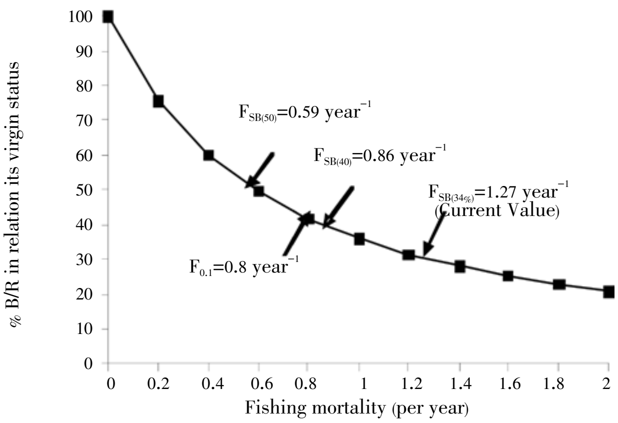

Figure 6. Percent B/R in relation to its virgin status as a function of fishing mortalities referring to current status and different biological reference points.

4. Discussion

Among carangid fish, *A. djedaba* is one of the large scads growing to 40 cm but often is encountered in much smaller size[1]. Length frequency analysis of *A. djedaba* from Arabian Gulf off Saudi Arabia revealed a total length range between 16.25 to 32.4 cm with a mean of 24 . Fish with length between 22 and 27 cm dominated the catch and represented 71% of the total catch. The fish less than 22 cm in total length represented 18.4% of the total catch and the fish of larger than 27 cm constituted of only 10.6% of the catch. All previous studies on the size distribution of the *A. djedaba* revealed small length compositions of the catch from different areas. For example, Edward *et al.* found that the catch composition of *A. djedaba* was between 18.5 and 35.5 cm fork length in the trawl from Gulf of Aden[42]. Sivakami has reported the total length of *A. djedaba* to be 31.5 cm from the catches of Cochin fisheries harbor in India[6]. Raje reported a maximum total length to be 33.4 cm for males and 33.6 cm for females in the catches landed at Veraval, Gujrat, India[7]. Shuaib and Ayub stated that the maximum total length of this species in the landing of Karachi fish harbor was 38.5 cm[8]. They added that the most of males and females were in size range between 21 and 30 cm. In other findings, it appeared in much smaller sizes. Virginia *et al.* (unpublished data) stated that the catch of *A. djedaba* from Sorsogon Bay Philippine contained fish size between 3 and 15 cm. Chu *et al.* found it between 2.5 and 14.5 cm in the catch of bottom trawl off the southwestern coast of Taiwan[9].

The study of age and growth is very important to all the fish species, because it is considered as the basic study of all other investigations in the fish world. It helps to make a clear picture about the cohort dynamics of the species, and shows how the fish grows and reaches the maximum length and age. Growth parameters are important input data in other analysis such as Y/R and virtual population analysis[34].

The present study revealed that growth parameters (L_∞, K and t_0) of *A. djedaba* were 40.71 cm total length, 0.36 year^{-1} and −0.76 years respectively. Some few previous studies investigated these parameters too. Reuben *et al.* found that L_∞ and K of *A. djedaba* in the Indean sea off Kerala Coast were 32.6 cm total length and 0.61 year^{-1} respectively[10]. Different findings were recorded by Corpuz *et al.* in Philippine waters who mentioned that L_∞ was 17 cm fork length and K was 1.2 year^{-1}[11]. According to Froese and Pauly, the estimate of L_∞ was very different (+/− one third) from the maximum length is doubtful[1]. Our result could be accepted, since the maximum length recoded in the present study was 32.5 cm. The differences in size distribution and the estimated values of growth parameters between different studies may be attributed to several factors, such as temperature, mortality, or food availability.

In the present study, the total mortality rate (Z) for *A. djedaba* from Arabian Gulf was 2.07 year^{-1}. This rate is lower than those found for the same species in other locations. Reuben *et al.* found that the total mortality for *A. djedaba* was 5.15 year^{-1}[10]. Virginia *et al.* in unpublished data recorded 4.96 year^{-1} for the same species in Sorsogon bay, Philippine. Moreover, the mean total mortality of *A. djedaba* from south and southeast Asia was 7.2 year^{-1}[13].

Natural mortality is considered to be one of the biological parameters most difficult to determine. Pauly reviewed natural mortality rates for 174 fish stocks[35], and stated that the modal mortality was between 0.2–0.3 year^{-1}[43]. The same species may have different natural mortality rates in different areas depending on the density of predators and competitors, whose abundance is influenced by fishing activities[34]. In the present study and according to the empirical formula of Pauly[35], the natural mortality of *A. djedaba* from Arabian Gulf is 0.8 year^{-1}. This is lower than the value (0.99 year^{-1}) estimated by Reuben *et al.* in the Indean sea and obviously lower than its estimate (1.77 year^{-1}) in Sorsogon bay[10], Philippine and the mean natural mortality (1.77 year^{-1}) for the same species in south and south east Asia[13]. Comparing our findings with that mentioned above by Vetter[43], it seems to be a high rate of natural mortality.

The present study showed that *A. djedaba* from Arabian Gulf off Saudi Arabia had a lower fishing mortality (1.27 year^{-1}) than in other areas. Reuben *et al.* recorded a fishing mortality equal 4.16 year^{-1} for the same species caught from Indian Sea off Kerala[10]. Virginia *et al.* (unpublished data) also recorded a higher fishing mortality (3.19 year^{-1}) for *A. djedaba* in Sorsogon bay, Philippine. Samuel *et al.* mentiond that the mean value of fishing mortality of *A. djedaba* in south and southeast Asia was 5.43 year^{-1}[13].

In the present work, the Y/R of *A. djedaba* in Arabian Gulf, Saudi Arabia increased with increasing the value of fishing mortality. This was obvious and rapid at lower levels of fishing mortality below 1.27 year^{-1}. After this point, the rate of increase went slower. The present study showed that the B/R was found to decrease with the increase of fishing mortality. At the current level of fishing mortality (1.27 year^{-1}), the stock of *A. djedaba* laid at 34% of the unexploited stock.

There are various levels of biological reference points that could be deduced from the Y/R and B/R analysis, such as $F_{0.1}$, $F_{SB(50)}$ and $F_{SB(40)}$. The use of these reference points is an objective of the fisheries managers to evaluate and manage fish stocks in its various locations and systems[23,25–27,29,44,45]. The present study also concerned with the determination of biological reference points to evaluate the stock of *A. djedaba*. It was found that at the current levels of natural mortality

(0.8 $year^{-1}$) and length at first capture (21.1 cm), $F_{0.1}$, $F_{SB(50)}$ and $F_{SB(40)}$ were 10.8, 0.59 and 0.86 $year^{-1}$ respectively. All of these reference points are lower than the current level of fishing mortality (1.27 $year^{-1}$). To increase the the Y/R and B/R, it would be appropriate to investigate these reference points and use the most suitable one of them as a limit to conserve the stock and maintain its sustainability. Different reference points are adopted by different authors according to the conditions of the stock and the availability of application of the reference point that give better management to the fisheries and the stock as well. Clark mentioned that $F_{SB(35)}$, the fishing mortality that reduces the stock to 35% of the unexploited stock would provide high yield at low risk, regardless, the spawner-recruit relationship[27]. Clark himself in another study based on stochastic trials supported this result and recommended the strategy of $F_{SB(40)}$[28]. This reference point strategy was also adopted and recommended by Mace[29]. The marginal yield strategy, $F_{0.1}$ was mentioned to be in average the most stable reference point and could be used with the least risk of stock depletion[23,28,29]. The present work revealed that adopting $F_{SB(40)}$ (0.86 per year) as a target reference point decreased the yield per recruit by about 16% of its current value and increased the B/R by about 18% of its current level. Increasing the fishing mortality up to the $F_{SB(50)}$ level (0.59 per year) would decrease the Y/R by about 43% of its current level and increase the B/R by about 48% of its current level. Adopting $F_{0.1}$ (0.8 per year) strategy would decrease Y/R by about 4% of its current status and increase in B/R (about 42% of its current level). From the above discussion, it appears that fishing mortality should be decreased for better status of B/R. However, further studies on catch and effort should be done to decide what reference point could or should be exactly adopted to keep the yield per recruit at good level and for better conservation of the stock.

For better status of *A. djedaba* stock in Arabian Gulf, Saudi Arabia, fishing mortality should be decreased to increase the biomass per recruit. Thus we recommend further studies on catch and effort for complete management strategies for the stock of such species.

Conflict of interest statement

We declare that we have no conflict of interest.

Comments

Background

The shrimp scad, *A. djedaba* (also known as the slender yellowtail kingfish), is a species of widespread tropical marine fish of the jack family, Carangidae. In Arabian Gulf Fishery of Saudi Arabia, shrimp scad is commonly caught by fish traps, gill nets and hand lines.

Research frontiers

This paper presents the basic information on the length frequency and some population parameters, age, growth and total morality rate of *A. djedaba* in Gulf water off Saudi Arabia. This study will indicate either under-exploitation or an overexploitation state of the fisheries of *A. djedaba* in Arabian Gulf.

Related reports

No much data or studies could be found on such species. Few studies concerned the length distribution, age and growth, length weight relationship and mortality.

Innovations and breakthroughs

The first objective of the current work is to give a recent study and basic information on the length frequency and some population parameters, age, growth and total morality rate of *A. djedaba* in Gulf water off Saudi Arabia using monthly length frequency distributions.

Applications

The findings will be used for sustainable management of *A. djedaba* in the Arabian Gulf off Saudi Arabia and also nearby areas.

Peer review

This paper focuses some useful data (findings) including the length composition, growth parameters, mortality rates, Y/R and B/R of *A. djedaba* in the Arabian Gulf off Saudi Arabia using monthly samples. The manuscript presents all these items in scientific way.

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