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Research Article

Reproduction and spawning patterns of *Atule mate (*Cuvier, 1833) in the Persian Gulf & Oman Sea, Hormozgan coastal waters

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Abstract

Reproduction and spawning patterns of the Yellowtail scad (*Atule mate*) were studied in the Persian Gulf and Oman Sea (Hormozgan coastal waters) from December 2016 to November 2017. A total of 447 fish were collected from Bandar Lengeh, Qeshm Island, Bandar Abbas, and Bandar Jask landing sites. Minimum and maximum fork lengths of this species were 10 and 33 cm, with average 20.63±1.73 cm. The total weight ranged from 12.9 to 363.2 g, with average 113.08±31.69g. The relationship between length and weight was obtained as $W=0.017L^{2.89}$ ($R^2=0.92$) which showed that the fish has an isometric growth. Monthly analysis of the reproductive stages and gonadosomatic index showed that reproductive cycle beginning in January and continued with a sharp decreasing trend from March. The mean length at first maturity ($L_{m50\%}$) for female was 19.8 cm. The sex ratio (F:M) was 1.5:1.

Keywords: *Atule mate*, Spawning, Gonadosomatic Index, Sex ratio, Persian Gulf, Oman Sea, $L_{m50\%}$

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Introduction

The Carangidae family is open-water pelagic fishes economically important and represent a large family of fishes with 32 genera and 140 species worldwide (Al-Marzouqi *et al*., 2013). Carangid fishes including trevallies, jacks, scads, or amberjacks are widely distributed in tropical and subtropical seas of the Indo-Pacific region. Carangid fishes support more than 50 species in Indian waters (Kasim, 2003), and 11 species in Omani waters (Fouda *et al*., 1997). The Yellowtail scad, *Atule mate* (Cuvier, 1833), is a small pelagic carangid that occurs in coastal waters throughout the tropical Indo-Pacific- from East Africa to Hawaii. Although it contributes heavily to commercial fishing yields, it forms important fractions of the mixed catch of certain fisheries (Kuthalingam 1959; Oakley and Bakhsh, 1989) and is sought by recreational and subsistence fishermen.

A few studies have been carried out about different aspects of *A. mate*. Clarke (1996) studied the reproductive biology of this species and the spawning season was found from spring to fall in Kane' ohe Bay, Hawaii. Mohd Azim *et al*. (2017) found normal growth pattern of Yellowtail scad in Marudu Bay, Sabah in Malaysia. Distributions of eggs and larvae have been reported in Hawaii (Miller and Sumida, 1974; Clarke, 1996).

This species is caught by trawl and gillnet in the Hormozgan waters, and the amount of Carangidae family catch increased from 5,527 tons in 1998 to 20425 tons in 2019 in the Persian Gulf and Oman Sea, a sharp increase in amount of catch during past two decades. (Taghavimotlagh, 2019; Iran Fisheries Organization, 2020).

Due to the commercial value of *Atule mate*, it is necessary to study the characteristics of reproduction, so, the aim of this study was to determine the period and peak of spawning, the first length of maturation ($L_{m50\%}$) and GSI of *A. mate* in Hormozgan coastal waters, Persian Gulf & Oman Sea.

Materials and methods

The study area and sampling

During study period from December 2016 to November 2017, altogether 447 specimens were caught randomly from Bandar Lengeh, Qeshm Island, Bandar Abbas and Bandar Jask landing sites situated between 52°30' E and 58° 30' E longitude (Fig. 1), samples were caught by gillnet, bottom trawl and wire net (trap) on a monthly basis . Fishes were sexed and weighed to the nearest 1 g and the fork length (FL) was measured to the nearest 1 mm in the laboratory (Biswas, 1993).

Data Analysis

To establish the length-weight relationship, the commonly used relationship $W = a L^b$ was applied (Pauly, 1983), Where W is the weight in gram, L is the fork length in cm, a is the intercept (condition factor) and b is the slope for log-transformed data. The Parameters a and b were estimated using power regression and the coefficient of determination (R^2) to show the length-weight relationship. The parameter b is a

shape parameter for the body form of the fish species. In theory, one might expect that the exponent b would have a value of roughly b=3 because the volume of a 3- dimensional objects is roughly proportional to the cube of length for a regularly shaped solid.

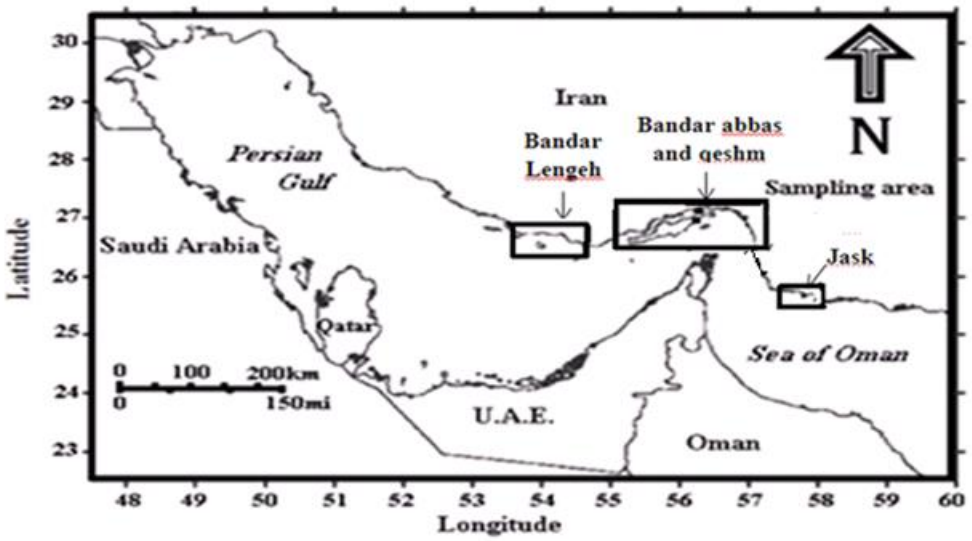

Figure 1: Map of the study area in the Persian Gulf and Oman Sea (waters of Hormozgan Province) in 2016-17.

Computing b value estimated was tested by using the t- test (Pauly, 1983),

$$t=\frac{s,d\ (L)}{s,d\ (w)}\times\frac{|b-3|}{\sqrt{1-r2}}\times\sqrt{n-2}$$

Where s.d. (L) is the standard deviation of the ln L values, and s.d. (W) the standard deviation of the ln W values, n is the number of samples. The value b is different from 3 if it is greater than the table value for t in n - 2 df. (Pauly, 1983).

The sex ratio analysis was carried out by monthly data sets of the total number of male and female. Chi-square (X^2) statistical was performed to test the difference between ratios in both sexes (Biswas, 1993).

Spawning season of this species was forecasted from the percentage of ovary stages and monthly GSI index trend. The Gonadosomatic Index (GSI) was calculated by using following formula (King, 2007),

GSI= 100 * (GM/TM)

Where GM is Gonad weight in g and TM is the total mass of the fish in g.

The $L_{m50\%}$ was estimated by using the following formula and the least square method (solver tools in Microsoft excel ver.2016) (King, 2007).

P = 1/ [1+exp (- r (L- Lm))]

Where r is the slope of curve, Lm is the mean fork length (cm) at sexual maturity (the length at which 50% of the individuals are ripped.), L is mean fork length (cm) in each length classes and P is probability of presence mature individuals.

Results

Length weight relationship

The fork length ranged from 10 to 33 cm, with average 20.63±1.73 cm. The total weight ranged from 12.9 to 363.2 g, with

average 113.08±31.69g. The relationship between fork length (cm) and weight (g) was estimated for 447 specimens (both sexes) as W=0.017 L $^{2.89}$(R^2=0.92) (Fig. 2), the result of t –test indicated isometric growth pattern for this species (p> 0,05),

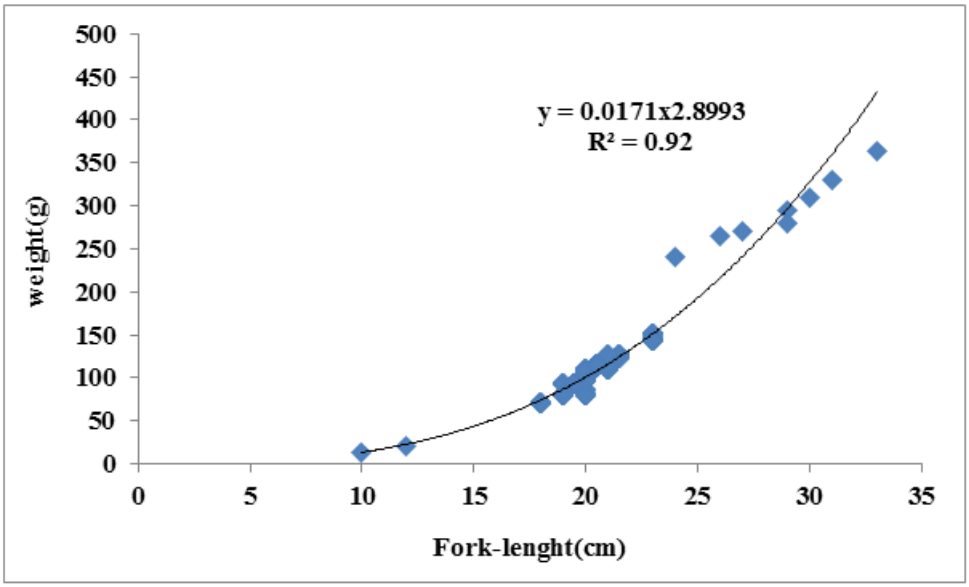

Figure 2: Length-weight relationship of *A. mate* in the Persian Gulf and Oman Sea (waters of Hormozgan Province) in 2016-17.

Sex ratio

The results showed that the sex ratio of females to males is 1.5 to 1. The total number of samples was 447, of which 237 were females, 158 were males, and 52 were immature. The overall sex ratio between female and male individuals of *A. mate* throughout the year was significantly different from 1:1 (p<0.05) . Monthly sex ratio revealed that there was a female dominant in sex ratio in most months of the year (Fig. 3).

Gonad Development and Size at Sexual Maturity ($Lm_{50\%}$)

All five stages of the ovarian development of *A. mate* were observed throughout the year. The abundance of mature fish had relatively high percentage and young fish (stages 1 and 2) showed the same trend, indicating that , this species have continuous spawning throughout the year. Monthly GSI estimations for both sexes had fluctuation in different months; the uptrend was observed after January with maximum values in March for male and female 0.85 and 2.64, respectively. (Figs. 4 and 5).

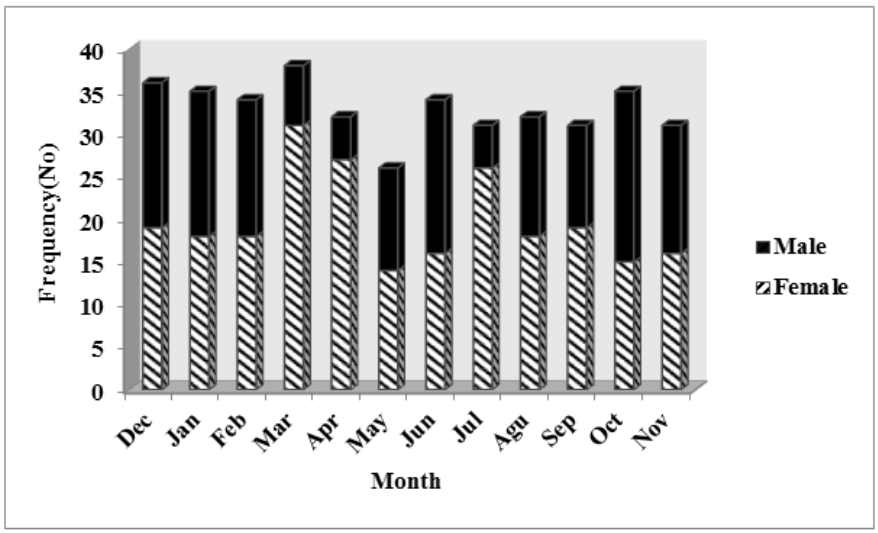

Figure 3: Sex ratio between male and female of *A. mate* in the Persian Gulf and Oman Sea (waters of Hormozgan Province) in 2016-17.

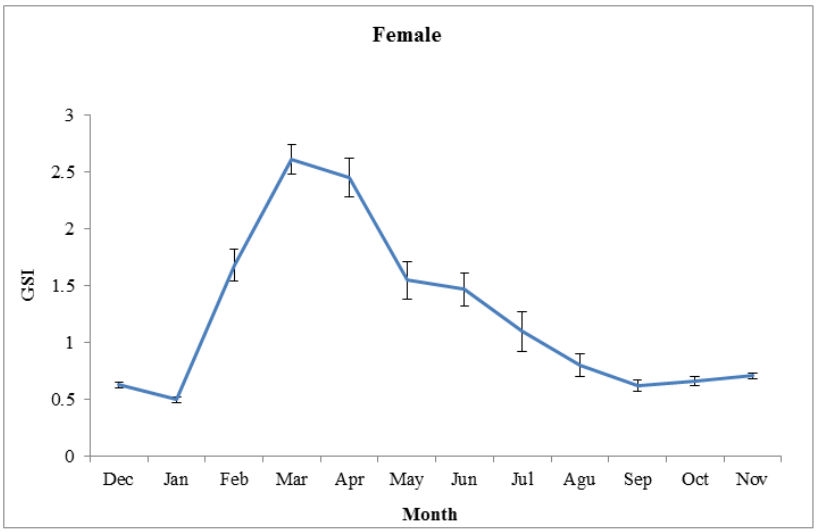

Figure 4: Monthly GSI index fluctuation of *A. mate* in the Persian Gulf and the Oman Sea (waters of Hormozgan Province) in 2016-17.

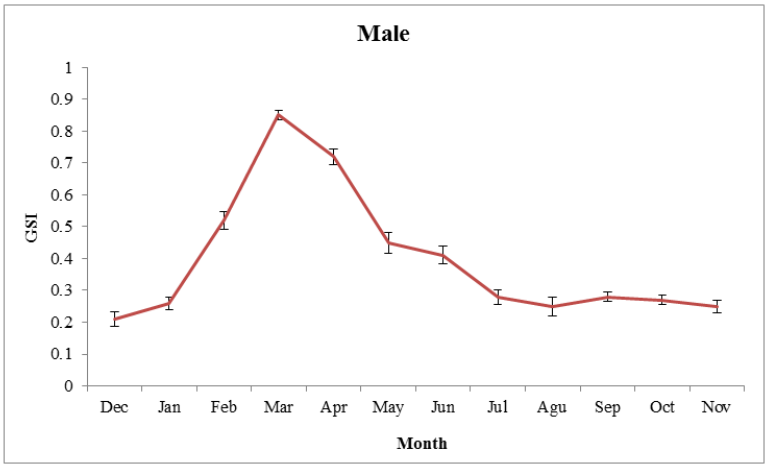

Figure 5: Monthly GSI index fluctuation of *A. mate* in the Persian Gulf and Oman Sea (waters of Hormozgan Province) in 2016-17.

Calculating monthly percentage of the ovary development of *A. mate* reveals that mature females were actively in the breeding condition throughout the year. In addition, according to the results of the study, maximum spawning activity took place after March in the Hormozgan waters.

Figure 6 shows a logistic curve fitted the estimation of length at which 50% of females are in stage 3 and upward (adult ones) with the estimated $L_{m50\%}$ equals 19.80 cm of fork length.

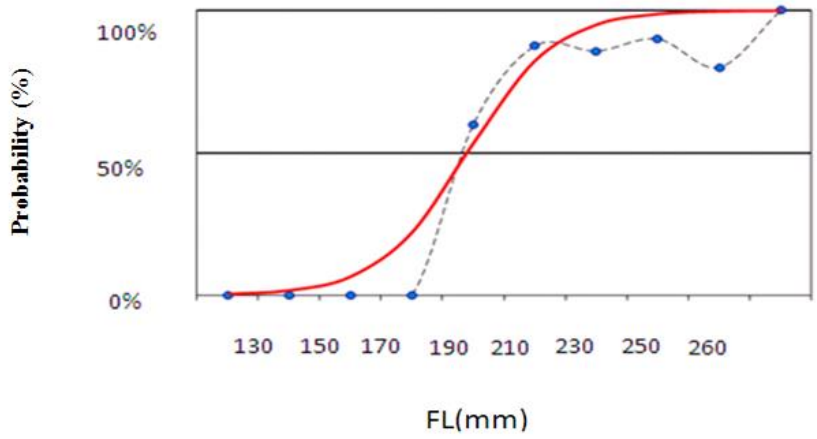

Figure 6: logistic curve for estimation $L_{m50\%}$ of female *A .mate* in the Persian Gulf and Oman Sea (waters of Hormozgan Province) in 2016-17.

Discussion

In this study, the fork length of *A. mate* ranged from 10 to 33 cm, with average 20.63±1.73 cm. Clarke (1996) reported the maximum Standard length for *A. mate* 254 mm in Kane'ohe Bay, Hawai'i. According to present study, the dominant length class of *A.mate* in all landing sites was 19-21cm. The range of standard length reported between 163 to 254 mm and mean length 211.9 mm in Kane'ohe Bay, Hawaii. In the present study, the total weight ranged from 12.9 to 363.2 g, with average 113.08±31.69 g while in the Kane'ohe Bay, Hawai'i.ranged from 68.1 to 306.6 g and average was 175.1g. (Clarke, 1996).

The "b" parameter value in the length – weight relationship was closed to 3 for the *A. mate* in study area (Area 51), indicating isometric growth (Sasidhara *et al*., 2018), the same result was obtained in the present study which indicated no significant difference with 3 by Pauly equation (p>0.05).

The length-weight relationship is considered as one of the most essential tools in the study of management of aquatic stock , and required in population dynamics and fisheries stock assessment (Gulland and Rosenberg, 1992). Several factors affect the accuracy of the length-weight relationships, e.g., condition of fishes caught in different seasons, sex, length

ranges, sample size and fishing methods (Haimovici and Canziani, 2000).

The difference of b in different places in the same species can have different reasons, the most important of which can be seasonal fluctuations in environmental parameters, physiological conditions of fish at the time of collection, sex, development, and growth of gonads and nutritional conditions in the fish environment (Biswas, 1993).

Sex ratio in the present study indicated the predominance of females over males of *A.mate* in the waters of Hormozgan province, the results showed that the sex ratio of females to males is 1.5 to 1. The sex ratio of *A. mate* in the Indian water Tamil Nadu, the male to female ratio ranged between 1:0.6 and 1:1.5 across the years (Surya *et al*., 2017) , but (Sasidhara *et al.,* 2018) indicated the sex ratio of *A. mate* 1: 0.63 (M: F) . Fluctuations in sex ratio throughout the year may indicate that male and female communities live separately in certain periods. If this assumption is correct, the factors affecting the separation or convergence of male and female populations should be investigated. Another factor that causes the difference between the number of males and females in different months of the year could be female presence in the spawning area for a longer period than males (Nikolsky, 1963). The cause of different numbers of males and females can be due to the migration of one sex from the area, different behavior between sexes and the desire of fishermen for larger fish due to more marketability, different growth, and mortality rates of males and females (Sandovy *et al*., 1994).

The seasonality in spawning in our study was determined based on the monthly changes in the percentage frequency of maturity stages and the mean monthly values of gonadosomatic index (GSI). The period in which there was a decline in the gonadosomatic index and when fish in spawning condition were observed in our samples suggested a spawning period from March to May, although small short spawning took place during other months of the year.

Surya *et al*. (2017) revealed the peak spawning for this species in Pamban coast, Tamil Nadu during September and the season starts from July. They found a good relation between GSI and Gastro-somatic Index (GaSI) of *A. mate* in September when the GSI was maximum, whereas the GaSI was minimum indicating correlation in feeding and spawning.

The results also revealed a single though earlier spawning season in September and July for Yellowtail scad in the Indian waters Tamil Nadu. The spring to fall spawning season observed for this species in Kane'ohe Bay agrees generally with earlier estimates by Watarai (1973); Watson and Leis (1974), which is in conformity with the results of present study. Reproductive data of this species is very similar to those reported for a slightly larger pelagic carangid, *Selar crumenophthalmus* (Clarke and Privitera ,1995) , many carangid species from

Indian waters show prolonged spawning seasons (Manojkumar, 2007).

In this study, the length of maturity ($Lm_{50\%}$) of *A. mate* was estimated to be 19.8 cm; while Surya *et al*. (2017) estimated the size at first sexual maturity, 22.9 cm FL in the Indian water Tamil Nadu. The mature fishes were found mostly in the length class 23.1-25.0 cm, but few female specimens with mature ovaries were also observed in the length classes 17.0-19.0 cm and 19.1-23.0 cm (Sasidhara *et al*., 2018).

In addition to the applications of assessing fishery stocks, maturity is one of the most important characteristics in reproduction and breeding. The use of $L_{m50\%}$ plays an important role in the analysis of fish reproductive status, which can be used in the fisheries management (Dadzie *et al*., 1998). The reproductive parameters (length-weight, length at 50% maturity) and reproductive patterns (spawning period, GSI) described in this study are commonly used as an input parameters to stock assessment analyses (e.g. per-recruit analyses) and fisheries management (e.g. setting gear restriction or minimum size and fishing season). Due to prolonged spawning period of the tropical species, the ban of gillnet fishery to prevent catch of *A. mate* and other species in the spawning peak time would be necessary and appropriate.

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