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Some reproductive aspects of the areolate grouper, *Epinephelus areolotus* from the Gulf of Suez

Alaa G.M. Osman [a,*], Azza El-Ganainy [b], Ezzat Abd-Allah [a]

[a] Department of Zoology, Faculty of Science, Al-Azhar University, 71524 Assiut, Egypt
[b] Fisheries Division, National Institute of Oceanography and Fisheries, Egypt

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ABSTRACT

Groupers are primary targets of artisanal, recreational and commercial fisheries in the Red Sea and Gulf of Suez. The reproductive biology of the areolate grouper *Epinephelus areolatus*, collected from the main landing site in the Gulf of Suez, was investigated, and females accounted for 87.2% of the total fish sampled for a 1:6.8 male to female sex ratio. The monthly analysis of gonado-somatic index values and the monthly distribution of maturity stages showed that the spawning season of *E. areolatus* was restricted to the period from June to August for both sexes. The length at which 50% of the fish were mature was 24.3 cm for males and 25.5 cm for females, and by referring this value to the corresponding age, it was determined that *E. areolatus* first attains sexual maturity at 2.04 years for males and 2.23 years for females. The species was characterized by high fecundity, with a mean of 169,952 to 1,433,022 ova per female, and the relative fecundity ranged from 7,081 to 32,569 ova for individuals with a total length between 24.0 and 44.0 cm. The results of this investigation can be utilized to develop suitable management practices for groupers and for planning appropriate control measures.

Introduction

Groupers are slow-growing and long-lived fish that are sedentary in character, top predators and strongly territorial (Heemstra and Randall, 1993; Craig et al., 2011). Groupers assemble in huge numbers to spawn, thus contributing to their over-exploitation, so they have become endangered by modern fishing operations. Groupers are a vital part of the coral-reef community structure (Aburto-Oropeza et al., 2008), so a declining grouper population can seriously affect local ecosystems.

The areolate grouper *Epinephelus areolatus* is a coral reef fish that is widespread in the Indo-Pacific region but has been recorded nearly worldwide, including in the Red Sea, Persian Gulf, South Africa, Japan, the Arafura Sea (Russell and Houston, 1989), and Australia, and it has recently been recorded in Tonga (Randall et al., 2003). A recent study (El Ganainy, 2017) revealed that *E. areolatus* form spawning aggregations in at least three sites in the southern part of the Gulf of Suez during the main spawning season from June to August. The spawning aggregations of this species showed distinct seasonality and site fidelity, and this behavior increases the susceptibility of *E. areolatus* to intensive fishing pressure during the spawning season. Consequently, the catches of this species during the three spawning months accounted for approximately 50% of the total annual catches in the Gulf of Suez (El Ganainy, 2017), which have declined by more than 60% over the past twenty years (GAFRD, 2015), indicating stock depletion.

Although *E. areolatus* is locally abundant and commercially important in the Red Sea, little information is available about its reproductive biology in the area, so Hassan (1988) and Mahmoud (2009) recorded some reproductive aspects of *E. areolatus* in the region. Ahmad et al. (2011) studied the fecundity (F), sex ratio and gonado-somatic index (GSI) of individuals sampled from the Arabian Gulf, and Sujatha et al. (2015) researched some aspects of the reproductive biology and life history of the species off the central eastern coast of India. Abdul Kadir et al. (2016) investigated the reproductive biology of the species from Malaysia waters.

This work aimed to investigate some reproductive biology aspects (sex ratio, maturity, GSI), the length and age at first sexual maturity (L_m and t_M, respectively) and fecundity (F) of *E. areolatus* in the Gulf of Suez.

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* Corresponding author.
E-mail address: agosman@azhar.edu.eg (A.G.M. Osman).

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Materials and methods

Random samples of *E. areolatus* (Fig. 1) were collected monthly from the main landing site in the Gulf of Suez (Fig. 2) from November 2013 to October 2014. The total length (TL) of each sampled areolate grouper was measured to the nearest cm, and the total weight (TW) was determined to the nearest 0.1 g. Gonads were weighed to the nearest 0.01 g and then preserved in 5% formalin for the subsequent maturation study. A total of 594 specimens with a TL range of 11.2–50.5 cm were examined for reproductive biology studies. Maturity stages were assigned based on morphological examination, and the sex ratio was determined monthly as the percentage of males to females (M:F), which was based on TL. A chi-square test at a 0.05 significance level was computed according to Snedecor (1956).

The seasonal variations in different maturity stages were determined for each individual. Six maturity stages were classified according to the scale of Gunderson (1993), with some modifications, as follows.

Thread: Sex cannot be determined at this maturity stage, and the gonads in individuals appear as filaments occupying a small portion of the body cavity

Stage I (Immature or inactive): The gonads have a translucent appearance, and testes are smaller and thinner than ovaries.

Stage II (Spent): The gonads are translucent and enlarged. The testes do not contain sperm, while the ovaries possess a few small eggs.

Stage III (Active or developing): Gonads are larger, and testes are opaque without sperm. Ovaries are translucent with small eggs.

Stage IV (Active-ripe or developed): Testes are white, and some sperm is expelled from the core when cut. Ovaries are not translucent but opaque and solid with fully formed eggs.

Stage V (Spawning or ripe-running): Gonads are enlarged, and occupy most of the body cavity. Milt and eggs are expelled from the genital openings on the application of slight pressure to the two sides of the genital tract.

Stage VI (Spent): Ovaries are flaccid with few degenerating eggs in the ovary, while the testes are almost empty.

The GSI was calculated for each fish according to Sokal and Rohlf (1969) using the following formula: GSI = (gonad weight/fish gutted weight) × 100.

After fitting the percentage of mature individuals against their mid-lengths (King, 1995), L_m was estimated as the point on the X-axis corresponding to the 50% point on the Y-axis.

Fecundity was estimated according to Sujatha et al. (2015), and the relationships between F and the three variables, TL, TW and age (A), were calculated.

Fig. 1. The areolate grouper *Epinephelus areolatus.*

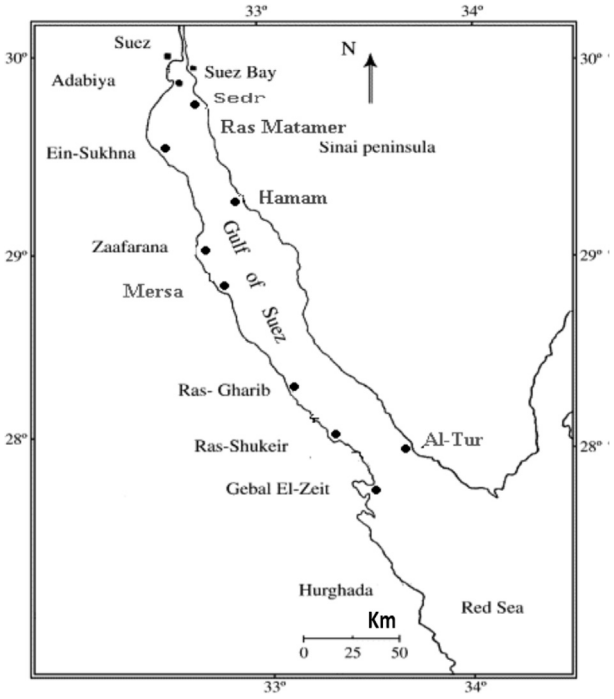

Fig. 2. Map of the study area (The Gulf of Suez).

Results

Sex ratio

During the investigation, females accounted for 87.2% of the total sampled fish for a M:F sex ratio of 1:6.8 (Fig. 3). The chi-square value was (328.90; $p < 0.05$), indicating a highly significant difference between both sexes. The highest number of males were in TL groups >35 cm (Fig. 4).

Monthly distribution of maturity stages

The sample included 1.7% immature females, 62.8% mature inactive females, 35.5% mature active females and 34.2% mature males. The *E. areolatus* spawning period began in June because ripe gonads could be observed in the samples, and the proportions were 66% and 16% of the males and females, respectively (Figs. 5 and 6). This stage extended until September, revealing a prolonged spawning season with a peak in July for males (80%) and in August for females (51%). Inactive females were collected during the spawning months throughout the sampling range, and on average, they were smaller (mean ± SE: 23.6 ± 1.2 cm TL) and younger than active females (38.5 ± 2.6 mm TL) (*t*-test: $t_{0.05}$, $p < 0.0001$).

Gonado-somatic index

The overall GSI values for female *E. areolatus* were higher than those for males. However, values were higher for both sexes during the breeding season, indicating that the spawning season was restricted to the period from June to August with intensive spawning in July (Fig. 7).

Length and age at first sexual maturity (L_M and t_M, respectively)

The analysis of the percentage of mature and immature fish in each TL class (Fig. 8) showed that males smaller than 20.0 cm were always immature, while those greater than 28.0 cm were mature. For females, individuals with a TL smaller than 18.0 cm were

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