Sex ratio, maturity stage and fist maturity of yellowfin parrotfish Scares flavipectoralis Schultz, 1958 in Wallace line at Spermonde Archipelago, South Sulawesi

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Sex ratio, maturity stage and fist maturity of yellowfin parrotfish *Scares flavipectoralis* Schultz, 1958 in Wallace line at Spermonde Archipelago, South Sulawesi

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Abstract. Yellowfin parrotfish *Scarus flavipectoralis* has a wide distribution in Indo-Pacific waters which has an important ecological role in maintaining the balance of coral reef ecosystems, as well as having important economic values that need to be managed sustainably. This study aims to analyze the sex ratio, gonad maturity stage, and the size at first maturity. This study was conducted on a population of yellowfin parrotfish in the Wallace line at Spermonde Archipelago, South Sulawesi. Fish samples were obtained from catches of fishermen who were landed at the Rajawali Fish Landing Area of Makassar City. The results of this study indicate that the sex ratio of yellowfin parrotfish not balanced between male and female, there was more female than male; the development of gonad maturity stage is synchronous between male and female; and the size at the first maturity sexual of yellowfin parrotfish female was 18 cm and the male was 21.7 cm.

1. Introduction

Parrotfish is a family of Scaridae that live in shallow waters in tropical and subtropical regions, especially in coral reef ecosystems. Parrotfish have a wide distribution in Indo-Pacific waters, can live from shallow waters to a depth of 25 m [1]; as a herbivorous fish, parrotfish have a very important role in maintaining the balance of the coral reef ecosystem [2]. Due to this, it can play an important role in maintaining the balance of the structure of marine plant communities, reduction of parrotfish populations in coral reef ecosystems can cause a shift in the community from coral to macroalgae because macroalgae can inhibit the recruitment and growth of coral organisms [3]. Besides having an important ecological role, parrotfish has important economic value so it needs to be managed based on sustainable principles [4]. As a target fish, many species of parrotfish are caught by fishermen in the waters of the Spermonde Islands, South Sulawesi [5]. Spermonde Islands are islands consisting of 120 islands [6], which has an area of around 2,500 km^2. Spermonde Islands is located in the Makassar Strait which is one of the important fishing are as traversed by the Wallace Line. As the transitional region between Asian and Australian species, Spermonde island is an area that has very diverse reef fish species [7-9].

Parrotfish are reef fish that are sensitive to variations in environmental factors because they are biologically classified as fish with a "r" reproductive pattern whose reproductive organ development is simpler than fish species with a "K" strategy reproductive pattern [10].

The results of previous studies indicate an imbalance in the nature of the study of reef fish, which is very qualitative. Previous studies of parrotfish in Indonesia and other Indo-Pacific regions have only been related to ecological aspects [11, 12]. There are studies of the biological aspects of parrotfish [13]. The results of previous studies have not concerned the quantitative aspects of the reproductive biology of parrotfish. In this study, quantitative aspects of reproductive biology were examined quantitatively on yellowfin parrotfish *S. flavipectoralis*. This study aims to analyze aspects of reproductive biology, which include sex ratio, maturity stages, and first maturity of yellowfin parrotfish *S. flavipectoralis* caught in the waters of the Spermonde Islands.

2. Materials and Methods

The research was conducted in October to December 2019, using a sample of yellowfin parrotfish (Figure 1a-b) from the waters of the Spermonde Islands, South Sulawesi Province, which was landed at PPI Rajawali in Makassar City. Based on interviews with fishermen, it was known that this yellowfin parrotfish was the catch on the Island of Langkai, Lanyukang, Kodingareng Lompo, Kodingareng Keke, Panambung, Lumu-lumu, Bonebatang, Barranglompo and Barrangcaddi (Figure 1c).

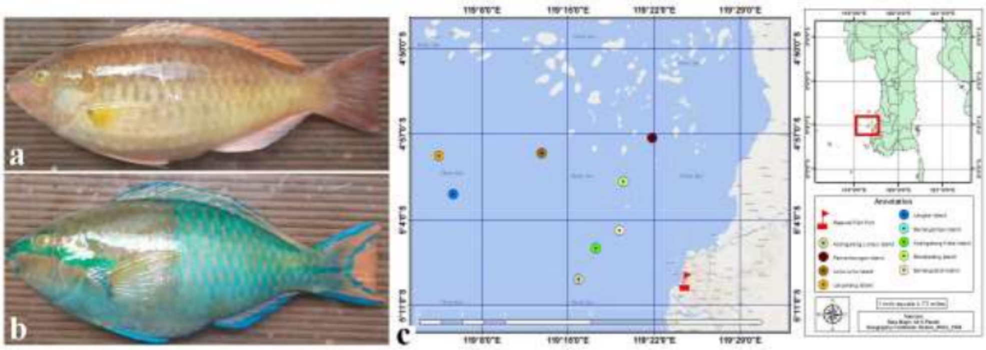

Figure 1. Yellowfin parrotfish *Scarus flavipectoralis* female (a), male (b), and the participative map of yellowfin parrotfish fishing area (c).

Reproductive parameters observed were maturity stages (MS), and first maturity (FM). The aspects observed were sex, maturity stages, gonad length and weight. The aspects measured for the first maturity analysis were total length and gutted weight. Weight is measured using an electrical balance with an accuracy of 0.01 g.

Sex ratio (SR) was calculated using the equation: $SR = \frac{\Sigma J}{\Sigma B}$, where: SR was sex ratio, $\sum J$ was the number of males, $\sum B$ was the number of females. The significance of the difference in sex ratio between male and female fish based on the sampling period, maturity stages, and length classes, a Chi-square test was done [14]. Maturity stages were divides to five maturity stages referring to *S. niger* [15], namely immature, early maturation, advanced maturation, end late maturation, mature, and post-spawning. Maturity stages distribution was analyzed based on the sampling period and length class distribution.

First maturity (FM) was estimated based on the size (length) where 50% (L_{FM}) of sexually mature based on MS III, IV and IV [15]according to the equation: FM = L_{FM}. The FM curve on the L_{FM} was calculated using Polynomial Trendline.

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3. Results

3.1. Sex-ratio

During sampling, there were 248 fish consisting of 64 male fish and 184 female fish. The percentage of female fish appeared to be more than male fish (Figure 2 a), and based on the chi-square test results showed that sex ratio based on the sampling period was significantly different ($X_h^2<X_t^2$). Sex ratio based on maturity stages shows that the number of females was greater than the number of males (Figure 2b), and based on the chi-square test results show the sex ratio based on maturity stages was significantly different ($X_h^2<X_t^2$). Sex ratios based on long classes also show that females were smaller in size (Figure 2c), and based on the chi-square test results show that sex ratio based on long classes was significantly different ($X_h^2<X_t^2$). Female was dominant in the small size group, whereas male was dominant in the large size group. This shows that yellowfin parrotfish was most likely a protogynous hermaphrodite with a length of transitional sex were between 18.6 and 24.7 cm.

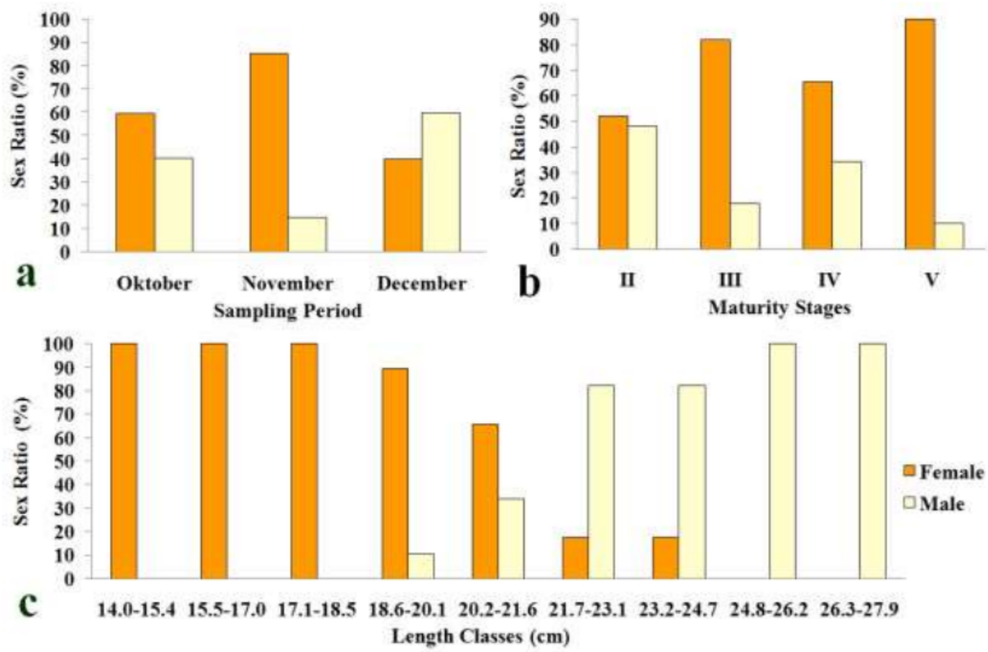

Figure 2. Sex ratio of yellowfin parrotfish *Scarus flavipectoralis* based on sampling period (a), maturity stages (b), and length classes (c).

3.2. Maturity Stages

3.2.1. Macroscopic Characteristics of Gonad

Macroscopically, male and female gonads can be distinguished by their colour and size (Figure 3 and Table 1). In male gonads, the colour varies from clear to milky white, whereas in female gonads, the colour varies from white to brownish red.

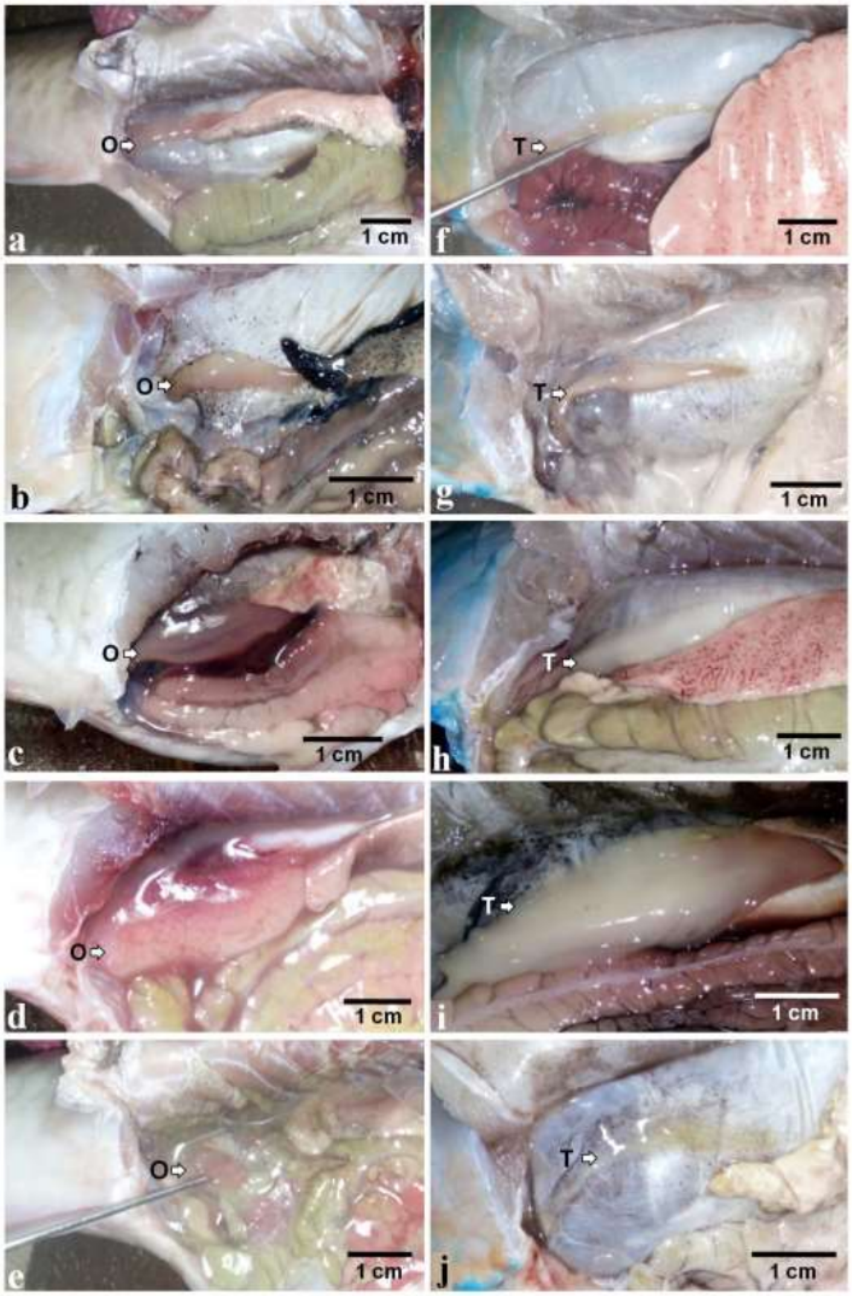

Figure 3. Macroscopic characteristics of the yellowfin parrotfish *Scarus flavipectoralis* at female stage II (a), stage III early (b), stage III late (c), stage IV (d), stage V (e) and male stage II (f), stage III early (g), stage III late (h), stage IV (i), and stage V (j). O: ovary, T: testes.

Table 1. Macroscopic characteristics of yellowfin parrotfish *Scarus flavipectoralis* gonads in female and male fish

MS	Female	Male
I	Gonadal colour was clear, cannot be distinguished, male or female. Gonadal weight was less than 0.02 g.	Gonadal colour was clear, cannot be distinguished, male or female. Gonadal weight was less than 0.02 g.
II	Ovaries colour was brownish white. Ovaries weight varied from 0.02 to 0.06 g with an average weight of 0,03±0,02 g.	Testicles colour was white. Testicles weight was varied from 0.02 to 0.09 g with an average weight of 0.05±0.02 g.
III	Ovaries colour was brownish white. Ovaries' weight varied from 0.06 to 0.60 g with an average weight of 0.18±0,09 g.	Testicles colour was milky white. Testicles' weight varied from 0.06 to 0.23 g with an average weight of 0.13±0.05 g.
IV	Ovaries colour was brownish-red. Ovaries' weight varied from 0.33 to 1.37 g with an average weight of 0.76±0,29 g.	Testicles colour was milky white. Testicles' weight was varied from 0.24 to 0.59 g with an average weight of 0.38±0,11 g.
V	Ovaries colour was brownish white. Ovaries' weight varied from 0.05 to 0.26 g with an average weight of 0.16±0,07 g.	Testicles colour was milky white. Weight was 0.06 g.

3.2.2. Maturity Stages Distribution

Monthly sampling results show that the presence of each MS was relatively synchronous between males and females, with varying percentages of males and females (Figure 4a). During the sampling period, MS II and III appeared to be more frequently found. Length classes based indicated that the presence of each MS was synchronous between males and females, with varying percentages of males and females, where MS II and III appear to be more frequently found (Figure 4b). The small size class was generally found in female fish, while the large size was only found in male fish. Almost all long classes were dominated by MS II and III.

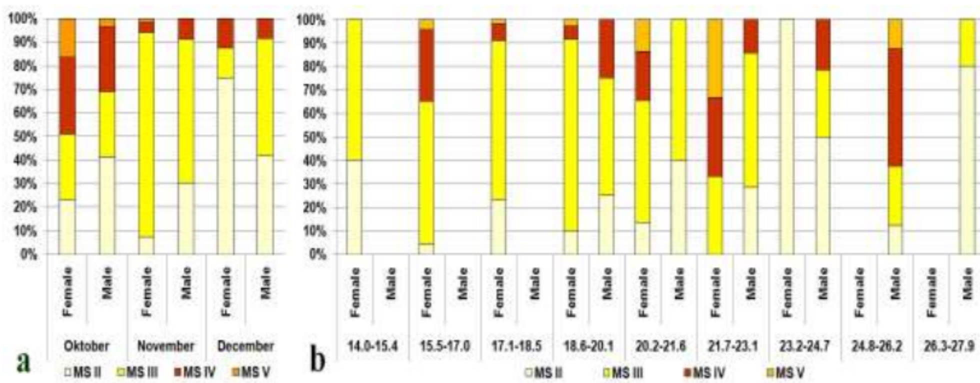

Figure 4. Maturity stages of yellowfin parrotfish *Scarus flavipectoralis* at the male and female based on sampling period (a) and length class in cm (b).

3.3. First Maturity Sexual

The size at the female first maturity obtained based on the equation $L_{FM} = -0.001x^6 + 0.160x^5 - 7.979x^4 + 208.2x^3 - 3002.x^2 + 22676x – 70146$ ($R^2 = 0.998$) was 18.0 cm (Figure 4a). Whereas male first maturity obtained based on the equation $L_{FM} = 0.002x^5 - 0.305x^4 + 12.79x^3 - 260.4x^2 + 2583.x – 10010$ ($R^2 = 0.998$) was 21.7 cm (Figure 4b).

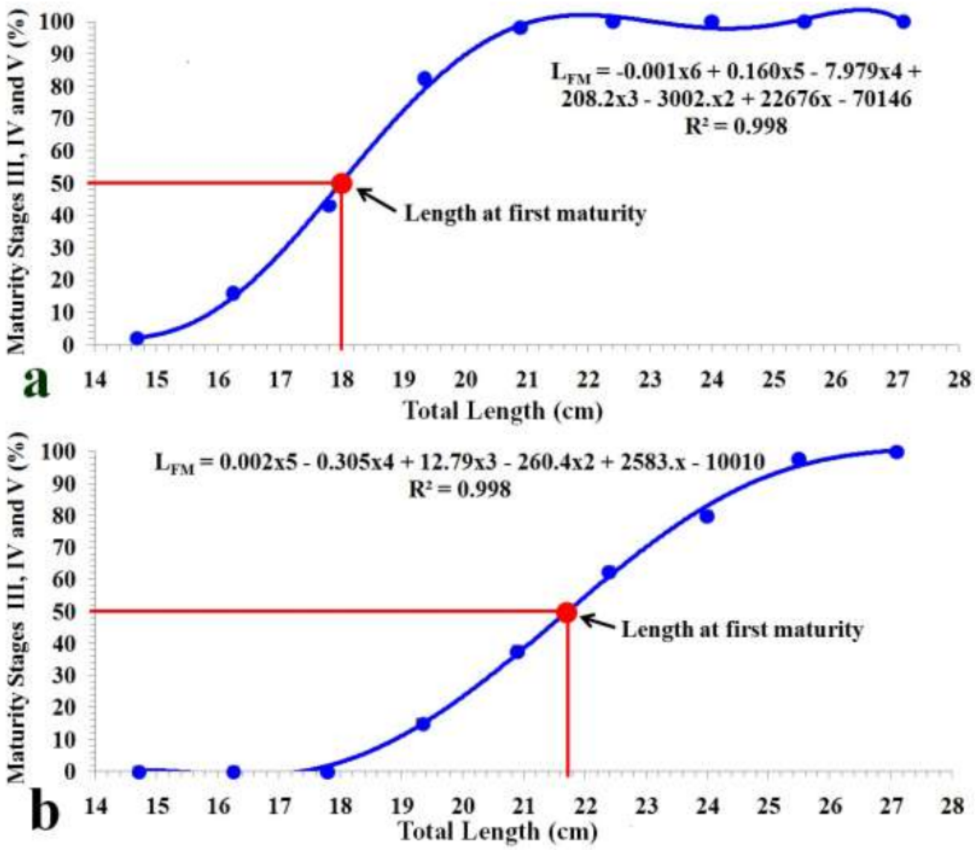

Figure 5. The length at the first maturity of yellowfin parrotfish *Scarus flavipectoralis* based on the length classes of female (a) and male (b).

4. Discussion

4.1. Sex-ratio

Sex ratio is influenced by many factors, such as fish migration patterns, growth rates, mortality rates, and FM differences [16]. Sex distribution based on sampling period, MS and long classes show that females are more abundant than male fish. This is different from usual where fish generally have a balanced sex ratio [17].

Fish that have an unbalanced sex ratio usually have a reproductive tactic in which fish are grouped before spawning; although group behavior when spawning has never been reported in yellowfin parrotfish, but group behavior when spawning has been reported in other parrotfish such as *Sparisoma rubripinne* [18-23], and in groupers like *Epinephelus guttatus* [24-26], *Epinephelus striatus* [27-29], *Epinephelus tauvina* [29], and *Mycteroperca bonaci* [30]. This grouping behavior usually begins with migration [31, 32]. This group behavior is strongly suspected to be related to an unbalanced sex ratio to overcome reproductive failure, especially spawning [24].

The results of previous studies have not been reported regarding the sex ratio in yellowfin parrotfish, but for other parrotfish species, namely *S. rivulatus*, the sex ratio of males and females is also unbalanced [33]. This shows the tendency for more female fish to parrotfish. This tendency is thought to have something to do with the model of protogynous reproduction in parrotfish. When young, female sex fish, with more numbers than male fish, older age.

Sex ratios based on long classes that show a very clear separation between females that dominate the small size classes and males that dominate the large size classes were very clear indications that yellowfin parrotfish were protogynous fish. Protogyny was a common reproductive pattern in Scaridae [15, 34]. At protogyny fish, the female was generally become male after passing through a reproductive period [35]

4.2. Maturity Stages

Gonadal structure that resembles an empty bag on MS V shows that *S. flavipectoralis* was classified as a fish with a total spawning pattern. Total spawner is a spawning pattern where all the oocytes were released at one time of the spawning season [36, 37]. Total spawning patterns have been reported before on other parrotfish such as *Scarus niger* [15], and in other reef fishes such as *Cheilinus fasciatus* [38]

Classification based on length classes indicated that the presence of each maturity stage was synchronous between males and females, with a very varied percentage, where MS II and III appear to be more frequently found. A large percentage of MS II in a sampling period indicates that spawning has occurred previously [33]. Although the classification of gonad maturity stages can be among researchers [39, 40], generally, the gonad maturity stages of aquatic organisms are divided into five, as used in this study.

The development of synchronous maturity stages between males and females based on sampling time and class length is a good thing because it can guarantee reproductive success, especially when spawning. The presence of MS IV simultaneously in males and females guarantees the success of the fertilization process during spawning. This synchrony is very important because even though the sex ratio is unbalanced because the sperm produced by a male can fertilize the eggs of several females. This synchrony explains the success of reproduction, even though the sex ratio is not balanced. Synchronous maturity stages like this have been reported in other parrotfish [15] and other reef fish [38].

Generally, organisms have synchronous maturity stages cycles in males and females. Maturity stages synchrony in yellowfin parrotfish has never been reported before, but other parrotfish in the Spermonde Islands have been reported for *Scarus niger* [15], and other reef fish such as *Cheilinus fasciatus* [38]. Synchronous stages were also reported before in other marine organisms in the tropics, such as *Holothuria scabra* [41, 42], and in four-season regions, such as *Holothuria forskali* [37].

4.3. First Maturity

The size of the first maturity at the female was smaller than male; this due to the protogyny reproductive pattern that has been stated in the sex ratio. This assumption was supported by the sex ratio and maturity stages distribution where small fish are all female and large fish are all male. Parrotfish (Scaridae) is a protogynous hermaphrodite, which at the beginning of its life cycle, is a female [43], then changes its sex into male [34, 35].

The previous studies have never reported size at the first maturity in yellowfin parrotfish; however, it reported for other parrotfish, namely *S. rivulatus* where the first maturity of females was smaller than male, namely female fish 16.5 -17.3 cm and male fish 17.7 cm-18.4 cm [33]. The size at the first maturity of *S. rivulatus* was smaller than the size at the first maturity of yellowfin parrotfish.

The size at the first maturity is closely related to the exploitation or capture effort [44]. Catching effort can cause a reduction of the population, which leads to a decrease in genetic diversity, which can have an impact on population structure, for example, growth. It reported that the first maturity has a relation with fish growth [45]. The size at first maturity can also be influenced by external factors, such as environmental conditions, food availability, temperature, and salinity [46].

5. Conclusion

The sex ratio of yellowfin parrotfish *S. flavipectoralis* is not proportional between males and female, but the development of maturity stages was synchronous between males and females. This synchrony helps to overcome the disproportionate sex ratio. Yellowfin parrotfish was a protogynous hermaphrodite. Size at the first maturity of female yellowfin parrotfish was 18.0 cm, and the male was 21.7 cm.

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