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Reproductive strategy of rivulated parrotfish *Scarus rivulatus* Valenciennes, 1840

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Abstract. The rivulated parrotfish *Scarus rivulatus* is a reef fish that use not to be a target fish, but is now becoming a fisheries target. This change in status is causing the rivulated parrotfish population to be depressed due to fishing effort and interspecific and intraspecific competition in their habitat. This research aimed to examine the parrotfish's reproductive strategies and tactics. The parameters observed were sex ratio, gonad maturity and first maturity at the female and male. Sex and gonad maturity was determined based on the macroscopic characteristics of the gonads. First maturity was estimated based on the total length. This study indicates that the sex-ratio of rivulated parrotfish was unbalanced, males was fewer than females (1: 2.49). The maturity stages of male and female were quite synchronous. Early maturation and maturity stages that were dominant during the study indicate that rivulated parrotfish can spawn at any time throughout the year. The size at first maturity of rivulated parrotfish was achieved very quickly with sizes 16.9 for female cm and 24.3 cm for male. Females that mature more quickly are an indication that the rivulated parrotfish is protogynous. An imbalance in sex ratios, spawning at any time throughout the year, early maturity, and protogynous could be a strong indication that rivulated parrotfish was an r- strategy.

1. Introduction

Parrotfish are Scaridae that live in coral reef ecosystems in tropical and subtropical waters [1]. Parrotfish are widespread in the Indo-Pacific waters to a depth of up to 25 meters [2]. Parrotfish are herbivorous [3], but in some cases, it can change their feeding habits from herbivores (eating algae) to omnivores (eating small fish and crustaceans) [4]. With its teeth in the shape of a parrot beak, Parrotfish feeds on algae that grow on dead coral, so ecologically, gracing parrotfish against algae populations that grow on coral reef ecosystems serves as a biological control against the algae community, thus, direct competition between algae and corals can controlled, so that the ecological balance of the coral reef ecosystem can be maintained [5]. Grazing parrotfish against algae populations can also prevent shifting of community structures and help to maintain high diversity in coral reef ecosystems [6, 7].

Parrotfish also have an important economic role because they are target fish that are traded live, fresh and dry [8]. Parrotfish are very popular with people in Asian countries, such as Hong Kong, Taiwan and Singapore. Parrotfish is popular because it has a smooth and soft texture of meat fibers. This causes the market demand for parrotfish to continue to increase [9]. As a target fish, parrotfish are mostly caught by fishermen in the Spermonde Islands [10, 11]. The Spermonde Islands is a coral reef area included in the Fisheries Management Area (FMA) 713 [12]. FMA 713 was the second largest fish producer in Indonesia (12.43%) of the total Indonesia fish production (6.03 million tons), where reef fish resources ranked fourth after small pelagic fish, large pelagic fish, and demersal fish [13]. The coral reefs in the Spermonde Islands are an area of the Wallacea line which is inhabited by various types of reef fish [11, 14, 15]. The area of the Spermonde Islands reaches about 2,500 km2. The Spermonde Archipelago consists of 120 islands with a total human population of about 50,000 people.

The morphological features of the rivulated parrotfish are the orange cheek area and gill cover (operculum), with wavy lines on the muzzle and cheeks. Pectoral fins are pale green (male); Gray or brownish gray color (female) with two fine stripes on the abdomen (abdomen). Dorsal fin with nine hard spines and ten soft spines, anal fin with three hard spines and nine soft spines. Rivulated parrotfish are distinguished by their characteristics, namely there are five to seven (generally six) scales before the dorsal fin. There are three rows of scales in the cheek area, in the first row (about five to seven), the second row (about five to seven), the third row (about one to four). The pectoral fin radius has 13-15 (usually 14) conical teeth on the side of the tooth plate, is absent in females and usually two above and zero to one on the bottom of the plate teeth in males. The lips almost cover the teeth plate, the caudal fin is truncate in females and emarginate in males [16, 17].

On the population growth curve, r is the sloping line representing exponential growth, and K is the flat line representing the carrying capacity. These two lines are used by ecologists to describe reproductive strategies for various organisms. Organisms that have an r-strategy usually live in an unstable and unpredictable environment. In these conditions, it is necessary to have the ability to reproduce fast (exponentially). In the r-strategy, organisms have high fertility (glossary) and relatively little investment in their offspring, they are usually weak and subject to predation and changes in their environment. The r-strategy animal floods the habitat with offspring so that, regardless of predation or death, at least some of the offspring will survive to reproduce. R-strategy animals have a short life span, are generally small in size, mature quickly and waste a lot of energy. The marine organism known to have r-strategy are coral Acropora [18]. K-strategist is owned by organisms that live in a more stable environment. They are larger and have a longer life expectancy. They are stronger or more protected and generally more energy efficient. They produce, over their lifetime, fewer offspring, but place a greater investment in each offspring. The reproductive strategy is to grow slowly, live close to the carrying capacity of its habitat and produce several offspring, each of which has a high chance of survival. The marine organism that are known to have the K-strategy are massive corals [18]. The reproduction pattern is very important to understand, especially in wild populations that are exploited. Based on tracing of previous research, it shows that there has never been a study of the reproductive strategy of parrotfish. Therefore, it is necessary to study the reproductive strategy to improve the sustainable fishery of parrotfish population. This study aims to analyze the reproductive strategy of rivulated parrotfish. These parameter observed were sex ratio, maturity stage, and the size at the first maturity.

2. Materials and Methods

The study was conducted for one year from July 2019 to June 2020 by collecting samples of parrotfish landed at TPI Rajawali, Makassar City. Based on the results of participatory mapping, it is known that the parrotfish landed at TPI Rajawali are caught by fishermen in the waters around the Island of Langkai, Lanyukang, Kodingareng Lompo, Kodingareng Keke, Panambung, Lumu-lumu, Bonebatang, Barranglompo and Barrangcaddi (Figure 1a). Males (Figure 1b) and females (Figure 1c) can be distinguished based on their morphological characteristics, especially body color.

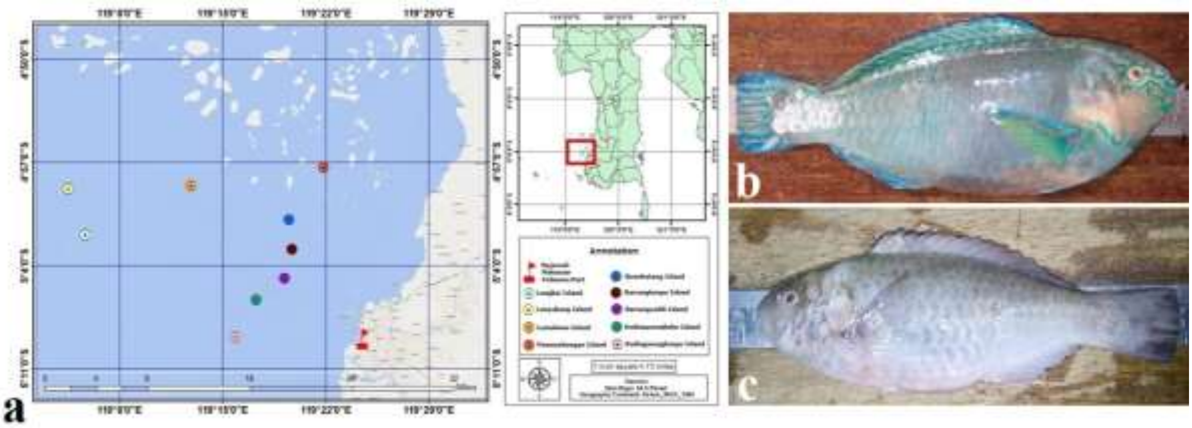

Figure 1. The participative map of rivulated parrotfish *Scarus rivulatus* in the Wallace line at Spermonde Archipelago (a). Rivulated parrotfish *Scarus rivulatus* male (b) and female (c) in the laboratory when measuring and observing fish parameters

The parameters measured are total length, total weight, and gutted weight. The length of the fish is measured using a measuring board with an accuracy of 1 mm. Fish weight was measured using digital scales to an accuracy of 0.01 g. The parameters observed were the macroscopic structure of the gonads and the maturity stage.

The reproductive parameters observed were sex ratio (SR), maturity stage (MS), and size at first maturity (FM). The observed aspect for the sex ratio is the number of male and female samples obtained during sampling. The aspect observed for the maturity stage was the development of male and female gonads. Determination of maturity stage refers to the results of research on other parrotfish species [19]. The observed aspects for size at first maturity were total length and gutted weight [20].

The sex ratio is calculated using the equation: $SR = \frac{\Sigma M}{\Sigma F} \text{ x } 100\%,$ where ΣM is the number of males (individuals), ΣM is the number of females (individuals). SR was tested using the chi-square test [21].

Determination of maturity stage refers to the previous study at other species of parrotfish in Spermode Islands [19, 22] which divides the five stages of parrotfish development, namely MS I (immature), MS II (early maturation), MS III (maturation), MS IV (late maturation) and MS V (post spawning). Maturity stage (MS) is determined by observing morphological parameters, namely body shape, color, body length, body weight and gonad development. The distribution of the maturity stage will be analyzed based on the sampling period and length class.

First maturity (FM) was estimated based on the total length of 50% of the samples obtained were mature (MS III, MS IV and MS V). Size at first maturity was estimated by using the equation: FM = Lm_{50}, where Lm_{50} was the length at which 50% of the fish was mature. The first maturity curve was calculated using a polynomial trendline in the Microsoft Excel software program.

3. Results

3.1. Sex-ratio

During the sampling period, 58 male and 142 female fish were found. The percentage of males is smaller than males (Figure 2a) with a ratio of 1: 2.45. Chi-square test results indicate that the sex ratio based on the sampling time is significantly different ($X_h^2 < X_t^2$).

The sex ratio based on maturity stage shows the percentage of female fish is more than male fish (Figure 2b). During the sampling period, one male sample was found at MS I; 89 samples of MS II consisted of 20 males and 69 females; 21 samples at MS III, consisting of male 13 and female 8; 87 samples at MS IV, consisting of 25 males and 62 females; and 2 female samples at MS V. Chi-square test results showed that the sex ratio based on MS was significantly different ($X_h^2 < X_t^2$).

The sex ratio base on the length class shows that females dominate the small class sizes, while males dominate the large class sizes (Figure 2c). This indicates that the rivulated parrotfish is most likely a protogyny with a length when the sex transition occurs, starting at about 15.3 - 26.8 cm.

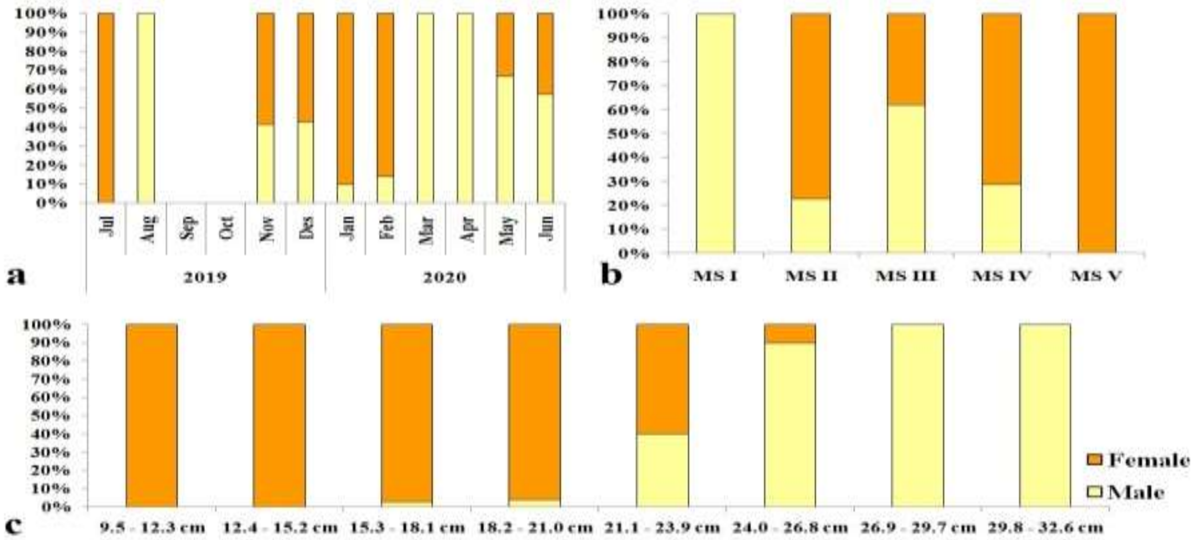

Figure 2. Sex-ratio rivulated parrotfish *Scarus rivulatus* related to the sampling period (a), maturity stage (b), and length class (c)

3.2. Maturity Stage

3.2.1. Macroscopic Characteristics of the Gonads. Macroscopically, male and female gonads can be distinguished based on their color and size (Figure 3) (Table 1). Male and female gonads have different color variations at each maturity stage (MS I - V), from clear to milky white (male) and brownish white to brownish red (female).

Table 1. Macroscopical characteristics of the gonad rivulated parrotfish *Scarus rivulatus* in female and male. MS: Maturity Stage

MS	Female	Male
I	Ovary is clear. Ovary weight less than 0.01 g.	Testes are clear. Testes weight less than 0.01 g.
II	Ovary are brownish white. Ovary weight varies from 0.01-0.09 g with mean weight 0.04±0.03 g	Testes are whitish clear. Testes weight varies from 0.01-0.06 g with mean weight 0.03±0.02 g.
III	Ovary are brownish white. Ovary weight varies from 0.06-0.23 g with mean weight 0.13±0.05 g	Testes are milky white. Testes weight varies from 0.06-0.60 g with mean weight 0.18±0.09 g.
IV	Ovary are brownish red. The weight of the ovary varies from 0.20-0.60 g with average weight 0.04±0.10 g	Testes are milky white. Testes weight varies from 0.33-1.37 g with average weight 0.76±0.29 g.
V	Ovary are brownish white. Ovary’s weight less than 0.06 g	Testes are milky white. Testes weight varies from 0.05-0.26 g with mean weight 0.16±0.07 g.

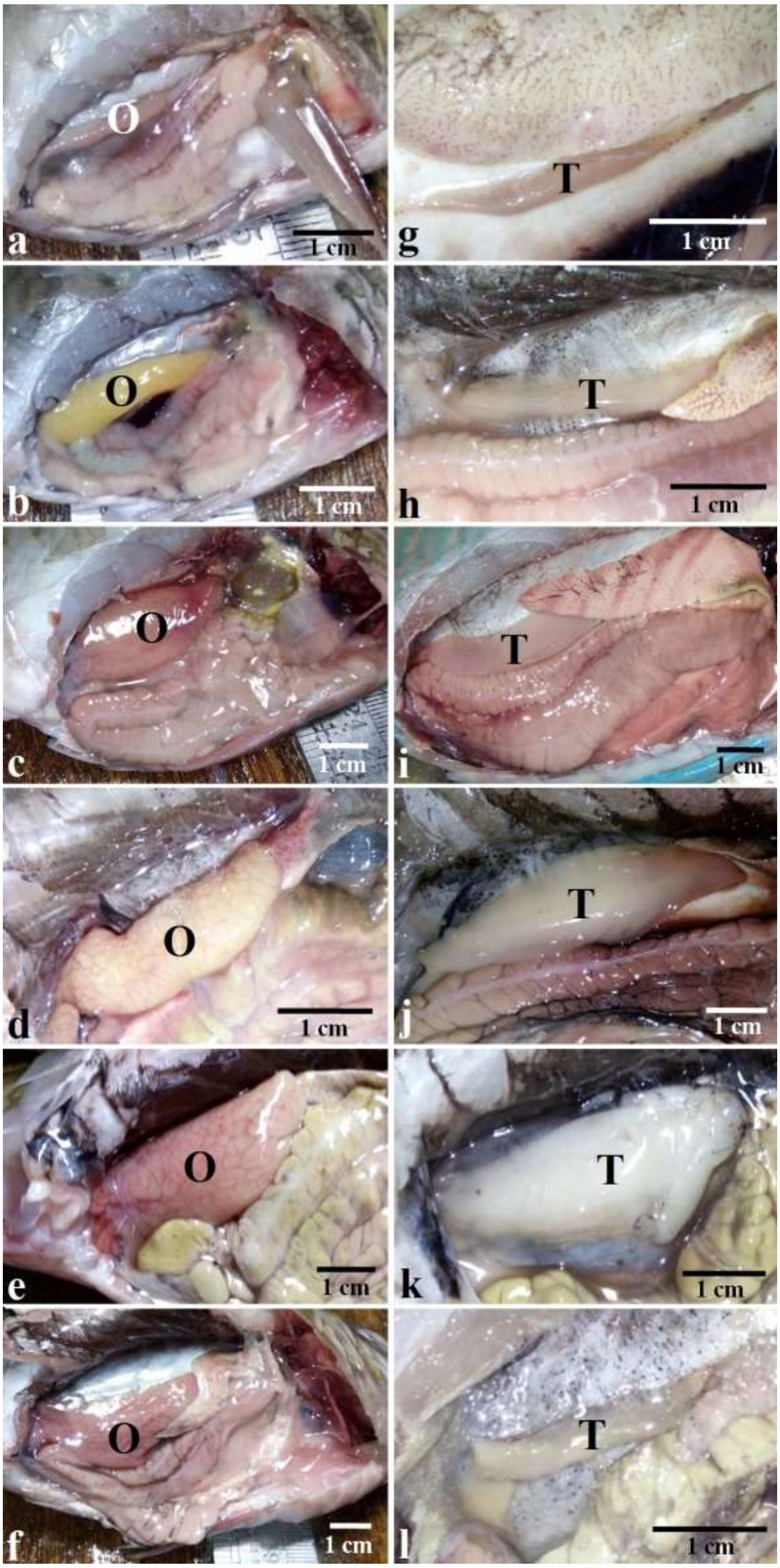

Figure 3. Macroscopic characteristics of the gonadal rivulated parrotfish *Scarus rivulatus* in females (a-f) and males (g-l). T: testes, O: ovaries

3.2.2. Maturity Stage Distribution. The distribution of the maturity stage related to the sampling period shows that the presence of MS IV was quite synchronous between male and female fish, with a fairly varied percentage. MS IV was seen in almost all sampling periods. During the sampling period, MS II was quite abundant in the period October to February (Figure 4a). Maturity stage related to the length class shows that MS IV spreads from length class 12.4 - 15.2 cm to 29.8 - 32.6 cm. MS II was present in all length classes (Figure 4b).

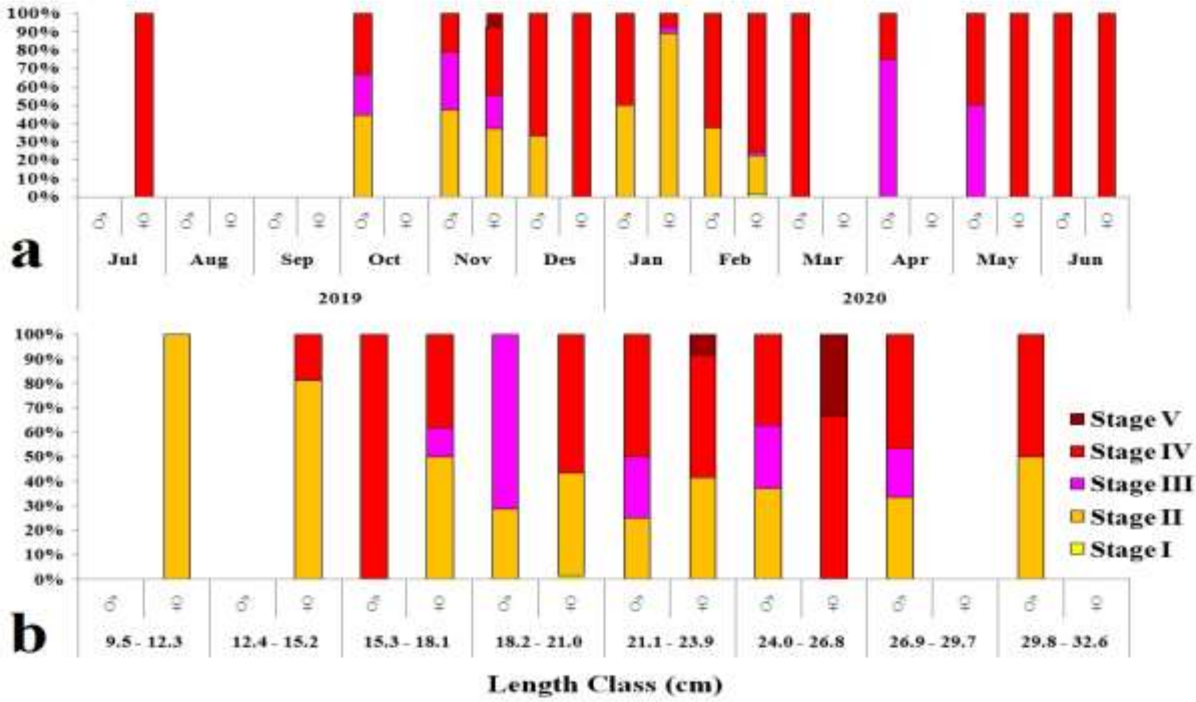

Figure 4. The maturity stages of rivulated parrotfish *Scarus rivulatus* related to the sampling period (a) and length class (b).

3.3. Size at First Maturity

Females reach size at first sexual maturity earlier than males. $FM_{50\%}$ from the equation M = 0.0003x5 - 0.0354x4 + 1.6473x3 - 35,792x2 + 364,36x - 1398 was 16.9 cm for females (Figure 5a). Meanwhile, FM $_{50\%}$ from the equation FM = 0.0003x5 - 0.0354x4 + 1.6473x3 - 35,792x2 + 364,36x - 1398, was 24.3 cm for male (Figure 5b).

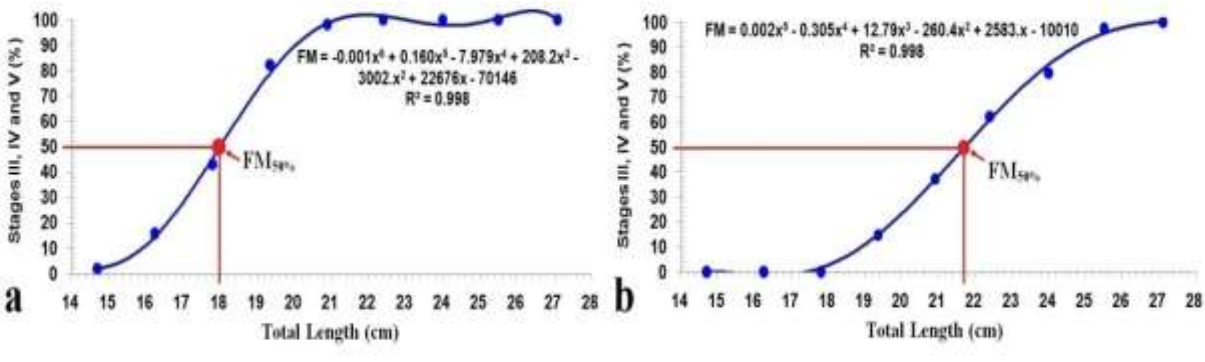

Figure 5. Size at first maturity of rivulated parrotfish *Scarus rivulatus* related to the total length at the female (a) and male (b).

4. Discussion

4.1. Sex Ratio

Ideally, the sex ratio should be in a balanced state so that population development and survival can be sustained [23], However, this ideal condition is difficult to achieve because the balance of the population structure is influenced by many factors, such as differences in growth patterns, age, size at first maturity, capture pressure, and recruitment [24, 25].

The unbalanced sex-ratio of rivulated parrotfish indicates that the population structure of the male and female was not balanced. This pattern happen also at the rivulated parrotfish population that live in other waters with a greater imbalance value, namely 1 : 3.5 [26]. This sex-ratio imbalance happen also at the other parrotfish population [22, 27] and other coral fish populations that live in the waters of Spermonde [28]. The imbalance of population structure is recoup by forming groups during spawning [29] so that all the eggs can be fertilized.

The population structure imbalance of the parrotfish is suspected of having relation to the hermaphroditism. Parrotfish is strongly suspected to be protogenic, where in the early life history it is a female, after reaching a certain size and age then it turns into a male. This pattern also happens in other parrotfish species [29].

An imbalance in sex ratios can cause a population to flock during or before spawning. Group spawning in rivulated parrotfish has never been reported before, however, another parrotfish, *Sparisoma rubripinne* has been reported in groups during spawning [30]. Grouping behavior during spawning has also been reported in the other reef fish [31-36], as well as in groupers that live in coral ecosystems, such as *Epinephelus guttatus* [37-39], *Epinephelus striatus* [40, 41], *Epinephelus tauvina* [42] and *Mycteroperca bonaci* [43]. Group behavior is a reproductive tactic to minimize reproductive failure [39]. The results of previous studies have reported an imbalance in the sex ratio of rivulated parrotfish with a male and female ratio of 1: 3.5 [26]. Biologically, a greater number of females than males is no problem because males can produce a lot of sperm, enough to fertilize all the eggs produced by several females.

An imbalance in sex ratio could be a reproductive strategy in which rivulated parrotfish try to produce as many eggs as possible to floods their habitat with offspring. The lower the number of males, biologically may have less impact on the existence of the population, because a male can produce a sufficient number of sperm to fertilize all eggs produced by several females. For rivulated parrotfish that live in highly competitive and hyper volume habitat at coral reef ecosystem, floods the habitat with offspring is the right strategy. Therefore, the regulated parrotfish likely has an r-strategy.

4.2. Maturity Stage

The presence of MS IV at each sampling period confirmed the suspicion that each sampling period there were individual rivulated parrotfish that matured gonads, so that there is a chance for spawning at any time of the year. The distribution pattern of MS IV and the possibility of spawning at any time like this also occurs in other parrotfish species that live in Spermonde waters [22] and other waters [29, 44]. The distribution pattern of MS IV and the possibility of spawning at any time like this also occurs in other reef fish species [45]. This reproductive pattern may be related to environmental factors which are relatively stable throughout the year in tropical areas where coral reef ecosystems develop. The relatively stable temperature throughout the year in the tropics means that fish are not too limited by environmental conditions to ripen gonads throughout the year. The results of this preliminary study still require further study to prove this conjecture.

Rivulated parrotfish have a bag-like gonad shape. The gonad walls were very thin in MS IV, and look like an empty bag on MS V, which confirms the suspicion that the rivulated parrotfish is the total spawner at which individuals can spawn at any time. This suspicion was confirmed by the presence of MS II and IV during one year sampling. The maturity stages distribution like this was also occurs in other parrotfish species [22, 27, 46] and other reef fish [28, 47], and other marine organisms that are more primitive in the development of their reproductive organs [20, 48, 49].

Spawning at any time throughout the year could be a reproductive strategy in which rivulated parrotfish try to floods their habitat with offspring throughout the year so that recruitment occurs throughout the year to recover their population that could be decrease at any time due to high predation in their hyper volume habitat at the coral reef ecosystem. This may reinforce the previous notion that regulated parrotfish is an r-strategy.

4.3. Size at First Maturity

The smaller size at fist sexual maturity in females confirmed the suspicion that rivulated parrotfish were hermaphrodite protogeny. This reproductive strategy was often found in parrotfish [22, 27] and other reef fish species [45, 47] that live in the Spermonde waters.

The results of previous studies have confirmed that rivulated parrotfish are protogynous who go through the early stages of their life as females, at the total length range of 126 - 270 mm, after which they turn into males at the total length range of 246 - 350 mm [50]. Female rivulated parrotfish reach maturity when they are two years old, then undergo a period of sex change to male sex when they are three years old [51].

Size at the first maturity is an indicator of maturity and will do spawning. The larger size at first maturity in males compared to females reinforces the notion that rivulated parrotfish are protogynous, which have an early stage of life as females, and at certain period will turn into male fish [52].

The size at first maturity value can be related to exploitation or fishing pressure. When fishing pressure is high or if environmental conditions are not suitable for growth and reproduction, it will have an impact on the behavior of the fish which will tend to delay spawning, so that it can affect the size at the first maturity [23]. Probability of spawning at any time, early maturity and protogeny are the reproductive biologist parameters that indicate that rivulated parrotfish was an "r" reproductive strategy.

Protogynous could be a reproductive strategy in which rivulated parrotfish could produce, early of their life history, as many eggs as possible to floods their habitat with offspring. The presence of large numbers of females early in their life history will increase the ability of the rivulated parrotfish population to produce offspring and increase reproductive success, thereby increasing the chance of recruitment. Rivulated parrotfish populations require a large recruitment to recover their population that could be decreased at any time due to high predation in their hyper volume habitat at the coral reef ecosystem. Protogynous at rivulated parrotfish may reinforce the previous notion that regulated parrotfish is an r-strategy.

5. Conclusion

The sex-ratio of rivulated parrotfish was not balanced, males was fewer than females (1: 2.49). The maturity stages of male and female were quite synchronous. Early maturation and maturity stages that were dominant during the study indicate that rivulated parrotfish can spawn at any time throughout the year. The size at first maturity of rivulated parrotfish was achieved very quickly with sizes 16.9 for female cm and 24.3 cm for male. Females that mature more quickly are an indication that the rivulated parrotfish is protogynous. An imbalance in sex ratios, spawning at any time throughout the year, early maturity, and protogynous could be a strong indication that rivulated parrotfish was an r- strategy

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