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## Interannual sex ratio and maturity of Indian parrotfish *Chlorurus capistratoides* Bleeker, 1847 in Wallace line at Spermonde Archipelago

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**Abstract.** Indian parrotfish *Chlorurus capistratoides* live in abundance in the Indo-Pacific region. Indian parrotfish is one of seven new species found in Indonesian waters, one of 34 species of economically important parrotfish caught in the waters of Spermonde, South Sulawesi. This study aims to examine the sex ratio, gonad maturity stage, and the size at first maturity of Indian parrotfish. This research was carried out in 2014 and 2019, using samples of Indian parrotfish from the waters of the Spermonde Islands, landed by fishermen in Rajawali Makassar Fisheries Port, Makassar city. Indian parrotfish sex ratio was not balanced between male and female fish. This imbalance was covered up by the synchrony of maturity stages of the female and male. This synchrony could increase the success of the fertilization process. This synchrony explains why the population of Indian parrotfish was always there, even unbalanced in sex ratio, and because males can produce enough sperm to fertilize the eggs produced by several females. The relatively same reproduction parameters in 2014 and 2019 indicated that the reproductive parameters of Indian parrotfish had not been affected by different environmental factors of the two different years that differ in 5 years.

### 1. Introduction

Indian parrotfish *Chlorurus capistratoides* live in coral waters in the Indo-Pacific region [1,2]. Indian parrotfish is one of six species found in the Mahatma Gandhi Marine National Marine Park in South Andaman, India [3], as well as in Philippine waters [4] and Malaysia [5]. Indian parrotfish is one of seven new species found in Indonesian waters [6]. Parrotfish is classified as an economically important consumption fish. This fish is quite popular with the community and is very popular in the market [7]. In Indonesia, parrotfish is an export commodity to destination countries such as Hong Kong, Taiwan and Singapore [8]. Indian parrotfish is one of 34 species of economically important parrotfish that are caught in the waters of Spermonde, South Sulawesi [9, 10].

Ecologically, parrotfish have a very important role in maintaining the balance of coral reef ecosystems [11] because parrotfish are herbivorous animals that prey on fine algae that grow and lives

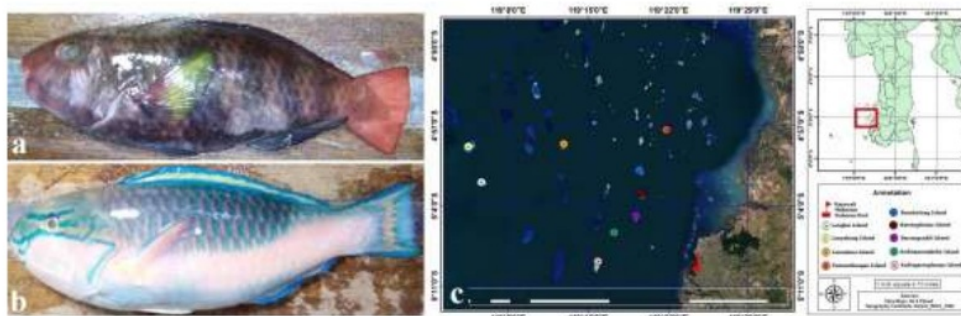
covering coral [8]. Parrotfish also prey crustaceans and foraminifera associated with algal vegetation, so these fish can also be classified as omnivorous animals. [12]. Therefore, parrotfish can play an important role in maintaining the balance of the structure of the marine plant community. Reduction of parrotfish populations in coral reef ecosystems can cause a shift in community structure from coral organisms to macroalgae because macroalgae can inhibit and growth of coral organisms [13].

Besides having an important ecological role, parrotfish has important economic value and needs to be managed based on sustainable principles [14]. As a target fish, many parrotfish are caught by fishermen in the waters of the Spermonde Islands, South Sulawesi [10]. Spermonde Islands are islands consisting of 120 islands [15], which has an area of around 2,500 km<sup>2</sup>. Spermonde Islands is inhabited by at least 64 species of high economic value reef fish that are caught every day [10, 16-18]. The Spermonde Islands are located in the Makassar Strait region, which is one of the Wallacea Lines [19].

Research on Indian parrotfish is still very rarely done. This fish is classified as least concern [20]. Therefore research will be carried out on the reproductive biology of Indian parrotfish caught in the waters of the Spermonde Islands. The purpose of this study was to analyze the interannual sex ratio and maturity of the Indian parrotfish population caught in the waters of the Spermonde Islands to find out if there are temporal variations within a period of 5 years.

## 2. Materials and Methods

This research was carried out in 2014 and 2019, using samples of Indian parrotfish from the waters of the Spermonde Islands, South Sulawesi Province, landed by fishermen in Rajawali Makassar Fisheries Port, Makassar City. Based on the participatory mapping involving fishermen who landed Indian parrotfish, it is known that Indian parrotfish come from nine fishing locations in the Spermonde Islands, namely the waters of Lumu-lumu, Lanyukang, Bonebatang, Panambung, Langkai, Kodingarengkeke, Kodingarenglompo, Barrang Lompo, and Barrangcaddi islands. (Figure 1).



**Figure 1.** Indian parrotfish *Chlorurus capistratoides* female (a), male (b) and map of fishing locations based on participatory mapping (c)

The reproductive parameters observed were sex, total length, total weight, empty weight, gonad weight, gonad size. Indian parrotfish weight was measured using a scale with a precision of 0.01 g.

Sex ratio is calculated using equations:  $SR = \frac{\sum J}{\sum B}$ , where: SR = sex ratio,  $\sum J$  = the number of males,  $\sum B$  = the number of females. A Chi-square test was used to determine the sex ratio between males and females [21] arranged in the form of a contingency table [22]. Maturity stages are determined by referring to the results of previous studies on other parrotfish [23]. First maturity (FM) is calculated based on the number of individuals in MS III, IV and V, namely:  $FM = L_{FM50}$ , where:  $L_{FM50}$  was 50% from the total length of the Indian parrotfish reaching maturity (MS III, IV, and V) [24].

## 3. Results

### 3.1. Sex Ratio

The total sample collected during the study was 662 Indian parrotfish, which consisted of 319 in 2014 and 343 in 2019. In 2014, there were more females (211) than male fish (108), the sex ratio between female and male was 1,95 : 1,00. The sex ratio related to sampling period in 2014 (Figure 2a) was significantly different ( $P < 0.05$ ). Likewise, in 2019, female fish (238 individuals) were also seen more than male fish (105), and the sex ratio between female and male was 2,26 : 1,00. The sex ratio related to sampling period in 2019 (Figure 2b) was significantly different ( $P < 0.05$ ).

In 2014, sex ratios distribution related to maturity stages were varied, and were significantly different ( $P < 0.05$ ) (Figure 3), as well as in 2019, female (238) were seen more than male (105), and significantly different ( $P < 0.05$ ).

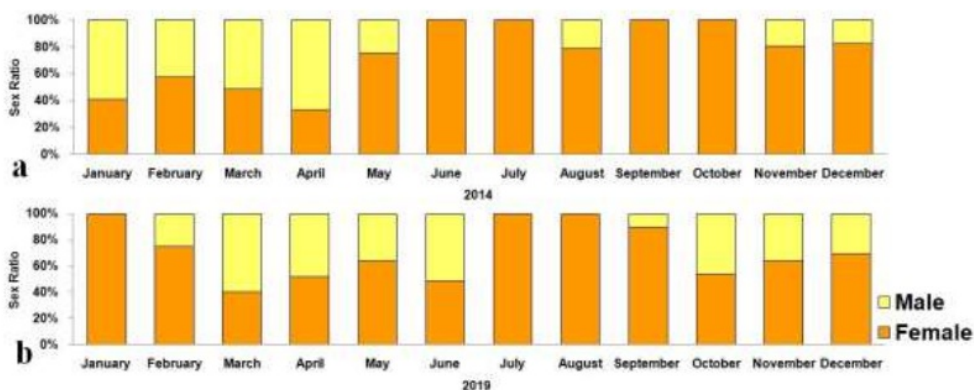


Figure 2. The sex ratio of Indian parrotfish *Chlorurus capistratoides* related to sampling period in 2014 and 2019

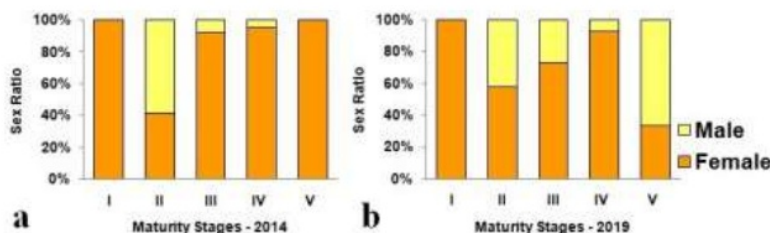
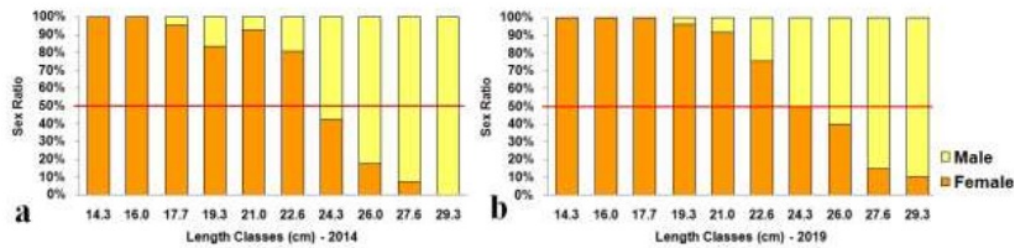


Figure 3. Indian parrotfish *Chlorurus capistratoides* sex ratio related to maturity stages in 2014 and 2019.

Sex ratios related to length classes indicated that females are more abundant at the small size (Figure 4), whereas male tend to be dominant at the large size. This indicated that Indian parrotfish is most likely a protogyny with the length of transitional sex between 17.7-19.3 cm. In the two years study, the length class in which male reached about 50% of samples was sized 24.3 cm. This study did not indicated if there were temporal variations of sex ration within a period of 5 years

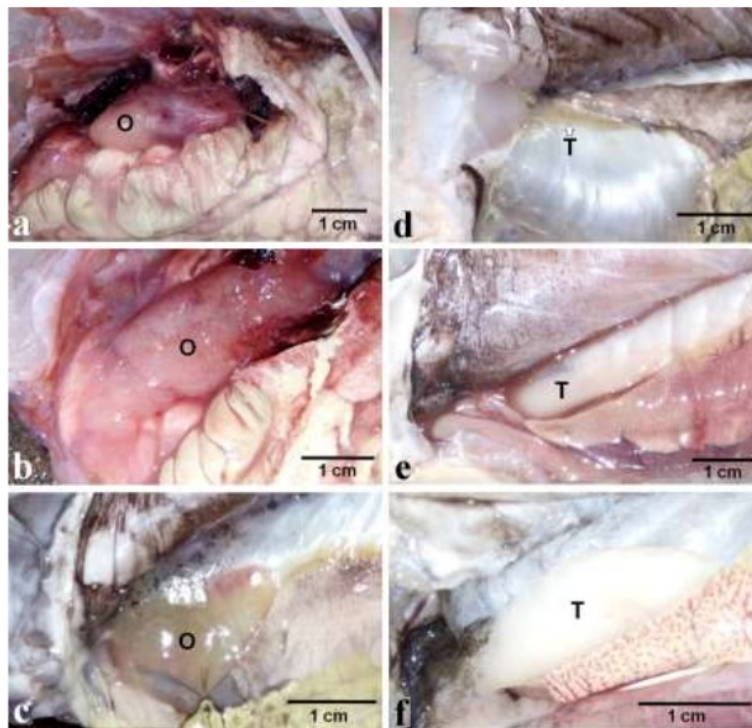
### 3.2. Maturity Stages

Macroscopically, male and female gonads can be distinguished by referring to the gonad colour and size (Figure 5). The colour testes vary from clear to milky white, whereas in the ovary colour varies from brownish white to brownish red (Figure 5 and Table 1). Referring to the macroscopic character, the maturity stages (MS) were divided into five classes, that were (1) MS I, which is immature in small samples that have never been spawned; (2) MS II, which is a transition stage in the big size sample that has been spawned at least once; (3) MS III, which is the sample in the maturation process; (4) MS IV, which is a mature sample; and MS V, which is spawning or post-spawn (Table 1).



**Figure 4.** Indian parrotfish *Chlorurus capistratoides* sex ratio related to length classes in 2014 and 2019.

Monthly samplings indicate a more pronounced distribution of maturity stages in females, both in 2014 and 2019. The presence of MS IV or mature gonads for most of the year indicate that Indian parrotfish have a long maturation process with a peak of spawning around June (Figure 6).

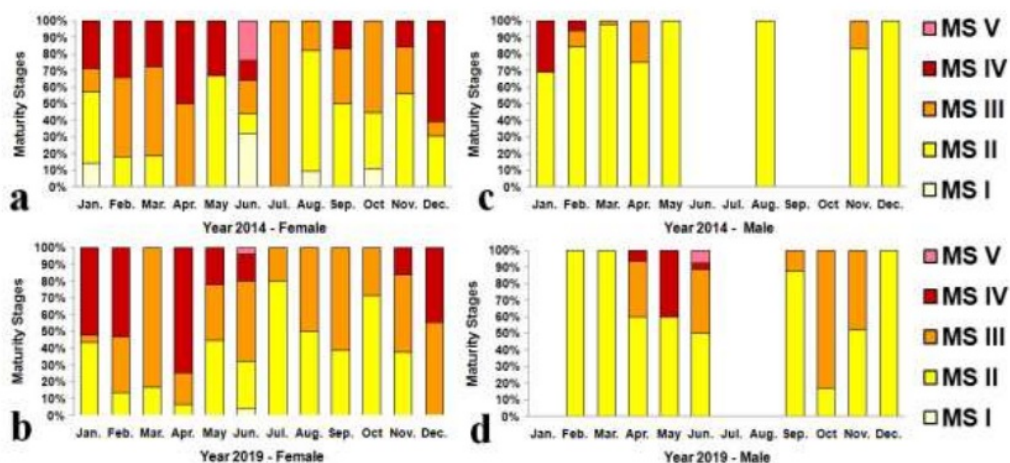


**Figure 5.** Macroscopic characteristics of gonad gonads parrotfish Indian *Chlorurus capistratoides* in male and female fish. Q: Testes, O: Ovary

**Table 1.** Gonads macroscopic characteristics of Indian parrotfish *Chlorurus capistratoides* in the male and female

MS	Female	Male
I (immature, have	The colour of the gonads was clear; the gonads cannot be distinguished	The colour of the gonads was clear; the gonads cannot be distinguished

never spawned)	between females or males. Gonad weight less than 0.02 g.	between females or males. Gonad weight less than 0.02 g.
II (transition stage, big size, have spawned)	The colour of the ovaries was brownish white. Ovary weight varies from 0.01-0.03 g with an average weight $0.02 \pm 0.00$ g	The colour of the testes was white. Testes weight varies from 0.02-0.04 g with an average weight $0.02 \pm 0.01$ g.
III (maturation)	The colour of the ovaries was reddish brown. Ovarian weight varies from 0.06-1.65 g with an average weight $0.69 \pm 0.42$ g	The colour of the testes was milky white. The gonad weight varies from 0.06-0.18 g with an average weight $0.11 \pm 0.04$ g.
IV (mature)	The colour of the ovaries was reddish brown. Ovarian weight varies from 0.64-10.30 g with an average weight $2.86 \pm 1.55$ g	The colour of the testes was milky white. Testicular weight varies from 0.30-0.48 g with an average weight $0.41 \pm 0.10$ g.
V (spawning or post spawn)	The colour of the ovaries was brownish gray. Ovary weight varies from 0.01-0.20 g with an average weight $0.04 \pm 0.07$ g	The colour of the testes was milky white. Testicular weight was less than 0.02 g.



**Figure 6.** The gonads maturities stages of Indian parrotfish *Chlorurus capistratoides* in 2014 (a and c) and 2019 (b and d) related to the sampling periods.

Length classes classification indicated the presence of mature stages (MS III) in each length class, especially in females. In males, MS III appears starting in the 19.3 cm, both in 2014 and in 2019. Whereas in females, MS III appear starting in the 16.0 cm, both in 2014 and 2019 (Figure 7). This study did not indicate if there were temporal variations of maturity stages within a period of 5 years.

### 3.3. First Maturity

Female first maturity for years 2014 and 2019 were almost the same, which were around 20.0 cm (Figure 11 a and b). Likewise, male first maturity for 2014 and 2019, which were around 23.4 cm (Figures 11 b and d). This study did not indicate if there were temporal variations of the size at the first maturity within a period of 5 years.

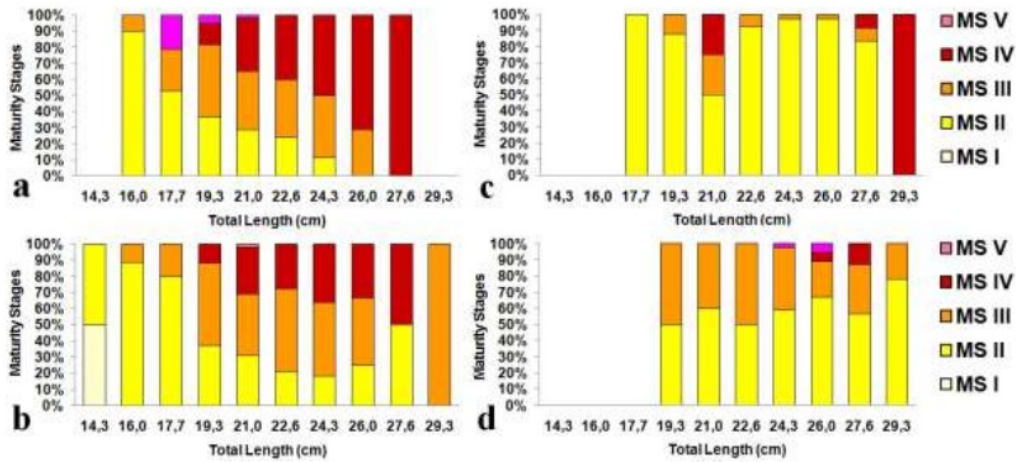


Figure 7. Maturity level of Indian parrotfish *Chlorurus capistratoides* in 2014 (a and c) and 2019 (b and d) based on length class.

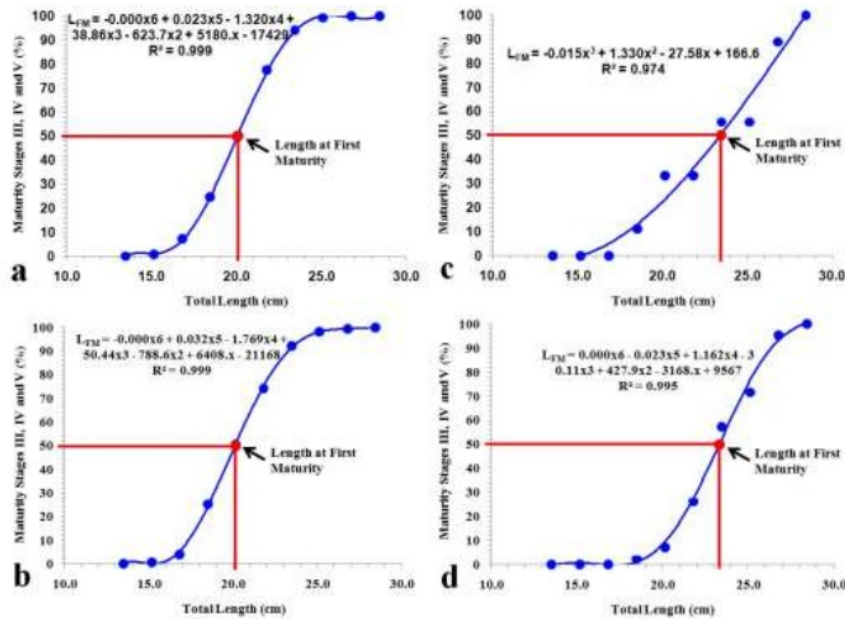


Figure 8. Size at the first maturity of Indian parrotfish *Chlorurus capistratoides* based on the length classes of male and female fish (a) and female fish (b).

#### 4. Discussion

##### 4.1. Sex Ratio

Sex ratio was the reproductive parameter that was influenced by many factors, such as migration, growth patterns, mortality rates, and differences size at the first maturity [25].

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The results of this study indicate that sex ratio was significantly different, where females were more abundant than males. This indicated the imbalance of population structure that can have an impact on the reproduction process, especially post-spawning fertilization. The results of previous studies have not been reported regarding the sex ratio in Indian parrotfish, but for other parrotfish species, namely, *Scarus rivulatus* found the same imbalance, which was 1: 1.3 [26]. This indicated that there was a tendency for females to be more abundant. This tendency was thought to be related to the reproductive model of protogyny, where at a young age was female. Younger fish are likely to have a greater number than older fish. This could cause male that are generally older in number will be less abundance due to natural mortality and fishing effort. In coral reef ecosystems that have very high competition, females that mature early are one of the strategies to reduce the impact of high mortality of the young fish; in such a strategy, males that are larger or older will monopolize spawning, and thus sexual selection is very strict [27-32]

Other causes of sex ratio imbalance can be caused by the reproductive patterns of Indian parrotfish, which are most likely protogyny. This can be seen in sex ratios based on long classes, where females dominate more small size classes, while males dominate more large size classes. Protogyny is the most common pattern and is often found, both in Scaridae and other tropical fish [33]. In protogyny fish, females will generally turn into male sex cells after going through a reproductive period [34]. The relatively same sex ratio distribution between 2014 and 2019 could indicate that the sex ratio has not been affected yet by different environmental factors that differ in 5 years, particularly climate change.

#### 4.2. Maturity Stages

The macroscopic structure of male and female gonads and the colour of the fish indicate that Indian parrotfish are dichromatism fish where the outer appearance of the female fish is dominated by brown and red, while the male fish is dominated by orange.

Determination of maturity stages was a bit complicated for MS I, II and V. MS I and II have the same gonadal macroscopic structure; the difference was only in the body size. MS I was an immature gonad at the small-sized fish which was thought to have never spawned, that was fish with the length smaller than a length at first maturity. While MS II was an immature gonad at the large fish that was allegedly already spawned, that was fish with the length greater than a length at first maturity. Likewise, MS V; the very small size of the gonads on MS V makes it very difficult to distinguish macroscopically. This complexity makes MS groupings differ slightly from one fish species to another [23, 35-39].

The presence of almost all maturity stages in each monthly and long-term sampling indicates that Indian parrotfish have a long reproduction period with one or more than one spawning. Previous studies have reported that reef fish can spawn twice a year [40]. It was strongly suspected that Indian parrotfish was total spawner. Total spawner is a spawning pattern where all eggs are released in one spawning season [41]. Total spawning patterns have been found before in other parrotfish such as *Scarus niger* [23], and in other reef fishes such as *Cheilinus fasciatus* [37].

Although Indian parrotfish have an unbalanced sex ratio, referring to the length classes, the presence of each maturity stages that were synchronous between male and female was a good thing. This synchrony can increase the success of the fertilization process after spawning. This synchrony is an explanation of why the sex ratio imbalance does not interfere with the existence of Indian parrotfish. Although the sex ratio was not balanced, the reproductive process, especially fertilization of the egg, did not matter because male fish can produce enough sperm to fertilize the eggs, which were spawned by several females.

The synchronous distribution of maturity stages at the male and female fish was a good indication because it indicated that the reproduction process could take place well, especially the spawning process. The synchronicity of maturity stages in Indian parrotfish has never been reported, but the synchronous distribution of maturity stages at the other parrotfish that found in the Spermonde Islands have been reported on *Scarus niger* [23], as well as other reef fishes such as *Cheilinus fasciatus* [37].

Synchronicity of maturity stages is common in reef fish and other marine organisms both living in the tropics sea, for example, in *Holothuria scabra* [42, 43], and in four seasons sea, for example in *Holothuria forskali* [44]. The relatively same distribution of maturity stages between 2014 and 2019 could indicate that the maturity stages of Indian parrotfish have not been affected yet by different environmental factors that differ in 5 years.

#### 4.3. First Maturity

The greater size at first maturity in the male confirms previous assumptions that the Indian parrotfish were protogyny. This assumption was strengthened by the distribution of sex ratio, and maturity stages where small-sized were almost all female and large-sized were almost all male. Parrotfish was the protogyny that at the beginning of the life cycle was female [45], then change sex later to be male [33, 34].

The previous studies have never reported the size at the first maturity in Indian parrotfish, but for other parrotfish, namely, *S. rivulatus*, where the female first maturity was also smaller than males, namely 16.5 -17.3 cm for females and 17.7 - 18.4 cm for males [26]. Both of these sizes at the first maturity of *S. rivulatus* were smaller than the size of the first maturity of Indian parrotfish.

Apart from biological and environmental factors, the size at the first maturity could be influenced by the exploitation rate or fishing effort. The fishing effort could decrease the population size that could have an impact on the decline in genetic diversity, for example, the decrease of growth rate [46]. Apart from fishing effort, size at the first maturity can also be influenced by external factors, such as environmental conditions, food availability, temperature, and salinity [47]. The relatively similar size at first maturity between 2014 and 2019 could indicate that the size at the first maturity of Indian parrotfish has not been affected yet by different environmental factors that differ in 5 years.

## 5. Conclusion

Indian parrotfish sex ratio was not balanced between male and female fish. This imbalance was covered up by the synchrony of maturity stages of the female and male. This synchrony could increase the success of the fertilization process. This synchrony explains why the population of Indian parrotfish was always there, even unbalanced in sex ratio because males can produce enough sperm to fertilize the eggs produced by several females. The relatively same reproduction parameters in the 2014 and 2019 indicated that the reproductive parameters of Indian parrotfish had not been affected by different environmental factors of the two different years that differ in 5 years.

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