Sex ratio and maturity of orange-dotted tuskfish *Choerodon anchorago* Bloch, 1791 in Wallace Line at Spermonde Archipelago

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**Abstract.** Orange-dotted tuskfish *Choerodon anchorago* was a Labridae family that could be found in coral reef and seagrass ecosystems. Orange-dotted tuskfish has a wide distribution in Indo-Pacific waters which has an important economic value that needs to be managed sustainably. This study aims to analyze the sex-ratio and maturity of orange-dotted tuskfish. The samples were collected from fishermen catches that were landed at the Rajawali Makassar Fishing Port at Makassar city. The orange-dotted tuskfish sex ratio was not balanced between males and females. Macroscopically, it was seen that orange-dotted tuskfish was a hermaphrodite. The synchronicity of maturity stages between male and female, both based on the sampling period, and the length class indicated that the process of reproduction, especially fertilization, was relatively safe. Female orange-dotted tuskfish that reach the first maturity earlier than male; suggest that orange-dotted tuskfish was most likely a protogyny.

1. Introduction

The Spermonde Islands was one of the most extensive areas of coral reef distribution and was inhabited by many species of reef fish [1-4]. Within the Spermonde Islands covering an area of about 150 km², there are 120 islands [5] that are inhabited and without inhabitants.

Spermonde Islands was located in the Makassar Strait, precisely to the west of South Sulawesi, which includes Makassar City, Maros Regency, and Pangkep Regency. In the Spermonde area, there is about 60,000 ha of coral reefs with a very diverse species of reef fish population, one of which was orange-dotted tuskfish or anchor tuskfish *Choerodon anchorago* [4].

Orange-dotted tuskfish are members of the Labridae family or known by the term “wrasse” which can be found in the waters of the coral reef ecosystem and seagrass ecosystem [4, 6, 7]. Orange-dotted tuskfish have a widespread in Indo-Pacific waters, can live at depths of 0-25 m, with a range of body length generally up to 50 cm [8, 9], but some can reach a length of 130 cm [10].

Besides having an important ecological role in maintaining the balance of the food chain so that diversity remains high, orange-dotted tuskfish has important economic value because the meat was...
white and tasty. Besides being sold as fresh fish and dried fish, it was also sold a life at a higher price in restaurants that provide live fish like in Hong Kong [11]. As a target fish, orange-dotted tusksfish are caught by fishermen in the waters of the Spermonde Islands, South Sulawesi [4]. The Spermonde Islands are a group of islands stretching in the Southwest of the Sulawesi Island from Takalar in the south to Pare-Pare in the north.

The ecological aspects of orange-dotted tusksfish have been widely reported by [7, 12-15]. Likewise with certain biological aspects such as otolith growth [16], food habit [15], reproductive behavior [17], the size of male and female [18, 19], and juvenile growth [20]. The results of previous studies have never reported the reproductive biology aspects of orange-dotted tusksfish. Therefore, research on the reproductive biology of orange-dotted tusksfish needs to be done. This study aims to analyze aspects of reproductive biology, including sex ratio, maturity stages, and first maturity orange-dotted tusksfish caught in the waters of the Spermonde Islands.

2. Materials and Methods

This research was conducted from January to December 2019, using orange-dotted tusksfish samples (Figure 1a-b) caught in the waters of the Spermonde Islands, South Sulawesi Province, which were landed at the Rajawali Makassar Fisheries Port of Makassar City. This orange-dotted tusksfish (Figure 1) was the catch of fishermen around the waters of the Island of Langkai, Lanyukang, Lumu-lumu, Panambung, Bonebatang, Barrangcaddi, Barranglompo, Kodingareng Keke, and Kodingareng Lompo (Figure 2).

![Figure 1. Orange-dotted tusksfish Choerodon anchorago when measuring (a) and when living in marine waters (b) [21].](image)

The parameters measured were total length, total weight, gutted weight, gonad weight, and gonad length. The parameters observed were the sex and maturity phase. The determination of the gonad maturity phase of the orange-dotted tusksfish sample refers to another wrasse that was Cheilinus fasciatus [22]. Weight parameters were measured using a digital scale with a 0.01 g accuracy. Sex ratio was calculated using equations: \( SR = \frac{\sum J}{\sum B} \), where: \( SR \) = sex ratio, \( \sum J \) = the number of male, \( \sum B \) = the number of female. The significance of the sex ratio between males and females was tested using the chi-square test [23].

Maturity stages were analyzed morphologically by observing the colour, gonad length, gonad weight, and gonad development. Maturity stages were determined by referring to wrasse C. Fasciatus [22]. The distribution of maturity stages was analyzed based on sampling time and distribution of long classes. First maturity (FM) was estimated based on length were 50% (\( L_{m50} \)) of sexually mature, that were MS III, IV and V [24]. The first maturity was calculated by using the equation: \( FM = L_{m50} \), where: \( L_{m50} \) was the length of 50% at the maturity.
3. Results

3.1. Sex ratio
During the study, there were 192 fishes consisting of 118 females, 43 males, and 31 not identified or MS II (male or female) (Figure 3a). The female and male sex ratio was 1: 2.74. The lowest sex ratio was obtained in September, consisting of 100% female and 0% male, and the highest in June, consisting of 56% female and 44% male. The percentage of females is significantly different from males (p<0.05).

During the study, 31 MS II (immature) were found, 70 MS III (maturation) consisting of 28 male and 42 female, 79 MS V (mature) consisting of 11 male and 68 female, and 12 MS V (post-spawning) consisting of 4 male and 8 female. Based on sex ratio distribution in accord with MS, the percentage of females was higher than males (Figure 3b). The percentage of females was significantly different from males (p<0.05). The smallest sex ratio was in the length class of 16.4-17.9 cm, and the higher sex ratio was in the length class of 23.1-24.6 cm (Figure 3c). The sex ratio between males and females was significantly different (p<0.05). Female is generally dominant in the small size class, whereas male was more dominant in the large size class, this sex ratio distribution indicates that orange-dotted tuskfish most likely a protogynous with a length of sex transitional between 21.4-24.6 cm.

3.2. Maturity Stages

3.2.1. Characteristic Macroscopic
The macroscopic structures' observations of the male and female gonads can be distinguished by their colour and size (Figure 4). MS III lasts long enough so that it was divided into three stages, namely MS III early, MS III advance, and MS III late (Table 1). In MS III to MS V, for males, the testes colour varies from clear white to milky white, whereas for females, the colour of the ovaries varies from brownish white to brownish red. During sampling, there have been cases wherein the individual testicles and ovaries were found together in a mature condition.
Figure 3. The sex ratio of orange-dotted tusksfish *Choerodon anchorago* based on sampling period (a), maturity stage (b), and length classes (c).

Table 1. Gonad macroscopic characteristics of orange-dotted tusksfish *Choerodon anchorago*

| MS  | Female | Male                                  |
|-----|--------|---------------------------------------|
| I & II | The colour of the gonad was clear, smooth like a thread, not yet distinguishable male or female. Gonad weight less than 0.02-0.10 g with an average weight 0.04±0.02 g. | Gonad colour was brownish white (Figure 6a). Gonad weight varies 0.04-0.47 g with an average weight of 0.24±0.13 g. |
| III Early | Gonad colour was brownish white (Figure 6a). Gonad weight varies 0.04-0.47 g with an average weight of 0.24±0.13 g. | Gonad colour was clear white (Figure 6f). Gonad weight varies 0.02-0.44 g with an average weight of 0.33±0.08 g. |
| III Advance | Gonad colour was brownish red (Figure 6b). Gonad weight varies 0.51-0.98 g with an average weight of 0.68±0.13 g. | Gonad colour was milky white (Figure 6g). Gonad weight varies 0.52-0.953 g with an average weight of 0.69±0.15 g. |
| III Late | Gonad colour was brownish red (Figure 6c). Gonad weight varies 1.00-2.46 g with an average weight of 1.73±0.38 g. | Gonad colour was milky white (Figure 6h). Gonad weight varies 1.02-1.46 g with an average weight of 1.16±0.15 g. |
| IV | Gonad colour was brownish red (Figure 6d). Gonad weight varies 2.10-23.24 g with an average weight of 6.23±4.47 g. | Gonad colour was milky white (Figure 6i). Gonad weight varies from 1.61-5.50 g with an average weight of 2.66±1.32 g. |
| V | Gonad colour was clear white (Figure 6e). Gonad weight varies 0.02-0.44 g with an average weight of 0.33±0.78 g. | Gonad colour was white spots (Figure 6j). Gonad weight of 0.16-0.50 g with an average weight of 0.32±0.18 g. |
Figure 4. Macroscopic characteristics of ovary (a-e) and testicles (f-j) of orange-dotted tuskfish *Choerodon anchorago*. O: ovary T: testicles
3.2.2. Maturity Stages Distribution

From 192 samples, 30 MS II samples were found, 57 MS III samples, 93 MS IV samples, and 12 MS V samples. Monthly sampling shows that the presence of each maturity stage was synchronous between males and females, but the presence of females appears more dominant in each sampling period (Figure 5a).

The lowest stage maturity (MS II) was found in the 19.7–21.3 cm long class. While the highest maturity stage (MS V) was found in the 23.1–24.6 cm length class. The results of grouping samples based on length classes indicated that the presence of each maturity stage was quite synchronous between males and females with a very varied percentage of males and females (Figure 5b). Females appear more often in small size classes, while males appear more often in larger size classes.

![Figure 5](image-url). Maturity stages of orange-dotted tuskfish *Choerodon anchorago* at female and male based on sampling period (a) and length classes (b).

3.3. First maturity

Females reach the first maturity at a length of 19.0 cm (Figure 6a), while males reach first maturity at a length of 22.4 cm (Figure 6b).

![Figure 6](image-url). Size a first maturity of orange-dotted tuskfish *Choerodon anchorago* at the female (a) and male (b) based on length class.
4. Discussion

4.1. Sex ratio

Previous studies no one has reported about the sex ratio in orange-dotted tuskfish, but in other reef fish studies, namely Scarus rivulatus have been previously reported [25]. Scarus rivulatus also shows an unbalanced sex ratio, where the sex ratio of males and females was 1: 3.5. Sex imbalance can be caused by factors of distribution, food, density, the balance of the food chain, and fishing effort [26, 27].

In wrasse fish, males grow faster than females, at Napoleon Chellinus undulatus, males grow faster than females, where males can reach a total length of 140 cm [28], while female fish can only reach a total length of 100 cm [29]. This size difference can have an impact on the sex ratio. C. undulate classified as a long-lived fish where the maximum age for males was 25 years and 30 years for females [30]. As protogynous hermaphrodite C. undulate undergoes sex changes at the age of nine years with a length of 50-70 cm [28].

4.2. Maturity Stages

The abundance of MS II was usually associated with the post-spawning period. Based on the previous studies, the abundance of MS II in a certain sampling period was an indication that spawning has occurred at the previous period [25]. The shape of the testes and ovaries that resemble an empty bag on MS V or post-spawning shows that orange-dotted tuskfish is classified as a total spawner. Total spawners like this also found in other wrasse fish in the waters of Spermonde, i.e., Cheilinus fasciatus [22], and in other reef fishes, i.e., Scarus niger in the waters of Spermonde [31].

At the fish and other marine organisms with total spawning patterns, post-spawning was the transition phase from MS V to MS II. In this transition phase, the next reproductive cycle begins through the formation of new testes and ovaries [22, 32, 33]. Determination of maturity stages in this transition phase requires accuracy because there are no characters related to secondary sex that can be used in determining the sex of male and female. Cases like this also occur in previous studies on other types of wrasse fish, where new male and female fish can be distinguished when entering MS III [22].

Classification of fish based on a long class shows that the presence of each maturity stage was synchronous between males and females, even though the percentage of males and females was very varied. This study indicated the synchronicity of maturity stages between male and female fish, both based on the sampling period and based on length classes. This was a good thing because it can guarantee reproductive success, especially during the spawning period. The presence of MS IV simultaneously will guarantee the fertilization process after spawning takes place. The synchronicity of maturity stages in orange-dotted tuskfish has never been reported or published before, but other wrasse fish that live on the Spermonde Islands have been reported on C. fasciatus [22]. Likewise in other reef fishes such as S. niger [31]. Maturity stages synchronicity in marine organisms was common, both in marine organisms that live in tropical waters [33-36], and in organisms that live in four-season waters [32].

The presence of synchronous testes and ovaries in one individual in mature conditions shows that orange-dotted tuskfish have the potential to be simultaneous hermaphrodite or protogynous hermaphroditism, but this still requires a deeper study by observing gonad microscopic structures. Previous studies have not reported hermaphroditism in orange-dotted tuskfish, but based on studies on other types of wrasse fish, namely Napoleon C. undulatus fish, it was known that Napoleon was protogynous hermaphroditism, with body size when the gonads mature was around 65 cm in females, and around 84.5 cm in male [29, 37]. The results of many previous studies have reported cases of hermaphroditism in reef fish from the Scaridae family [38].

In protogynous hermaphroditism fish, the general structure of female and male populations was not balanced so the reproductive tactic was needed to overcome this imbalance problem. In other wrasse fish C. undulatus which has a male and female sex ratio between 1: 6 and 1:10, the spawning
process begins with the release of sperm by the male fish into the waters, then followed by the release of eggs by female fish [30].

4.3. First maturity
The first maturity was considered as an indicator where an individual has reached adulthood and will do spawning. This study indicates that first maturity in females was smaller than males, but this difference was not as big as in other wrasse fishes C. undulatus, which was also a protogyny hermaphrodite [37]. So far, no one has reported the first maturity of orange-dotted tusksfish, as well as other species of wrasse, except C. undulatus. When compared to the other reef fish, for example, S. rivulatus research results [25], the first maturity of orange-dotted tusksfish was larger but generally smaller than the first maturity of other reef fish [39, 40]. Sooner or later, fish reaching the first maturity is closely related to the level of exploitation and growth [41].

5. Conclusion
The orange-dotted tusksfish sex ratio is not balanced between males and females. Macroscopically, it is seen that orange-dotted tusksfish is a hermaphrodite. The synchronicity of maturity stages between male and female fish, both based on the sampling period, and the length class indicated that the process of reproduction, especially fertilization, is relatively safe. Female orange-dotted tusksfish that reach the first maturity earlier than males suggest that orange-dotted tusksfish is most likely a protogyny.

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