Macroscopic characteristics of the gonad maturity stages of dusky parrotfish Scarus niger

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Abstract. The dusky parrotfish Scarus niger is an important economic fish. Like other reef fish that have good taste, white and thick meat, and don't have a lot of tiny bones, the dusky parrotfish is a fine food fish. The dusky parrotfish has a very wide distribution in tropical and subtropical sea waters. This study aimed to validate the maturity stage descriptions based on macroscopic characters. The results of this study are expected to be a reference in the study of the reproductive biology of dusky parrotfish and other parrotfishes, such as first maturity and the reproductive cycle. The samplings were done monthly at Makassar Fisheries Port from January 2018 to May 2019. The parameters measured were total length, body weight, gonad weight, gonad length and width, and liver weight. The observed aspect was the gonad colour and condition for both male and female fishes. Five stages of gonad maturity used to identify the gonad maturity stages were quite accurate. The accuracy was indicated by the gonadosomatic index (GSI) and hepatosomatic index (HSI) values that increased progressively from Stage I to IV. This accuracy validates macroscopic characters used for identifying the maturity stage of dusky parrotfish

1. Introduction
The dusky parrotfish Scarus niger is an economically important fish that has a good taste, white and thick meat, and doesn't have a lot of tiny bones. It belongs to the Scaridae family because it has the diagnostic meristic characters of nine dorsal spines, ten dorsal soft rays, three anal spines, and nine anal soft rays [1]. The dusky parrotfish is widely distributed in Indo-Pacific waters; from the Red Sea south to Sodwana Bay, South Africa and east to the Society Islands, north to the Ryukyu Islands, south to Shark Bay, Western Australia and the southern Great Barrier Reef [2] (Figure 1). This fish can be found in shallow waters to a depth of 20 m [3] in many coral reef ecosystems in Indonesia, including the Wakatobi National Park [4], Natuna Island [5], and Weh Island [6].

The dusky parrotfish is a herbivorous fish [4] that feeds on benthic algae [7]. This fish inhabits coral-rich areas of clear lagoons, trench, and outer reef slopes [5], often living solitary [6] with males maintaining small harems [5]. The fish is oviparous, with distinct pairing during breeding [3].

Previous studies have examined the biological aspects of Dusky parrotfish, such as life history, growth patterns, and spatial variability [8], density and biomass [9]. However, the analysis of the reproductive biology cycle of the dusky Parrotfish has not been studied quantitatively. To produce a
practical and valid standard for reference, such as gonad maturity stage identification, a comprehensive study is required.

The best way to produce a practical and valid standard for gonad maturity stages is by observing the gonad under a microscope; however, this method is difficult, impractical, takes time and is costly. The alternative method that can be used is to observing the gonad structures with the naked eye; nevertheless this method has several disadvantages. It is difficult to determine the initial stage (Stage I, II) and final stage (Stage V) of the gonad maturity phases. Therefore, the use of macroscopic characteristics in determining the maturity stages requires precision, experience, and standards of observation. This study aimed to validate the descriptions of dusky Parrotfish maturity stages based on the macroscopic characters of the gonads. The results of this study are expected to be a reference in the study of parrotfish reproductive biology, particularly for first maturity and the reproductive cycle of *Scarus niger*.

This paper is part of a long-term study conducted since January 2014 to evaluate the impact of climate change and global warming on coral fish communities in the Spermonde Archipelago.

![Figure 1. Dusky parrotfish *Scarus niger* (A) and its distribution around the world after [9] (B)](image)

### 2. Materials and Methods

Dusky parrotfish that were landed at Makassar Fisheries Port on sampling days, were collected monthly throughout the year in 2014 and from January 2018 to May 2019. Makassar Fisheries Port (Figure 2) is the main fish landing site in the Makassar Straits, which is one of the major fishing grounds in Indonesia [10].

The parameters measured for each specimen were total length, body weight, gonad weight, gonad length and width, and liver weight. The measurement precision was 1 mm for length, and 0.01 g for weight. The observed aspect was the gonad colour and condition for both males and females.

The maturity stage was determined by referring to macroscopic characters of the gonads, namely the colour, gonadal condition and gonad morphometric characters. Validation of the descriptive gonad maturity stage used the Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI). GSI was calculated using the formula of Garcia-Salazar, Abdel, African, Suarez and Avella [11], while the HSI was calculated referring to Hun-Han [12].

### 3. Results

#### 3.1. Length and weight distribution

A total of 117 *Scarus niger* were collected during monthly sampling days during 2014 and January 2018 through May 2019. The fishes were divided into eight groups based on fish length and weight. At a glance, the collected fish seemed to fall into more than three size groups (Figure 3).
3.2. Maturity stage
Theoretically all species of Scaridae undergo a sex change; males in most species that have been studied are likely to be primary or secondary males [14]. Specific studies on *Scarus niger* revealed that mating occurs in one group of females which is dominated by only one secondary male who was originally a dominant female of the group; this species is therefore known as a protogynous hermaphrodite [15]. However, has been suggested that additional work is needed [16].

In this study, based on their appearance, male and female gametes were easily differentiated in the mature stage of the gonad. At the mature stage, the length, width and weight of the female gonads were larger than the male. The gonad consists of two interconnected lobes. Viewed from the ventral
side, the left gonad lobe is generally larger than the right gonad, especially in the mature stage. The maturity stage of male and female dusky parrotfish were synchronous and could be divided into five stages based on their macroscopic characteristics, namely immature or transition, early maturation, maturation, maturity and post spawning or resting (Table 1).

Table 1. Morphometric and reproductive parameters of Dusky parrotfish Scarus niger in all Stages of gonad maturity.

| Gonad Maturity          | Statistics | Total length (mm) | Body weight (g) | Gonad weight (g) | Liver Weight (g) | GSI   | HSI   |
|-------------------------|------------|-------------------|-----------------|------------------|------------------|-------|-------|
| Stage 1-Immature        | Mean       | 165               | 87.51           | 0.02             | -                | 0.02  | -     |
| N=2                     | SD         | 9                 | 16.56           | -                | -                | 0.00  |       |
| Stage I - transition    | Mean       | 252               | 281.85          | 0.02             | 6.27             | 0.01  | 2.22  |
| N=1                     | SD         | -                 | -               | -                | -                | -     |       |
| Stage II                | Mean       | 230               | 223.35          | 0.17             | 3.77             | 0.10  | 1.62  |
| N=18                    | SD         | 39                | 113.30          | 0.14             | 3.46             | 0.08  | 1.23  |
| Stage III               | Mean       | 239               | 245.12          | 0.68             | 6.03             | 0.33  | 2.41  |
| N=34                    | SD         | 32                | 87.60           | 0.73             | 4.50             | 0.43  | 1.36  |
| Stage IV                | Mean       | 229               | 202             | 2.54             | 5.61             | 1.39  | 2.88  |
| N=62                    | SD         | 61                | 81              | 2.44             | 5.57             | 1.18  | 2.45  |
| Stage V                 | Mean       | 243               | 224             | 0.37             | 2.05             | 0.14  | 0.93  |
| N=11                    | SD         | 20                | 58              | 0.45             | 1.35             | 0.13  | 0.63  |

3.2.1. Macroscopic characteristics of stage I - Immature and Stage I - Transition.
The immature stage gonad was only found in small-sized fish that have never been ripe yet. During the study only two fish were found in the immature stage. Stage I transition is a stage where both male and female gonads are in phase I after phase V of the previous cycle is complete. The gonad characteristics in transition stage were the same as the immature stage but found in larger fish. In Stage I, the gonad colour was transparent, small and smooth with a diameter of less than 1 mm. In this phase it is impossible to distinguish macroscopically the testes from ovaries. The gonad maturation phase between phase I immature and phase I transition can only be predicted from the size of the fish which needs to be used as a distinguishing point of reference (Table 1).

3.2.2. Macroscopic characteristics of Stage II - Early Maturation.
The colour of male (Figure 4A) and female (Figure 4E) gonads were still quite clear, but they can already be distinguished from each other. The gonads lie upon the swim bladder (Figure 4A and 4E), and extend from the liver to the oviduct, with gonad diameter 0.2-0.4 mm, and gonad weight 0.02-0.58 g (Table 1). Starting from this stage, the testes and ovaries increase in size progressively. The average value of GSI had increased by about ten times compared to the previous stage (Table 1).
3.2.3. Macroscopic characteristics of Stage III - Maturation.
The colour of the gonads was white in males (Figure 4B), orange amber in females (Figure 4F). The gonads lie upon the swim bladder, and extend from the liver to the oviduct, with diameter 0.5-1.2 mm, and gonad weight 0.04-3.82 g (Table 1). The average value of GSI increased by about three times compared to the previous stage, and the average value of HSI increased about 1.5 times. This indicates that the HSI can be used as supporting information in the determination of maturation stage (Table 1).

3.2.4. Macroscopic characteristics of Stage IV – Maturity
The colour of the gonads was white in males (Figure 4C), orange amber in females (Figure 4G). The gonads were becoming larger and denser. The gonads that lie upon the swim bladder extend from the
liver to the oviduct, with diameter 1.5-2.5 mm, and gonad weight 0.16-13.06 g (mean 5.61 g). The weight of the gonads varies depending on the size of the fish. At this stage, GSI was increasing rapidly, about 4.2 times that in the previous stage (Table 1). By the end of this stage, sperm or eggs were flowing out when the gonad was slashed with a scalpel.

3.2.5. Macroscopic characteristics of Stage V – Post Spawning or Resting.

The size of the gonads in males and females has decreased dramatically (Figure 4D and 4H). The female gonad looks flat and wrinkled, and becomes brown in colour (Figure 4H). In males, there were sometimes remnants of sperm still in the testes (Figure 4D). The gonad size decreased dramatically, with an average weight of 0.27 ± 0.45 g, and a diameter of 0.3-0.6 mm. In this phase the size of the liver also decreases dramatically (Table 1).

3.3. GSI and HSI Curves

GSI and HSI curve increased progressively from stage I to IV, then decreased dramatically in stage V. The standard deviations were very large in stage IV (Figure 5).

![Figure 5. The GSI (A) and HSI(B) curves of dusky parrotfish Scarus niger from present study.](image)

4. Discussion

The stages of dusky parrotfish gonad maturity based on the macroscopic character of the gonad show the consistency of the data which was reflected by the progressive increase in GSI. According to its morphological characteristics, the dusky parrotfish is a total spawner, therefore, naming used for the initial stage (Stage I and II) was the same as that used for sea cucumbers that are also total spawners [17-19].

The progressive increase in GSI value was related to the increase in gonad mass during the process of gamete formation in the gonads. The GSI values vary and become even greater when entering stage IV. This variation, which could be seen in the value of standard deviation (Table 1), is normal and common in aquatic organisms [19] because the reproductive capacity of each group is different [19, 20].

GSI and standard deviation dropped dramatically in stage V (Table 1), a trait which is also commonly observed in aquatic total spawners [19], whereas in organisms with a partial spawning pattern, GSI and standard deviation do not decrease drastically [10, 21, 22]. There are two scenarios that might occur in partial spawners: firstly, the organism has two stages with a long-lasting spawning stage before entering the post spawning stage. Secondly, the organism does not have a true post-spawning stage, as for Thunnus albacores. As soon as the spawning stage is complete, the gonad maturation process begins immediately [10], which makes the gonad look as if the spawning process has not been completed yet.

Environmental factors, such as the presence of pollutant compounds are also very influential on the reproduction of organisms. Pollutant compounds are generally neutralized by the liver. Although a few samples were found with hardened livers, the fact that the value of GSI and HSI were very low
indicate that the environmental effects on the egg development that happens partly in the liver, was not affecting the specimens in the present study. Therefore, the environmental factors could be ignored. Moreover, the liver is not the only place to neutralize pollutants that enter an organism's body.

The uniqueness of the dusky parrotfish maturity stage classification was that the gonad maturation stage is divided in two stages, namely early maturation and maturation stage which are long lasting phases. The reason for this division was the long maturation phase so that it needs to be divided into two.

5. Conclusion
The five stages of gonad maturity used to identify the stages of gonad maturity in the dusky parrotfish *Scarus niger* are quite accurate. This accuracy is demonstrated by the values of GSI and HSI, which increased progressively from Stage I to IV. This accuracy validates the macroscopic characters of the gonad which will be used to identify maturity stages. Based on the results of this study it can be concluded that the combination of macroscopic and morphometric characters of the gonad could overcome the weaknesses of naked-eye visual examination in determining the maturity stages of *Scarus niger*.

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References

[1] Kuiter R H and Tonozuka T 2001 Pictorial Guide to Indonesian Reef Fishes. Part 1. Eels-Snappers, Muraenidae - Lutjanidae vol 5 (Australia: Dive & Dive's)
[2] Randall J 1986 Scaridae Smiths' sea fishes. Berlin, Springer-Verlag 706-14
[3] Breder C M and Rosen D E 1966 Modes of reproduction in fishes (New York: Natural History Press)
[4] Darmaillacq A-S, Dickel L, Rahmani N and Shashar N 2011 Do reef fish, variola louti and *Scarus niger*, perform amodal completion? Evidence from a field study Journal of Comparative Psychology 125 273
[5] Lieske E and Myers R 1994 Collins Pocket Guide. Coral Reef Fishes. Caribbean, Indian Ocean Including the Red Sea: Harper Collins Publisher)
[6] Myers R F 1999 Micronesian reef fishes (Barrigada, Gua: Coral Graphics)
[7] Sommer C, Schneider W and Poutiers J 1996 Species identification field guide for fishery purposes: the living marine resources of Somalia (Rome: FAO)
[8] Barba J 2010 Demography of parrotfish: age, size and reproductive variables. (Townsville: James Cook University)
[9] Aquamaps 2019 Computer Generated Native Distribution Map for *Scarus niger* (Dusky parrotfish), with modelled year 2100 native range map based on IPCC A2 emissions scenario. (Aquamaps)
[10] Kantun W, Mallawa A and Tuwo A 2018 Reproductive pattern of yellowfin tuna *Thunnus albacares* in deep and shallow sea FAD in Makassar Strait AAACL Bioflux 11 884-93
[11] Valdés P, García-Alcázar A, Abdel I, Arizcun M, Suárez C and Abellán E 2004 Seasonal changes on gonadosomatic index and maturation stages in common pandora *Pagellus erythrinus* (L.) Aquaculture International 12 333-43
[12] Htun-Han M 1978 The reproductive biology of the dab *Limanda limanda* (L.) in the North Sea: gonosomatic index, hepatosomatic index and condition factor Journal of Fish Biology 13 369-78
[13] Knittweis L, Jompa J, Richter C and Wolff M 2009 Population dynamics of the mushroom coral *Heliofungia actiniformis* in the Spermonde Archipelago, South Sulawesi, Indonesia Coral Reefs 28 793-804
[14] Nelson J S, Grande T C and Wilson M V 2016 *Fishes of the World* (New Jersey: John Wiley & Sons)

[15] Choat J and Robertson D 1975 *Intersexuality in the animal kingdom*: Springer pp 263-83

[16] Howard J and Randali E 1986 A review of the parrotfishes (family Scaridae) of the Great Barrier Reef of Australia with description of a new species *Records of the Australian Museum* **38** 175-228

[17] Tuwo A and Conand C 1993 Fécondité de trois holothuries tempérées un développement pélagique. In *Echinoderm trough Time*, ed B. David et al, 561-568, Rotterdam: A. A. Balkema. ISBN: 90 5410 514 3

[18] Tuwo A and Conand C 1992 Reproductive biology of the holothurian *Holothuria forskali* (Echinodermata) *J. Mar. Biol. Assoc. U. K.* **72** 745-58

[19] Tuwo A 1999 Reproductive cycle of the holothurian *Holothuria scabra* in Saugi Island, Spermonde Archipelago, Southwest Sulawesi, Indonesia *SPC Beche-de mer Information Bulletin* **11** 9-12

[20] Burton M and Idler D 1984 The reproductive cycle in winter flounder, *Pseudopleuronectes americanus* (Walbaum) *Canadian Journal of Zoology* **62** 2563-7

[21] Burton M and Idler D 1987 An experimental investigation of the non-reproductive, post-mature state in winter flounder *Journal of Fish Biology* **30** 643-50

[22] Hassanin A, Kuwahara S, Tsukamoto Y, Ogawa K, Hiramatsu K and Sasaki F 2002 Gonadosomatic index and testis morphology of common carp (*Cyprinus carpio*) in rivers contaminated with estrogenic chemicals *Journal of Veterinary Medical Science* **64** 921-6