Early maturity of Sandfish *Holothuria scabra* offers more prospective broodstock supply of a commercially important aquaculture species

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Abstract. The supply of broodstock is a critical limitation on aquaculture of the commercially important sea cucumber *Holothuria scabra*. Previous research reported that *H. scabra* mature at a size of more than 450 g. This size is questionable because biologically primitive organisms such as *H. scabra* mature relatively early. This study aimed to analyze the size at first maturity of *H. scabra*. The first sexual maturity was analysed by dividing the *H. scabra* by weight with 25 g weight class intervals, resulting in 12 weight groups. The size at first sexual maturity was determined using mature *H. scabra* (Stages III, IV, and V). The first maturity of *H. scabra* was reached at a smaller size than previously reported, from 178 *H. scabra* that were observed, the first sexual maturity is achieved at 42 g gutted body weight. Small *H. scabra* potentially used as broodstock, which will produce *H. scabra* seeds in hatcheries. Although small in size, *H. scabra* mature can reproduce, of course, with a smaller reproductive capacity. Small size at the first sexual maturity offers the potential for dramatic improvements in the procurement of broodstock stock, by providing a much more accessible supply of *H. scabra* prospective broodstock.

1. Introduction

Sea cucumbers in the Southeast region of Asia, including Indonesia, have a significant economic value, especially for coastal communities [1-5]. Indonesia is the largest sea cucumber producer in the world [2, 6, 7]. However, sea cucumber production is still reliant on catches from the wild [8]. This wild catch is causing over-exploitation [9-12]. Moreover, in some areas sea cucumber populations have decreased to the point where they can be regarded as a rare species [13]. Several attempts have been made to increase sea cucumber production through the cultivation of the *H. scabra* in coastal ponds [14] and coastal areas [3, 8], but these efforts have not yielded the anticipated results [15]. *H. scabra* species was chosen to be cultivated because of its ability to tolerate a wide range of salinity [16]. Furthermore, it is one of the 16 main holothurians harvested commercially in Indonesian coastal waters [17].

Seed availability is one of the problems for culture and restocking of wild stocks of the sea cucumber [18]. The numbers of *H. scabra* juveniles caught from the wild is insufficient to meet the
needs of seeds. Meanwhile, *H. scabra* can be reproduced under hatchery conditions in millions but the number is not enough for their use in aquaculture. Seed production in hatcheries is limited by the availability of broodstock that can spawn in the hatchery [1]. There are two reasons that caused the limitation of broodstocks. Firstly, the number of *H. scabra* broodstock catches from nature is unpredictable. Secondly, large brooders are preferred for use in a hatchery, and the quantity available does not meet the demand [14, 19]. It means that the number of eligible broodstock is limited.

*H. scabra* is one of the most abundant and widely distributed tropical sea cucumbers [11, 20-27]. Over this broad distribution, *H. scabra* exhibits two main basic reproductive patterns, which are seasonally predictable spawning at high latitude [28, 29]; and year-round spawning, with seasonal spawning peaks, at low latitudes [30-32]. Previous research has also reported that *H. scabra* mature at a weight of 450-500 g [33]or 16.8 cm in length [23]. This size is questionable because biologically primitive organisms, such as *H. scabra*, generally tend to mature relatively early [32]. This size is also in contradiction with the reality observed in nature, where smaller sized sea cucumber with mature gonads have been encountered [32].

This uncertainty regarding the life history characteristics of *H. scabra* indicated the need for a study to determine the first maturity of *H. scabra*. It is hoped that the results of this study could help to overcome one of the problems experienced by *H. scabra* hatcheries, i.e., the availability of viable broodstock.

2. Materials and methods

*H. scabra* were collected at night during low tide, from the waters of Liukang Tupabbiring Utara Village, Pangkep Regency, South Sulawesi, Indonesia (4°42’13” S, 119°37’04” E), from March to June 2017. Total length (TL), gutted body weight (BW), and gonad wet weight (GW) of each individual was measured. Distribution of gonad maturity stage, gonad indices, and the bodyweight at first sexual maturity were analyzed by grouping the *H. scabra* into 12, based on their weight, with intervals of 25 g. The twelve groups were: <25 g, 25 to <50 g, 50 to <75 g, 75 to <100 g, 100 to <125 g, 125 to <150 g, 150 to <175 g, 175 to <200 g, 200 to <225 g, 225 to <250 g, 250 to <725 g, and 725 to <750 g.

Gonad maturity stages were determined by referring to the five stages of gonadal maturity for *H. scabra* described by Tuwo [32], which are the immature stage (Stage I), resting (Stage II), maturation (Stage III), mature (Stage IV), and post-spawning (Stage V). The level of gonad maturity of each sample for each group was determined and then calculated. The data was then presented as a percentage.

Gonad index (GI) was calculated from gutted body weight (BW) and gonad wet weight (GW) for each weight class using the equation described by [29]. \( GI = \left( \frac{GW}{BW} \right) \times 100 \). The length-weight relationship [24] was analysed using the exponential regression equation [34].

The size and weight at first maturity were defined from the percentage of sexually mature *H. scabra* [24], with gonad stage of III, IV, and V [28]. The size and weight at 50% of *H. scabra* attained sexually mature [23, 35] was estimated using the logarithmic regression equation [34].

3. Results

3.1. Holothuria scabra size

During the study, 178 *H. scabra* was observed. The length range of the sampled *H. scabra* was 3.0–23.0 cm with a mean of 12.60±4.03 cm, while the weight range was 7.80–363.51 g with a mean of 84.17±57.29 g. The regression equation for the length-weight relationship is \( Y = 8.635e^{0.159X} \), with \( R^2 = 0.645 \) (Figure 1).
3.2. Gonad maturity
During the study, all five maturity levels/stages were observed. Each stage occurred over a given weight range, characterized by the mean weight and standard deviation. Individuals in maturity Stage I ranged from 7.80-76.70 g (29.49±17.09 g); those in maturity Stage II ranged from 10.83-344.34 g (113.49±72.79 g), while maturity Stage III individuals ranged from 15.09-363.51 g (99.12±59.92 g), maturity Stage IV individuals ranged from 18.44-354.15 g (131.05±77.22 g), and maturity Stage V individuals ranged from 126.34-187.87 g (161.44±24.03 g). Maturity Stage I was found up to class 75-100 g. Maturity Stage II found from size 75 g upwards. Maturity stage III and IV were found in all gutted body weight groups. Maturity Stage V was found in both small and large-sized *H. scabra* (Figure 2).

3.3. Gonad index
The gonad index of *H. scabra* found in this study ranged from 0.03–59.48% (mean of 5.41±7.48%). The standard deviation range quite large for both overall and in each size class, especially for size classes above 275 g (Figure 3).
3.4. First maturity
Male and female H. scabra were observed to mature at a relatively small size (Figure 4). First maturity was 42 g gutted body weight (Figure 5).

Figure 3. Gonad Index of Sandfish Holothuria scabra by gutted bodyweight class.

Figure 4. Sandfish Holothuria scabra at the mature gonads (A: Male Stage IV; B: Female Stage IV).

4. Discussion
4.1. Holothuria scabra
Changes in the size of the average individual in a population can describe harvesting effort that occurs in a population [36]. During this study, the largest size class that collected was 275-300 g. The relatively small size of the individuals observed and collected during this study could be due to the effects of overfishing [11, 23], especially as there is anecdotal evidence that larger H. scabra used to be common at this site around 20 years ago [37]. As a comparison in the Sudanese Red Sea, even in poor habitat conditions, it has been reported that the gutted bodyweight of H. Scabra can reach 833-3000 g [33].
4.2. Gonad maturity
Gonad maturity represents the phase of reproductive organ development for both male and female organisms. Macroscopically, the structure of the sandfish gonads is the same as that of other sea cucumber gonads [28], and fish that have gonads resemble bags [38-40]. Previous studies indicate that the development of gonad maturity for both males and females H. scabra was synchronous [28, 32]; therefore, in this study, the distribution of gonad maturity was described using the combined gonad maturity of male and female. The size of mature H. scabra (Stages III, IV, and V) found in this study is much smaller than those found in previous studies for this species [32], as well as for other species of sea cucumbers [29, 41, 42]. Harvesting effort can lead to a negative impact on the size and age of organisms maturity. Therefore, it is necessary to search for ways to minimize harvesting impact on the reproductive biology of H. scabra [36]. Biologically, there are two types of reproductive strategies in organisms, strategies ‘r’ and ‘K’. The ‘r’ strategy is found in organisms that are dominantly controlled by their environmental factors and tend to reach physical maturation faster, while the ‘K’ strategy is controlled more by biological factors, such as the presence of competitors. Organisms that carry out the ‘K’ strategy are generally slow to achieve physical maturity compared to the other strategy [43]. The results of present study indicating that, H. scabra is an organism that uses the ‘r’ strategy and classified as total spawners, where each gonad tube only spawns once [32].

4.3. Gonad index
Gonad index portray the proportion of the weight of the gonad relative to the weight of the organism [44]. The gonad index value will increase, along with the development of gonad maturity [28]. The gonad index values found in the present study (Figure 5) were similar to those previously found in larger H. scabra from the same spot [32], and also relatively not different from the species found in the Indo Pacific region [28, 29], which shows that small H. scabra has reached maturity and ability to reproduce.

Naturally, H. scabra has many predators [45] and relatively easy to prey on because of its slow movements. Naturally, H. scabra is also prone to evisceration if disturbed [46]. Therefore, early maturity is thought to be a reproductive strategy for H. scabra to speed up its reproductive process so that it can reproduce at least once before being eaten by predators. On the other side, if it looks at the gonad index value, H. scabra seems to allocate more energy for reproduction than reef fish [39, 40] or large pelagic fish [47]. It is also thought to be a reproductive strategy for H. scabra to produce more eggs to increase the success of the reproductive process. These indicate that small H. scabra could be used as broodstock at a young age. The young H. scabra can be collected easily in a low tide zone without suffering from evisceration, so that it is more suitable for hatcheries conditions compared to

![Figure 5. Size at first maturity of Holothuria scabra related to gutted body weight.](image-url)
the larger *H. scabra*, which usually inhabit deeper water that it is usually more prone to eviction when they are moved from deep waters.

4.4. First maturity

The first maturity is not only an important parameter in the management of fisheries resources [35], but also important for broodstock management [48]. The average size at first maturity for *H. scabra* found in this study is smaller than that reported elsewhere. *H. scabra* from the lagoon of New Caledonia had an average size at first maturity of 140 g gutted body weight [29], while *H. scabra* from the Sudanese Red Sea Coast had an average size of 450-500 g at first maturity [33]. Two closely related species have also been reported as having higher weights at first maturity compared to the result found. *Holothuria atra* found in Sudanese waters [33], and from the lagoon of New Caledonia [29] had a gutted body weight at first maturity of 101 to 110 g and 110 g respectively, while *H. grisea* in Brazil had an average weight at first maturity of about 90 g [49]. Size at first maturity is generally used as a biological parameter in maximizing the yield per recruit [50, 51].

The ability of *H. scabra* to reproduce quickly could be an advantage in the context of aquaculture. This study indicates that, on average, from 178 *H. scabra* that were observed, the first sexual maturity is achieved at 42 g gutted body weight. This result offers the potential for dramatic improvements in the procurement of broodstock stock by providing a much more accessible supply of *H. scabra* prospective broodstock. Although small in size, *H. scabra* mature can reproduce, of course, with a smaller reproductive capacity. This smaller reproductive capacity can be solved by spawning large numbers of small broodstock through mass spawning.

5. Conclusion

The first maturity of *H. scabra* was reached at a smaller size than previously reported, from 178 *H. scabra* that were observed, the first sexual maturity is achieved at 42 g gutted body weight. Small *H. scabra* potentially used as broodstock, which will produce *H. scabra* seeds in hatcheries. Although small in size, *H. scabra* mature can reproduce, of course, with a smaller reproductive capacity. Small size at the first sexual maturity offers the potential for dramatic improvements in the procurement of broodstock stock, by providing a much more accessible supply of *H. scabra* prospective broodstock.

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