Size at the maturity of sea cucumber *Holothuria scabra*. Is it an overfishing sign in Wallacea Region?

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Abstract. As the largest trepang producer in the world, Indonesian trepang product still depends on wild catches. This wild catch could cause overfishing. In many fishing areas, sea cucumber populations have decreased to the point where they can be considered as a rare species. The wild catch could lead to a negative impact on size at maturity. Biologically, there are two types of reproductive strategies at marine organisms, i.e. 'r-selection' and 'K-selection'. The 'r-selection' type was found in organisms that are dominantly controlled by their environmental factors and tend to reach physical maturation faster, while the 'K-selection' type was controlled more by biological factors, such as the presence of competitors. This study aims to analyze the size at the maturity of sea cucumber *Holothuria scabra* for different years to find out if the size at maturity can be used as a reference of the overfishing sign in the Wallacea region. The *H. scabra* or sandfishes were taken from the catches of fishermen at the Sub-district Liukang Tupabbiring Utara, Pangkep Regency, South Sulawesi, Indonesia. The Liukang Tupabbing area is in the Spermonde Islands region, which is part of the Wallace line trajectory. Samplings were carried out for four years, from 2016 to 2019. The parameters measured were a total length (TL), total weight (TW), and gutted body weight (BW). The parameters observed were the color and stage of the gonad. The sizes at maturities were defined as the percentage of sexually mature, which were the sandfish with gonad stages of III, IV, and V. The study reveals that the size at maturity of sandfish was reached at a smaller size than previously reported. Biologically, smaller sizes at maturity could be a sign that sandfish has overfishing. As one organism whose biological organ structure was still primitive, Sea cucumber probably maintains the continuity of its generation by adapting reproductive strategy "r-selection type".

1. Introduction
Trepang has been collected, processed, traded, or consumed by diverse groups of people, largely in East and Southeast Asia [1]. Southeast Asia is the principal producer of sea cucumber worldwide, and many species of sea cucumbers in the region have significant economic value, especially for coastal communities [2–4].
H. scabra or sandfish is one of the most abundant and widely distributed tropical sea cucumbers [5]. Sandfish harvests are one of the largest sea cucumbers catches worldwide, and it is an important source of income for marginal fishers in impoverished coastal villages in Southeast Asian countries [2]. Indonesia has been and still remains the top producer of dried sea cucumber or trepang on a global scale. The sea cucumber fishery and trepang trade have already been described from several islands in Indonesia [4].

As the largest trepang producer in the world, Indonesian trepang product still depends on wild catches. This wild catch could cause overfishing. In many fishing areas, sea cucumber populations have decreased to the point where they can be considered as a rare species [6]. The wild catch could lead to a negative impact on size at maturity.

Biologically, there are two types of reproductive strategies at marine organisms, i.e. ‘r-selection’ type and ‘K-selection’ type. The ‘r-selection’ type was found in organisms that are dominantly controlled by their environmental factors and tend to: (1) rapid development, (2) high $r_{\text{max}}$, (3) early reproduction, (4) small body size, and (5) semelparity; while the ‘K-selection’ type was controlled more by biological factors, such as the presence of competitors and tend to: (1) slow development, greater competitive ability, (2) lower resource thresholds, (3) delayed reproduction, (4) larger body size, and (5) iteroparity [7]. This study aimed to analyze the size at the maturity of sandfish Holothuria scabra for different years to find out if the size at maturity can be used as a reference for the overfishing sign in the Wallacea region.

2. Methods
The Sandfishes were taken from the catches of fishermen at the Sub-district Liukang Tupabbiring Utara, Pangkep Regency, South Sulawesi, Indonesia (Figure 1).

Figure 1. Map of the sampling location in Sub-district Liukang Tupabbiring Utara.
The Liukang Tupabbiring Utara is located within the Spermonde Islands region, which is part of the Wallace line trajectory. The Spermonde Islands are located in the Makassar Strait region, which is one of the fishing grounds in South Sulawesi. The Spermonde Islands is an archipelago that consists of 120 islands which have an area of around 2,500 km², consisting of 50 vegetated islands and 70 non-vegetated sand dunes [8]. The vegetated islands was inhabited around 50,000 people [9].

Samplings were carried out for four years, from 2016 to 2019. The parameters measured were the total length (TL), total weight (TW), and gutted body weight (BW). The length was measured with an accuracy of 1 mm, while the weight was measured with an accuracy of 0.01 g. The length-weight relationship was estimated using the regression equation.

Class interval determination of the BW frequency distribution, starting by determining the range (R) value of BW, which was the largest value subtracting by the smallest value of BW. The number of interval classes (I) was determined by using the formula: \( I = 1 + 3.3 \log n \), where \( n \) was the number of samples. The length of the class interval (C) was determined by using the formula: \( C = R/I \). The first interval class was determined by summing the smallest BW value by the length of the class interval (C) then subtracting the BW value by the smallest unit of the accuracy of the measuring instrument (scales). The second interval class was determined by summing the lower limit of the first class to the length of the class interval (C) then subtracting from the smallest unit of the accuracy of the measuring instrument (scales). The third class and so on until reaching the number of interval classes (I) were determined in the same way.

The parameters observed were the color and stage of the gonad. Gonad maturities stages were determined by referring to the five stages of gonad maturity for sandfish described by Tuwo [2], which were the immature stage (Stage I), resting (Stage II), maturation (Stage III), mature (Stage IV), and post-spawning (Stage V). The BW at the first maturity was defined from the percentage of sexually mature sandfish [10], by using gonad stage of III, IV, and V.

Length-weight relationship was estimated using the regression equation. The size and weight at 50% of sandfish attained sexually mature [11] was estimated using polynomial trendline order three for the year 2016 and order six for years 2017-2019.

3. Results

3.1. Samples size distribution and length-weight relationship

The BW range (R) values were determined using BW of all samples from 2016-2019. The integration of all samples was expected to get the same size class for all year samplings. The Range (R) values of BW were 343.32 (354.15 - 10.83). The number of interval classes (I) was approximately 9 class intervals \((1 + 3.3 \log n)\). The length of the class interval (C) was 42.92 g (343.32/9). The nine interval classes were 10.83-53.74, 53.75-96.66, 96.67-139.58, 139.59-182.50, 182.51-225.42, 225.43-268.34, 268.35-311.26, 311.27-354.18, and 354.19. In 2016 there were 115 samples with sizes from 1.81 to 354.15 g (69.47 ± 91.90 g). Of the 115 samples, only 20 samples were on stages III, IV, and V, with sizes from 47.55 to 354.15 g (195.70 ± 94.76 g) (Figure 2A). In 2017 344 samples were obtained with sizes from 3.12 to 363.51 g (70.01 ± 55.52 g). Of the 344 samples, only 111 samples are on stages III, IV, and V, with sizes from 10.83 to 268.99 g (97.76 ± 49.81 g) (Figure 2B). In 2018 49 samples were obtained with sizes from 3.49 to 131.15 g (33.07 ± 21.26 g). Of the 49 samples, only 22 samples are on stages III, IV, and V, with sizes from 16.58 to 106.24 g (35.79 ± 19.05 g) (Figure 2C). In 2019 there were 118 samples with sizes from 9.99 to 159.38 g (35.76 ± 30.90 g). Of the 118 samples, only 38 samples are on stages III, IV, and V, with sizes from 13.83 to 159.38 g (62.62 ± 41.94 g) (Figure 2). The length-weight relationship were exponential with equation \( TW = 4.156e^{0.228TL} \) (\( R^2 = 0.790 \)) for total length and total weight, and \( BW = 4.222e^{0.208TL} \) (\( R^2 = 0.735 \)) for total length (TL) and gutted body weight (BW) (Figure 3).

3.2. Size at the first maturity

In 2016, size at the first maturity was around 170 g (Figure 4A), and size at the first maturity was in the fifth class interval. In 2017, it was 75 g (Figure 4B), size at the first maturity dropped to the third
class interval. In 2018 was 15 g (Figure 4C), the size at the first maturity dropped to the first class interval. And in 2019 was 30 g (Figure 4D), up slightly and was slightly below the average size of the second class interval.

Figure 2. Samples size distribution of sandfish *Holothuria scabra*.

Figure 3. The length-weight relationship of sandfish *Holothuria scabra*.

Figure 4. Size at the first maturity of sandfish *Holothuria scabra*. 
4. Discussion

Even Indonesia is the largest sea cucumber producer in the world [3,12], Indonesian trepang is still reliant on catches from the wild. This wild catch was could cause over-exploitation [13,14]. Moreover, in some areas, sea cucumber populations have decreased to the point where they can be regarded as a rare species.

Changes in the size at the first maturity can describe harvesting effort that occurs in a population. During this study, the size at the first maturity decrease progressively indicates that sandfish population was overfishing [11,14]. Reduce in size is questionable because biologically primitive organisms, such as sandfish, generally tend to mature relatively early [4]. This size is also in contradiction with the reality observed in nature, where smaller sized of sandfish with mature gonads have been encountered [2].

The size of mature sandfish (Stages III, IV, and V) found in this study is much smaller than those found in previous studies for this species [2], as well as for other species of sea cucumbers [15]. Fishing effort can lead to a negative impact on size and age of organism's maturity. Therefore, it is necessary to look for ways to minimize harvesting impact on the reproductive biology of H. scabra.

The first maturity is a very important parameter in the management of fisheries resources. The average size at first maturity of sandfish found in this study is smaller than that reported elsewhere. Sandfish from the lagoon of New Caledonia had an average size at first maturity of 140 g gutted body weight, while sandfish from the Sudanese Red Sea Coast had an average size of 450-500 g at first maturity [16]. 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 [16], and from the lagoon of New Caledonia 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 [17]. Size at first maturity is generally used as a biological parameter in maximizing the yield per recruit [18]. The results of this study indicate that sandfish reach size at the first maturity at a very small size (15 g BW). This indicates that the sandfish has a reproductive strategy "r-selection" type. This explains why the reduction in the size of the sandfish caught still found sandfish at maturity.

5. Conclusion

The study reveals that the size at maturity of sandfish was reached at a smaller size than previously reported. Biologically, smaller sizes at maturity could be a sign that sandfish has overfishing. As one organism whose biological organ structure was still primitive, sandfish probably maintains the continuity of its generation by adapting the reproductive strategy "r-selection" type.

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