JPPIPA 9(4) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Study of Length-Weight Relationship and Condition Factor of Sandfish Sea Cucumber (*Holothuria scabra*)

Andy Rasyadi[1*], Etty Riani[2], Sigid Hariyadi[2], Neri Kautsari[3]

[1] Post Graduate Student at Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, Bogor, Indonesia.
[2] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, Bogor, Indonesia.
[3] Aquatic Resources Management Program, Faculty of Animal Husbandry and Fisheries, Universitas Samawa, Sumbawa, Indonesia.

Received: February 7, 2023
Revised: April 20, 2023
Accepted: April 25, 2023
Published: April 30, 2023

Corresponding Author:
Andy Rasyadi
andyrasyadi@gmail.com

DOI: 10.29303/jppipa.v9i4.3115

Abstract: The overfishing of the sandfish *Holothuria scabra* is increasing due to its various benefits, thus reducing its population in nature. This study aimed to examine sandfish's length-weight relationship and condition factors on the North Coast of Sumbawa Island, with sampling locations at two stations, Ai Limung (Pungkit Village), and Labu Prajak (Batu Bangka Village). The study was conducted in September-October 2022. A total of 142 specimens were obtained from both stations, 122 samples at Ai Limung station (mean length 9.22±2.12 cm; weight 43.34±25.07 grams). Then 20 samples at the Labu Prajak station (mean length 13.69±3.74 cm; weight 88.70±60.06 grams). Growth patterns of each research station are negative allometric, indicating the body length of the sandfish grows faster than its weight. Condition factor at Ai Limung station Kn=1.03±0.26, Wr=1.03±0.26, K=5.33±1.76, and at the Labu Prajak station Kn=1.05±0.28, Wr=104.88±27.83, K=3.27±1.14. The results showed significant differences in length, weight, and fulton condition factor. The mean body length and weight of sandfish at both stations are smaller than previous study, indicating the earlier sign of overfishing. Meanwhile, the fulton condition factor at Ai Limung station showed a higher value, which indicated the location was better, with abundant food sources and fewer predators.

Keywords: Biometric information; Condition factor; *Holothuria scabra*; Length-weight relationship; Sandfish; Sumbawa

Introduction

Sea cucumbers are one of the most widely used marine invertebrates from the phylum Echinodermata. The economic value of these animals is enormous in local and international markets. Since the expansion of the use of sea cucumbers in various industries, especially the medical industry, the annual harvest rate of sea cucumbers has increased (Kautsari et al. 2019). The sandfish (*Holothuria scabra*) is the most commonly caught species of sea cucumber in the wild. This is because sandfish (*H. scabra*) have a relatively higher and more stable price when compared to other sea cucumber species, especially in Asian markets (Abidin et al. 2019). For example, in Guangzhou, China, 1 kg of sandfish is priced on average at US$153 and in Hong Kong US$396 (Purcell et al. 2018), while in Indonesia the price can reach to IDR 3-5 million/kg (Aprianto et al. 2020).

Besides high price, sandfish sea cucumbers are known for their extraordinary nutritional value that bring benefits for humans. According to Ardiansyah et al. (2020), sea cucumber *Holothuria scabra* is a valuable source of nutrition due to its high protein content and low fat content. In addition to its protein and fat content, it is also rich in important minerals such as Calcium, Sodium, and Magnesium, which are essential for maintaining good health. Furthermore, *Holothuria scabra* contains Glycine as its primary amino acid, which is important for building and repairing tissues in the body. Glycine also plays a role in regulating the immune system and promoting healthy brain function. Additionally, the fatty acid profile of *Holothuria scabra* is dominated by Omega-6 and Omega-9 fatty acids, which are essential for maintaining good cardiovascular health and reducing inflammation in the body. Several studies have identified additional benefits of sandfish, including

How to Cite:
Rasyadi, A., Riani, E., Hariyadi, S., & Kautsari, N. (2023). Study of Length-Weight Relationship and Condition Factor of Sandfish Sea Cucumber (Holothuria scabra). *Jurnal Penelitian Pendidikan IPA*, *9*(4), 1687–1695. https://doi.org/10.29303/jppipa.v9i4.3115

their use as a natural source of aphrodisiacs, as potential anti-aging agents in postmenopausal women, as potential drugs that can improve men's reproductive quality (Riani et al. 2017; Hoang et al. 2022). As a source of natural antioxidants, fucoidan, and triperten glycosides, also have antibacterial, antifungal, and antitumor properties (Hossain et al. 2022).

The demand for the sandfish (*H. scabra)* which fluctuates and tends to increase from year to year will result in high fishing efforts, where efforts to catch this organism in the wild without considering its carrying capacity will result in a severe population decline (Hasan, 2019). Due to overexploitation and inefficient management, sea cucumber fisheries have declined drastically globally over the last decades (Conand, 2018). Sandfish (*H. scabra*) is one of the species included in the "endangered" category on the IUCN red list of threatened species (Junus et al. 2018).

Sandfish (*H. scabra*) have been caught in many regions in Indonesia, one of which is in Saleh Bay, Sumbawa Regency. These areas are located in the northern part of Sumbawa Island, the main collection center for sandfish. According to Kautsari et al. (2019), although sandfish have been harvested off the coast of Saleh Bay for quite a long time, there still needs to be more information and study data regarding this type of sea cucumber. This is due to the need for more research conducted in Saleh Bay, especially in the Sumbawa region. However, there is still a lack of research on the length-weight relationship, and condition factors of sandfish.

The examination of the relationship between the length and weight of fish, in this case sea cucumber, is a crucial and advantageous pursuit for numerous reasons. It allows for the acquisition of valuable data concerning growth patterns, general health, life history, habitat conditions, sea cucumber fatness, and morphological characteristics of sea cucumber (Khalid et al. 2020). The determination of length-weight relationships and relative condition factors is particularly significant in fishery assessment studies since it provides insights into the growth, general wellbeing, and fitness of sea cucumber within a marine environment. Furthermore, these studies have considerable implications for the management and conservation of natural sea cucumber populations (Jisr et al. 2018). Thus, the main objective of this study was to examine the length-weight relationship, and condition factors of the sandfish *H. scabra* caught around the northern coastal area of Sumbawa Island.

Method

This research was conducted in September-October 2022 in two intertidal areas of Sumbawa Island, namely in Ai Limung Hamlet, Pungkit Village (station A: 8°24'12.50"S, 117°33'4.56"E), and Labu Prajak Hamlet, Batu Bangka Village (station B: 8°26'23.66"S, 117°33'53.09"E). The two research locations were selected using a purposive technique. Primary considerations were based on the results of literature studies and pre-research interviews. It is known that native peoples and migrants have long used these two areas as the central location for searching for sandfish with the local name *Bantin Loto*, either for sale or direct consumption. The following is a map of the research location on Sumbawa Island, Sumbawa Regency, NTB Province (Figure 1).

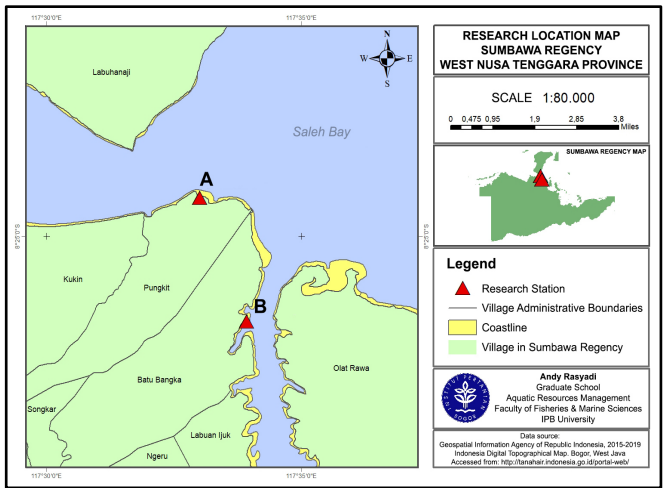

Figure 1. Sampling Locations of Sandfish *H. scabra* A: Ai Limung Hamlet, Pungkit Village; B: Labu Prajak Hamlet, Batu Bangka Village, Sumbawa-NTB

The research procedure was adapted from Gamage et al. (2021) direct measurements were made, namely in the form of the length and weight of sandfish, using a measuring ruler (accuracy 0.1 cm) and analytical scales (accuracy 0.01 g). Determination of sandfish samples for metric measurements using a random sampling technique. Assuming the caught sandfish sea cucumbers represent the overall population size. Sampling locations were conducted in the intertidal zone, many sea grasses occur and few corals, with a characteristic sandy mud substrate. Sampling was carried out at night with the help of fishermen, when the sea water receded by direct catch.

Because of their elasticity, sea cucumbers can lengthen and shorten themselves, and their body weight can also vary depending on their physiological conditions. Before measurement, the sandfish were taken out of the water, then placed in a dry container for about two minutes, and the water in their bodies drained on their own. The outside of the body that is still wet is wiped with a tissue or until dry enough so that it is possible to determine the actual size of the sea cucumber. This method is to anticipate the occurrence of error at the measurement stage.

Based on the length and weight data of the sandfish *H. scabra* that has been collected, the data is analyzed using simple linear regression to determine the relationship between length and weight, then calculating the condition factor. Analysis of the relationship between the length and weight of the sandfish *H. scabra* used the formula:

$$W = a\,L^b \quad (1)$$

Description:
W = sandfish total weight (g)
L = sandfish total length (cm)
a = ordinat
b = slope
Interpretation of the value of b as growth pattern as follows:
b = 3 (isometric)
b > 3 (positive allometric)
b < 3 (negative allometric)

Correlation analysis of the relationship between length and weight uses Pearson's correlation, with the interpretation of the correlation as follows:
0.00-0.19 = very weak correlation
0.20-0.39 = weak correlation
0.40-0.69 = moderate correlation
0.70-0.89 = strong correlation

In this study, the condition factors analyzed were limited to relative condition factors, relative weight condition factors, and fulton condition factors. Relative condition factor formula, follows:

$$K_n = \frac{W}{a\,L^b} \quad (2)$$

Description:
Kn = relative condition factor
W = sandfish total weight (g)
L = sandfish total length (cm)
a = ordinat
b = slope

Relative weight condition factors formula:

$$W_r = \frac{TW}{WS} \times 100 \quad (3)$$

Description:
Wr = relative weight
TW = sandfish total weight (g)
Ws = standard weight, obtained via Ws = a L^b
Fulton condition factor formula:

$$K = \frac{W}{L^3} \times 100 \quad (4)$$

Description:
K = fulton condition factor
W = sandfish total weight (g)
L = sandfish total length (cm)
3 = length coefficient or correction factor

Statistical Analysis

Differences in mean body length, weight, and condition factors for sandfish *H. scabra* were tested using the classical assumptions of normality and homogeneity of variance using the Shapiro-Wilk and Levene tests. If it meets the classical assumptions, further tests are performed using independent parametric statistical t-tests. If it does not meet the classical assumptions, the Mann-Whitney non-parametric test will be used.

Result and Discussion

Length-Weight Relationship Sandfish Sea Cucumber H. scabra

Sandfish *H. scabra* samples obtained from the two study locations totaled 142 specimens. There were 122 individuals around the intertidal waters of Ai Limung station and 20 individuals around the area of the intertidal waters of Labu Prajak station. The mean length of *H. scabra* caught at Ai Limung station was 9.26 ± 2.12 cm, while the mean weight was 43.34 ± 25.07 grams, with a body length range of 5.4–18.9 cm, and the weight range is 7.84–149.37 grams. Meanwhile, at the Labu Prajak station, higher results were found. Namely, the mean length of *H. scabra* caught was 13.69 ± 3.74 cm, with a mean weight of 88.70 ± 60.06 grams, then a range of 7.0–20.3 cm and weight between 18.23–216.1 grams. Based on the results of the Mann-Whitney test, there were significant differences in the length and weight of *H. scabra* at the two study sites (Table 1).

Table 1. The Number of Samples, the Mean Body Length and Body Weight of Sea Cucumbers *H. scabra* at the Two Study Sites

Station	n	Mean ± SD	
		Body length (cm)	Body Weight (gr)
Ai Limung	122	9.22±2.12[a]	43.34±25.07 [a]
Labu Prajak	20	13.69±3.74[b]	88.70±60.06 [b]

Note: Different superscript letters in the same column indicate a significant difference ($p<0.05$)

This difference is perhaps because the sandfish *H. scabra* caught at Labu Prajak was at a slightly deeper depth of seawater than the sandfish caught at Ai Limung with shallow water conditions. In addition, Labu Prajak station has aquaculture activities, a marine restaurant, and very close to settlement which might contribute unused feed waste and household waste, which are then consumed by sandfish sea cucumbers, and it might contribute to a larger mean body size on this station. Meanwhile, Ai Limung station has no similar anthropogenic activity like Labu Prajak station.

Beside differences in mean body length and weight, there were significant differences in the number of *H.*

scabra samples found. Furthermore, the mean body length and body weight of sandfish *H. scabra* in this study were smaller when compared to previous studies; for example, the mean body weight of *H. scabra* in Papua New Guinea, Oman, and India were 300 grams, Australia was 335 grams, and Egypt was 500 grams. While the mean body length of *H. scabra* in Papua New Guinea, Oman, India, and Australia is 19-25 cm, and in Egypt is 37 cm (Yussuf & Yahya, 2020). This may be a sign of overfishing and overexploitation due declining population in this area, especially on Labu Prajak station.

Labu Prajak station has long been regarded as the first catchment area for sea cucumbers, followed by Ai Limung station later. The lack of regulation in fishing practices has also been identified as a contributing factor to the declining population. This has led to a similar pattern of fishing behavior at the nearby Ai Limung station. Due to their proximity, the Ai Limung station is also susceptible to the same pressures and risks as the Labu Prajak station. Furthermore, according to the confessions of some fishermen at the study site, juvenile sandfish measuring 4–6 cm and weighing 10–20 grams were also caught, although this size was not recorded in this study. This fishing behavior could lead to smaller catch sizes. These findings are consistent with recent findings by Yanti et al. (2020), sandfish are now reaching maturity at a smaller size than what was previously recorded. This decrease in the size at which they reach maturity may indicate that overfishing has occurred, as smaller sizes at maturity can be a biological indicator of fishing pressure. Yussuf & Yahya (2020) also state that differences in the size of *H. scabra* from different populations or countries can be associated with differences in environmental factors such as food availability, fishing pressure, and water depth when sampling.

Based on the results of the calculation of the length-weight relationship of *H. scabra* from the two study locations, the equation $W=0.2980\ L^{2.1950}$, the correlation of the length-weight relationship (r)=0.8748 (strong correlation), and the value of the coefficient of determination (R^2) = 0.8109 or 81% at Ai Limung station. Whereas at the Labu Prajak station, the equation $W = 0.2154\ L^{2.2416}$, the correlation of the length-weight relationship (r) = 0.8826 (strong correlation), and the value of the coefficient of determination (R^2) = 0.8246 or 82%. The values of the coefficient of determination resulting from the calculation of the length-weight relationship from the two research locations indicate that the body weight of *H. scabra* can be used to predict its actual body length, and based on the regression analysis, the body length of sea cucumbers has a significant effect on body weight gain.

The b value can be obtained from the above equation, namely b = 2.1950 at the Ai Limung station and b = 2.2416 at the Labu Prajak station; both values are below three (b<3), which means the growth pattern is negative allometric. This growth pattern indicates that *H. scabra*'s body length increased faster than its body weight. The results of the calculation of the length-weight relationship and the growth pattern of *H. scabra* at each study location are presented in Table 2, and graphs of the regression analysis of the length-weight relationship are presented in Figure 2 and Figure 3.

Table 2. Length-Weight Relationship (LWR) and Growth Pattern of *H. scabra* at Each Study Sites

Station	a	b	r	R^2	Growth Pattern
Ai Limung	0.2980	2.1950	0.8747	0.8109	Negative allometric
Labu Prajak	0.2154	2.2416	0.8826	0.8246	Negative allometric

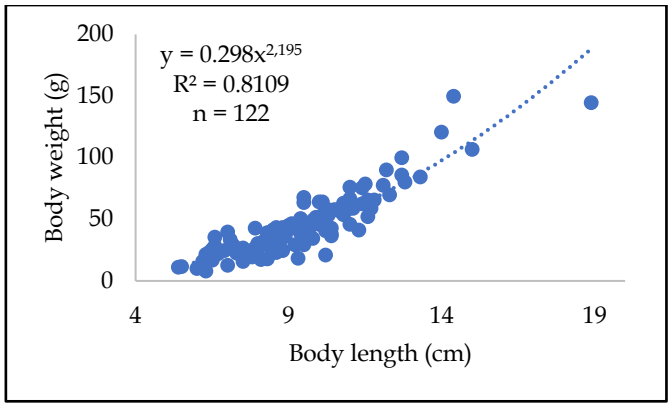

Figure 2. Length-Weight Relationship of Sandfish *H. scabra* on Ai Limung Station

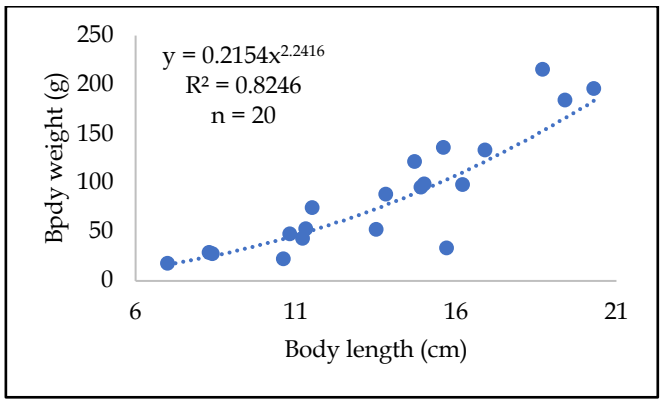

Figure 3. Length-weight relationship of Sandfish *H. scabra* on Labu Prajak station

These growth pattern of *H. scabra* in both locations have a similarity with previous study, which states that the growth pattern or the mean b value of *H. scabra* species is below 3, for example in Central Maluku-Indonesia b=1.662 (Manuputty, 2019), Zanzibar-Tanzania b=1.288-1686 (Yussuf & Yahya, 2020), Fiji b=2.5807 (Lee et al. 2018), and Oman b=1.22-1.88 (Al Jufaili et al. 2021). According to Azevedo e Silva et al.

(2021), negative allometric growth is a common phenomenon in sea cucumbers, which has been observed across most of the species. In this type of growth, sea cucumbers tend to increase in length more than their relative volume. It is believed that this pattern of growth serves as an adaptive strategy for sea cucumbers to increase their surface area to volume ratio as they grow. Since sea cucumbers rely on their body surface for important functions such as respiration, feeding, and excretion, increasing their surface area is essential. By becoming more elongated, sea cucumbers can achieve this without increasing their volume at the same rate, which allows them to perform their physiological functions more efficiently. Furthermore, Madruga et al. (2023) state that another advantage of negative allometric growth is that it helps sea cucumbers conserve energy as they grow. By investing more in length than in weight, they can reduce the amount of energy needed to maintain their body functions, which can be particularly crucial in environments where food is scarce.

The pressure of environmental change has also may be influenced these results. The two research locations have become new tourist destinations in Sumbawa Regency, especially Labu Prajak station which will later bring in anthropogenic pollutants. However, this assumption still requires supporting data. Many factors related to water pollution strongly influence the length-weight relationship, although this is still limited to fish species research only (Nur et al. 2020). In addition, studies on the length-weight relationship of the same species in different locations also show highly variable b values (Dinh et al. 2022), influential factors are food availability (quality, quantity, and size), seasonal variability of the environment, salinity, water temperature, sex and stage of maturity or sampling size (Famoofo & Abdul, 2020).

Condition Factor

Condition factor data were obtained from the results of length-weight relationship analysis. Condition factors can provide information about the health of aquatic organisms, their communities, and the quality of their habitat and ecosystem (Veronika et al. 2018). Relative condition factors, relative weight, and *H. scabra* fulton condition factors at both study locations are presented in Table 3.

Table 3. Relative Condition Factors, Relative Weight Condition Factors, and Fulton Condition Factors of Sandfish *H. scabra* in Both Study Locations

Station	Kn	Wr	K
Ai Limung	1.03±0.26	103.42±26.05	5.33±1.76[a]
Labu Prajak	1.05±0.28	104.88±27.83	3.27±1.14[b]

Note: Different superscript letters in the same column indicate a significant difference ($p<0.05$)

At Ai Limung station, the relative condition factor (Kn) with a value range of 0.43–1.87 (mean 1.03 ± 0.26), relative weight condition factor (Wr) with a value range of 42.80–187.17 (mean 103.42 ± 26.05), and condition factor fulton (K) with a value range of 1.97–12.21 (mean 5.33 ± 1.76). Whereas at Labu Prajak station, the relative condition factor (Kn) and the relative weight condition factor were found to be higher with a value range of 0.33–1.46 (mean 1.05±0.28), and 32.54–145.94 (mean 104.88 ± 27.83). However, the fulton condition factor (K) was lower than at the Ai Limung station, 0.87–5.31 (mean 3.27±1.14). Based on the results of the Mann-Whitney U test, there is no significant difference in the relative condition factor (Kn) and the relative weight condition factor (Wr). In contrast, in the fulton condition factor value (K), there is a significant difference ($p<0.05$) (Table 3).

Although there was no significant difference, the relative condition factor (Kn) at both stations was above ≥ 1, indicating that the sea cucumbers at both stations were in sufficient nutritional condition. The results are the same for the relative weight factor (Wr), which shows that the two research stations are above ≥ 100. If the relative weight condition factor is above 100, this indicates a surplus amount of food and few predators in their natural habitat (Ul Hassan et al. 2020). This condition factor is also influenced by abiotic and biotic factors, also anthropogenic factors such as exploitation and the fishery resources management status of the species (Manuputty, 2019; Vander Bloemen et al. 2020).

The fulton condition factor at both research stations was above 3, so it can be seen that the sample of sandfish *H. scabra* in this study came from populations that both had excellent physical condition and came from a healthy environment (Yussuf & Yahya, 2020). However, there is a significant difference between the two, the Ai Limung station has a much higher fulton (K) condition factor than the Labu Prajak station. This result could indicate that the Ai Limung station has a more fertile habitat than the Labu Prajak station. High condition factor values indicate the presence of protein, high fat, and abundant carbohydrates in these waters (Afdhila et al. 2019), also high abundance of detritus, which is one of primary food sources of sea cucumbers (Zhang et al. 2023). The high value of the condition factor is based on the number of organisms present, the availability of food, and the conditions of the aquatic environment (Afdhila et al. 2019).

Ideal aquatic environmental conditions can support the sandfish *H. scabra*'s growth. This result can also indicate water quality parameters in the habitat for living of sandfish sea cucumbers is within the optimal range (Manuputty, 2019; Meirinawati et al. 2020). The water quality parameters measured in this study are supporting data to describe the condition of the waters when the sandfish *H. scabra* was found (Table 4).

Table 4. Range of Water Quality Values Each Research Locations

Water Quality Parameter	Minimum-maximum value	
	Ai Limung Station	Labu Prajak Station
Temperature (℃)	27.80 – 31.70	29.00 – 32.20
Water depth (cm)	20.00 – 100.00	62.00 – 125.00
Salinity (ppt)	32.00 – 34.00	30.00 – 33.00
Dissolved Oxygen (mg/l)	5.51 – 7.14	5.37 – 7.06
pH (unit)	8.29 – 8.62	8.10 – 8.43
Water current (m/s)	0.00 – 0.10	0.00 – 0.10
Water brightness (cm)	76.00 – 99.00	45.00 – 63.00

The temperature at Ai Limung station is in the range of 27.8-31.7, and at Labu Prajak station is in the range of 29.0-32.2. Oxygen consumption and activity of metabolic enzymes are continuously affected by temperature. Prolonged exposure to 33 °C causes metabolic changes, which are indicated by changes in oxygen consumption and enzyme activity. In experiments at 22–38˚C *H. scabra* could still positively maintain aerobic capacity, with optimal temperature ranges between 29–31.5˚C (Kühnhold et al. 2019).

Ai Limung station's water depth is 20-100 cm (0.2-1 m), and Labu Prajak station's is 62-125 cm (0.6-1.2 m). The distribution of sea cucumbers is extensive in several seawaters with a depth of 1–40 m (Liubana et al. 2022; Matrutty et al. 2021). Sea cucumbers live in shallow or intertidal water habitats, in addition to deeper waters with seaweed, sandy and muddy substrates (Liubana et al. 2022).

Salinity at Ai Limung station is 32-34 ppt, while at Labu Prajak station, it is 30-33 ppt. The salinity findings at the Labu Prajak station are slightly different from previous studies, the optimum salinity for *H. scabra* is 32-34 ppt. However, *H. scabra* is known to have a greater tolerance limit for salinity than other sea cucumber species; it can be up to 47 ppt (Tuwo et al. 2021).

Dissolved oxygen at Ai Limung station is 5.51-7.14 mg/l, and at Labu Prajak station is 5.37-7.06 mg/l. These findings are similar to previous studies; sandfish sea cucumber can grow optimally in the range of 5-6 ppm dissolved oxygen (Manuputty, 2019). According to Magcanta et al. (2021), sandfish *H. scabra* can still grow well at dissolved oxygen with a concentration of 5.18 – 9.36 ppm.

The range of pH values at each station is Ai Limung 8.29–8.62 and Labu Prajak station 8.10–8.43. Sandfish sea cucumber can live at a pH with optimal conditions in the range of 7.5-8.5. However, if the pH is above 9 or below 6, the growth of sandfish *H. scabra* will be disrupted (Meirinawati et al. 2020).

The water current at both stations is in the range of 0.0-0.1 ms^{-1}, which indicates a minimal current strength. Sandfish sea cucumbers prefer to live at low and relatively stable current speeds to avoid stress and save energy (Lin et al. 2020). Water current is also an indicator of water quality, which positively correlates with the abundance of sea cucumbers in nature, apart from temperature, pH, total nitrogen, phosphate, and C-organic (Susetya et al. 2020).

In terms of water brightness, the Ai Limung station was found to have better brightness than the Labu Prajak station, which was in the range of 76-99 cm (76-99%), while the Labu Prajak station had lower water brightness in the range 45-63 (36-50%). This is alleged because the Labu Prajak station has become a more vibrant and bustling tourist destination. This station also is very close to settlements, and there are aquaculture activities. A good level of water brightness is in the range of 60-100 cm, meaning that sunlight can still penetrate at a depth of 60-100 cm (Dewi et al. 2022). Good sunlight penetration can optimize photosynthesis so that it can affect water fertility (Boyd, 2019).

Conclusion

Based on the analysis of the length-weight relationship and condition factors of the sandfish *H. scabra* on the North Coast of Sumbawa Island, it can be concluded that the two growth patterns of each research station are negative allometric which indicates that the sandfish sea cucumber's body is growing faster than its body weight. Statistical analysis showed significant differences in mean body length, mean body weight, and fulton condition factor. The mean body length and weight of sandfish at both stations is smaller than previous study, indicating the earlier sign of overfishing. Meanwhile, the fulton condition factor at Ai Limung station showed a higher mean than Labu Prajak station, which indicated that the location was more fertile or suitable, with abundant food sources for sandfish and fewer predators.

References

Abidin, N. A., Muhamad Shaleh, S. R., Ching, F. F., Othman, R., Manjaji-Matsumoto, M., Mustafa, S., & Senoo, S. (2019). Appropriate Diet and Stocking Density for Sea Cucumber (*Holothuria scabra*) Larvae Rearing. *Journal of Physics: Conference Series*, *1358*(1), 0–9. https://doi.org/10.1088/1742-6596/1358/1/012015

Afdhila, R., Muhammadar, A. A., & Chaliluddin, M. A. (2019). Length-weight relationship and condition factors of layang fish (Decapterus macrosoma) that landed at Lampulo Ocean Fishing Port, Banda Aceh. *IOP Conference Series: Earth and Environmental Science*, *348*(1), 0–5. https://doi.org/10.1088/1755-1315/348/1/012079

Al Jufaili, S. M., Al Rashidi, K. M., & Al Kharusi, I. S. (2021). The Omani sandfish sea cucumber, *Holothuria scabra* Jaeger, 1833 (Holothuroidea:

Holothuriidae): Fishery, length-Weight relationship and condition factor. *International Journal of Aquatic Biology*, *9*(2 SE-Articles), 115–123. https://doi.org/10.22034/ijab.v9i2.1168

Aprianto, R., Amir, N., Kasmiati, Matusalach, Fahrul, Syahrul, Tresnati, J., & Tuwo, A. (2020). Bycatch sea cucumber *Holothuria scabra* processing and the quality characteristics. *IOP Conference Series: Earth and Environmental Science*, *473*(1). https://doi.org/10.1088/1755-1315/473/1/012001

Ardiansyah, A., Rasyid, A., Siahaan, E. A., Pangestuti, R., & Murniasih, T. (2020). Nutritional value and heavy metals content of sea cucumber *Holothuria scabra* commercially harvested in indonesia. *Current Research in Nutrition and Food Science*, *8*(3), 765–773. https://doi.org/10.12944/CRNFSJ.8.3.09

Azevedo e Silva, F., Brito, A. C., Simões, T., Pombo, A., Marques, T. A., Rocha, C., Sousa, J., Venâncio, E., & Félix, P. M. (2021). Allometric relationships to assess ontogenetic adaptative changes in three NE Atlantic commercial sea cucumbers (Echinodermata, Holothuroidea). *Aquatic Ecology*, *55*(2), 711–720. https://doi.org/10.1007/s10452-021-09856-3

Boyd, C. E. (2019). *Water quality: an introduction*. Springer Nature. Retrieved from https://books.google.co.id/books?id=h0mvDwAAQBAJ

Conand, C. (2018). Tropical sea cucumber fisheries: Changes during the last decade. *Marine Pollution Bulletin*, *133*(June), 590–594. https://doi.org/10.1016/j.marpolbul.2018.05.014

Dewi, T. A. R., Mauludiyah, M., & Munir, M. (2022). Study of The Relationship of Water Quality with The Ecological Index of Aquatic Biota in The Permata Pilang Beach Estuary Area, Probolinggo. *Jurnal Biota*, *8*(2), 123–131. https://doi.org/10.19109/Biota.v8i2.35065

Dinh, Q. M., Truong, N. T., Duc Nguyen, T. H., Huyen Tran, L. T., Kieu Nguyen, T. T., & Phan, L. H. (2022). Variations in length-weight relationship, growth and body condition of the commercial mullet Ellochelon vaigiensis in the Vietnamese Mekong Delta. *Heliyon*, *8*(11), e11789. https://doi.org/10.1016/j.heliyon.2022.e11789

Famoofo, O. O., & Abdul, W. O. (2020). Biometry, condition factors and length-weight relationships of sixteen fish species in Iwopin fresh-water ecotype of Lekki Lagoon, Ogun State, Southwest Nigeria. *Heliyon*, *6*(1), e02957. https://doi.org/10.1016/j.heliyon.2019.e02957

Gamage, L. K. T., Thushari, G. G. N., Atapaththu, K. S. S., Kondaramage, R. S. K. H., & Senevirathna, J. D. M. (2021). Diversity, length-weight relations, and condition factor of sea cucumbers in three coastal areas along the southern coast of sri lanka: A case study. *Turkish Journal of Fisheries and Aquatic Sciences*, *21*(12), 575–588. https://doi.org/10.4194/1303-2712-v21_12_01

Hasan, M. H. (2019). Destruction of sea cucumber populations due to overfishing at Abu Ghosoun area, Red Sea. *The Journal of Basic and Applied Zoology*, *80*(1), 5. https://doi.org/10.1186/s41936-019-0074-6

Hoang, T. H., Liang, Q., Luo, X., Tang, Y., Qin, J. G., & Zhang, W. (2022). Bioactives From Marine Animals: Potential Benefits for Human Reproductive Health. *Frontiers in Marine Science*, *9*(March), 1–13. https://doi.org/10.3389/fmars.2022.872775

Hossain, A., Dave, D., & Shahidi, F. (2022). Antioxidant Potential of Sea Cucumbers and Their Beneficial Effects on Human Health. *Marine Drugs*, *20*(8), 1–22. https://doi.org/10.3390/md20080521

Jisr, N., Younes, G., Sukhn, C., & El-Dakdouki, M. H. (2018). Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. *The Egyptian Journal of Aquatic Research*, *44*(4), 299–305. https://doi.org/10.1016/j.ejar.2018.11.004

Junus, S., Kwong, P. J., & Khoo, G. (2018). A review on the recent advances in the biology and aquaculture technology of *Holothuria scabra*. *Journal of Survey in Fisheries Sciences*, *4*(2), 5–25. https://doi.org/10.18331/sfs2018.4.2.2

Kautsari, N., Riani, E., TF Lumbanbatu, D., & Hariyadi, S. (2019). Sandfish (Holuthuria scabra) Fisheries in Saleh Bay: Stock Status Based on Fishermen's Perception and Catches. *Jurnal Ilmiah Perikanan dan Kelautan*, *11*(2), 59. https://doi.org/10.20473/jipk.v11i2.13432

Khalid, M., Masud, S., Naeem, Z., Shahid, M. M., Naeem, A. D., Ishtiaq, A., & Naeem, M. (2020). Length-weight and Length-length Relationships of Farmed Catla catla during Winter Season from Muzaffargarh, Pakistan. *Sarhad Journal of Agriculture*, *36*(3). https://doi.org/10.17582/journal.sja/2020/36.3.924.928

Kühnhold, H., Steinmann, N., Huang, Y. H., Indriana, L., Meyer, A., & Kunzmann, A. (2019). Temperature-induced aerobic scope and Hsp70 expression in the sea cucumber *Holothuria scabra*. *PLoS ONE*, *14*(3), 1–16. https://doi.org/10.1371/journal.pone.0214373

Lee, S., Ford, A., Mangubhai, S., Wild, C., & Ferse, S. (2018). Length-weight relationship, movement rates, and in situ spawning observations of *Holothuria scabra* (sandfish) in Fiji. *SPC Beche-de-mer Information Bulletin*, *38*(March), 11–14. Retrieved from https://rb.gy/76abg

Lin, C., Liu, X., Sun, L., Liu, S., Sun, J., Zhang, L., & Yang, H. (2020). Effects of different flow velocities on behavior and TRPA1 expression in the sea

cucumber Apostichopus japonicas. *Journal of Oceanology and Limnology*, *38*(4), 1328–1340. https://doi.org/10.1007/s00343-020-0061-2

Liubana, D., Joi Alfreddi Surbakt, & Claudya Zyta Tobu. (2022). Cultured sand sea cucumber growth with different water exchange systems. *Jurnal Akuakultur Indonesia*, *21*(2), 178–185. https://doi.org/10.19027/jai.21.2.178-185

Madruga, A. S., Félix, P. M., Sousa, J., Azevedo e Silva, F., Brito, A. C., Mendes, S., & Pombo, A. (2023). Effect of rearing temperature in the growth of hatchery reared juveniles of the sea cucumber Holothuria arguinensis (Koehler & Vaney, 1906). *Aquaculture*, *562*, 738809. https://doi.org/10.1016/j.aquaculture.2022.738809

Magcanta, M. L. M., Sornito, M. B., Espadero, A. D. A., Bacosa, H. P., & Uy, W. H. (2021). Growth, survival, and behavior of early juvenile sandfish *Holothuria scabra* (Jaeger, 1883) in response to feed types and salinity levels under laboratory conditions. *Philippine Journal of Science*, *150*(5), 871–884. https://doi.org/10.56899/150.05.04

Manuputty, G. D. (2019). Hubungan Panjang Berat dan Faktor Kondisi Teripang Pasir (*Holothuria scabra*) di Perairan Suli, Maluku Tengah, Maluku. *Agrikan: Jurnal Agribisnis Perikanan*, *12*(1), 174. https://doi.org/10.29239/j.agrikan.12.1.174-181

Matrutty, M., Wakano, D., & Suriani, S. (2021). Struktur Komunitas Teripang (Holothuroidea) Di Perairan Pantai Desa Namtabung, Kecamatan Selaru, Kabupaten Kepulauan Tanimbar. *TRITON: Jurnal Manajemen Sumberdaya Perairan*, *17*(1), 10–17. https://doi.org/10.30598/TRITONvol17issue1page10-17

Meirinawati, H., Prayitno, H. B., Indriana, L. F., Firdaus, M., & Wahyudi, A. J. (2020). Water quality assessment and monitoring of closed rearing system of the sea cucumber *Holothuria scabra*. *ASEAN Journal on Science and Technology for Development*, *37*(2), 73–80. https://doi.org/10.29037/AJSTD.624

Nur, M., Rahardjo, M. F., Simanjuntak, C. P. ., Djumanto, D., & Krismono, K. (2020). Length-weight relationship and condition factor of an endemic Lagusia micracanthus Bleeker, 1860 in Rivers of the Maros Watershed. *Jurnal Iktiologi Indonesia*, *20*(3), 263. https://doi.org/10.32491/jii.v20i3.532

Purcell, S. W., Williamson, D. H., & Ngaluafe, P. (2018). Chinese market prices of beche-de-mer: Implications for fisheries and aquaculture. *Marine Policy*, *91*, 58–65. https://doi.org/10.1016/J.MARPOL.2018.02.005

Riani, E., Nurjanah, S., Syamsu, K., Gumbira-Said, E., Suprihatin, Kaseno, & Dzikrifishofa, M. (2017). Potency of Sandfish (*Holothuria scabra*) Powder to Increase Sperm Quality and Sperm Quantity in Mice (Musmusculus). *Indian Journal of Science and Technology; Vol 10, No 22 (2017)*, *10*(22). https://dx.doi.org/10.17485/ijst/2017/v10i22/90502

Susetya, I. E., Dewinta, A. F., Harahap, Z. A., Leidonald, R., Yusni, E., Suriani, M., & Lesmana, I. (2020). Characteristics of environment and habitat of sea cucumbers in Pane Island, Tapanuli Tengah Regency. *IOP Conference Series: Earth and Environmental Science*, *454*(1). https://doi.org/10.1088/1755-1315/454/1/012133

Tuwo, A., Yasir, I., Bestari, A. D., Yanti, A., Aprianto, R., & Tresnati, J. (2021). High salinity effect on mortality of sandfish *Holothuria scabra* (Jaeger, 1833). *IOP Conference Series: Earth and Environmental Science*, *763*(1). https://doi.org/10.1088/1755-1315/763/1/012019

Ul Hassan, H., M. Ali, Q., Rahman, M. A., Kamal, M., Tanjin, S., Farooq, U., Mawa, Z., Badshah, N., Mahmood, K., Hasan, M. R., Gabool, K., A. Rima, F., Islam, M. A., Rahman, O., & Hossain, M. Y. (2020). Growth pattern, condition and prey-predator status of 9 fish species from the Arabian Sea (Baluchistan and Sindh), Pakistan. *Egyptian Journal of Aquatic Biology and Fisheries*, *24*(4), 281–292. https://doi.org/10.21608/ejabf.2020.97439

VanderBloemen, S. N., Gorne, J. A., Sass, G. G., & Shaw, S. L. (2020). Influence of cisco (Coregonus artedi, Lesueur) on muskellunge (Esox masquinongy, Mitchill) mean length, population size structure, and maximum size in northern Wisconsin lakes. *Journal of Applied Ichthyology*, *36*(2), 159–167. https://doi.org/10.1111/jai.13997

Veronika, K., Edrisinghe, U., Sivashanthini, K., & Athauda, A. R. S. B. (2018). Length-weight relationships of four different sea cucumber species in North-East coastal region of Sri Lanka. *Tropical Agricultural Research*, *29*(2), 212. https://doi.org/10.4038/tar.v29i2.8290

Yanti, A., Tresnati, J., Yasir, I., Syafiuddin, Rahmani, P. Y., Aprianto, R., & Tuwo, A. (2020). Size at the maturity of sea cucumber *Holothuria scabra*. Is it an overfishing sign in Wallacea Region? *IOP Conference Series: Earth and Environmental Science*, *473*(1). https://doi.org/10.1088/1755-1315/473/1/012056

Yussuf, Y. S., & Yahya, S. A. (2020). Size-distribution and length-weight relationship of a deep-water population of *Holothuria scabra* (Jaeger, 1833) in Zanzibar, Tanzania. *Western Indian Ocean Journal of Marine Science*, *19*(1), 113–121. https://doi.org/10.4314/wiojms.v19i1.9

Zhang, Y., Gao, F., Xu, Q., Wang, Y., Wang, H., & Wang, A. (2023). Eukaryotic food sources analysis in situ of tropical common sea cucumber Holothuria

leucospilota based on 18S rRNA gene high-throughput sequencing. *Journal of Oceanology and Limnology*. https://doi.org/10.1007/s00343-022-1302-3