Community structure of sea cucumber on Harapan Island and East Penjaliran Island, Kepulauan Seribu National Park, Indonesia

T R Yuniarga, T B Satriyo and R I Adharini*

Department of Fisheries, Faculty of Agriculture, Universitas Gadjah Mada
Jl. Flora, A4 Building, Bulaksumur Yogyakarta, Indonesia

*Corresponding author e-mail: ratih.adharini@ugm.ac.id

Abstract. Sea cucumbers are marine animals of the Holothuroidea Class that have ecological, health, and socioeconomic benefits. This study aims to determine the structure of the sea cucumber community on Harapan Island and East Penjaliran Island, Kepulauan Seribu National Park, Kepulauan Seribu Regency. Data collection was conducted in January 2020, where each island was divided into two stations, and each station was divided into three substations for data retrieval. The method is a quadratic transect method using a plot measuring 1x1 m. In each square plot, observations were made regarding the type and number of sea cucumbers found and water quality parameters, including salinity, temperature, pH, DO, and total organic matter. Observation parameters include diversity index, uniformity index, frequency, density, important value index, dominance, and sea cucumber distribution index. During the study, species found on Harapan Island include *Holothuria atra*, *H. scabra*, *H. leucospilota*, *Bohadschia marmorata*, and *Stichopus herrmanni*. Meanwhile, species found on East Penjaliran Island include *H. atra*, *H. leucospilota*, *H. coluber*, *H. pardalis*, *H. fuscocinerea*, *H. hilla*, *Bohadschia marmorata*, *Stichopus ocellatus*, and *Stichopus monotuberculatus*. The most abundant and predominant species on both islands is *Holothuria atra*. The average diversity index on Harapan Island falls into the low category, while East Penjaliran Island is classified as medium. The dominance index of both islands is low and has a uniform distribution. Environmental conditions and sea cucumber exploitation affect the structure of sea cucumber communities on both islands.

1. Introduction
Sea cucumbers are animals from the phylum Echinoderms that live in intertidal areas and consist of more than thousands of species in the world [1]. Sea cucumbers have ecological, health, economic, and social roles. Ecologically, sea cucumbers act as deposit feeders that help reorganize organic matter and enrich the oxygen content in sediments [2]. Sea cucumbers are also crucial in coral reefs and their associated ecosystems at various trophic levels [3]. Dried sea cucumbers from Indonesia have high nutritional content because they contain 62.7% protein, 1.83% lipid, 11.9% ash, 5.21% carbohydrates, 18.4% moisture, and are rich in magnesium, calcium, potassium, and sodium [4]. Sea cucumbers also contain bioactive compounds such as vitamins, minerals, collagens, mucopolysaccharides, saponins, and glycosaminoglycans, acting as antioxidants, antitumors, antimicrobial, and anticoagulants [5; 6; 7; 8]. The production and trade of sea cucumbers also affect the socioeconomic life of fishers around the coast [9].
The increasing global market demand for natural resource products such as sea cucumbers also increases the pressure for exploitation in nature on a large scale [10]. FAO [11] reports that there has been an increase in the production of sea cucumbers from natural catches from 2015 by 31 thousand tonnes from 2015 to 32 thousand tonnes in 2018. The exploitation of sea cucumbers has triggered large-scale fishing in Indonesia, a country known as one of the major sea cucumber suppliers in the international market. Jasmadi et al. [12] stated that the structure of the sea cucumber community in Tual Southeast Mollucas was in a depressed condition. Rumlus et al. [13] stated that the distribution and development of sea cucumbers are highly dependent on the substrate and the amount and type of food available in the waters. The distribution of sea cucumbers in Indonesia includes Sabang, North Nias, Thousand Islands, Mentawai, Kaimana, Raja Ampat, Sekotong, Maluku, North Minahasa, Nusa Dua Bali, Siau, Pulau Panjang, and Karimunjawa [14; 15; 16; 17; 18; 19; 20]. Kepulauan Seribu National Park (KSNP) is an administrative area geographically located at 50°24'-50°45' latitude and 106°025'-106°040' east longitude with an area of 107,489 ha. KSNP is divided into several zones according to their respective functions. Harapan Island is classified as a residential zone so that population activities could be found here, while East Penjaliran Island is included in core zone II. Core zone II is part of the protected national park area, and no changes are allowed, so the natural condition is still naturally excellent, and the ecosystem is diverse and abundant [21]. Kepulauan Seribu is one of the potential producers of sea cucumbers in Indonesia. According to Taurusman [22], sea cucumber catching activities have been carried out since 1973. Around 14,000 sea cucumbers can be obtained very easily in just two weeks on Pari Island at that time.

Even though sea cucumbers themselves are decreasing, they have not been mentioned on the list of conservation targets in Kepulauan Seribu National Park. Several types of sea cucumbers have even been included in the IUCN (International Union for Conservation of Nature) red list since 2013 under the endangered category [23]. So this study aims to determine the structure of the sea cucumber community on Harapan Island and East Penjaliran Island, Kepulauan Seribu National Park, to support the conservation of sea cucumber species in Indonesia.

2. Material and method

2.1 Sampling collection

Data collection was carried out in January 2020. Data collection was carried out in the afternoon until late at night because sea cucumbers are nocturnal animals that will come to the surface in the afternoon until the evening. Data collection was carried out at the Thousand Islands National Park (KSNP), i.e., on Harapan Island and East Penjaliran Island, divided into two sites. Site 1 on Harapan Island has a substrate of sand with mangrove and seagrass vegetation, while Site 2 has a substrate in rubble or dead coral debris with seagrass vegetation. Both sites located on East Penjaliran Island have a substrate in rubble or dead coral debris with seagrass vegetation.

2.2 Data collection and identification

The data collection sites are divided into three subsites. Each subsite has a transect length of 100 m measured using a rolling meter. Transects are installed perpendicular to the shoreline. The horizontal distance of each subsite is 50 m. Data were collected by placing a plot measuring 1x1 m every 10 m.

The identification of the type of sea cucumber (Holothuroidea) samples found was observed morphologically using the General Guidelines for Identification and Monitoring by the Ministry of Marine Affairs and Fisheries [24] and the Indonesian Sea Cucumber book by the Indonesian Institute of Sciences [14]. The water quality parameters observed included temperature, salinity, pH, turbidity, DO, and organic matter.

2.3 Data Analysis

The data analysis carried out includes the Shannon-Wiener diversity index (H’), the Evenness Index (J) evenness, the density and dominance index by Odum [25], and the Morisita distribution index. In
addition, the Important Value Index uses the Fachrul [26] formula.

3. Result and discussion

3.1. Species Diversity of sea cucumber

Sea cucumbers found on Harapan Island and East Penjaliran Island consist of Holothuria, Bohadschia, and Stichopus. The genus Holothuria is most abundant on both islands. However, there were fewer species of sea cucumber found on Harapan Island than on Penjaliran Timur Island. The species diversity in the two islands is presented in Tables 1 and 2.

Table 1. Species diversity of sea cucumber in Harapan Island

| Class        | Ordo         | Family     | Genus       | Species                  |
|--------------|--------------|------------|-------------|--------------------------|
| Holothuroidae| Aspidochirotida| Holothuriidae | Holothuria  | *Holothuria atra*         |
|              |              |            | Holothuria  | *Holothuria scabra*       |
|              |              |            | Holothuria  | *Holothuria leucospilota* |
|              |              |            | Bohadschia  | *Bohadschia marmorata*    |
|              |              |            | Stichopus   | *Stichopus hermani*       |

Table 2. Species diversity of sea cucumber in East Penjaliran Island

| Class        | Ordo         | Family     | Genus       | Species                  |
|--------------|--------------|------------|-------------|--------------------------|
| Holothuroidae| Aspidochirotida| Holothuriidae | Holothuria  | *Holothuria atra*         |
|              |              |            | Holothuria  | *Holothuria leucospilota* |
|              |              |            | Holothuria  | *Holothuria coluber*      |
|              |              |            | Holothuria  | *Holothuria pardinis*     |
|              |              |            | Holothuria  | *Holothuria fuscocinerea* |
|              |              |            | Bohadschia  | *Bohadschia marmorata*    |
|              |              |            | Stichopus   | *Stichopus ocellatus*     |
|              |              |            |             | *Stichopus monotuberculatus* |

3.2. Diversity, evenness, and dominance index

The diversity, evenness and dominance indices on Harapan Island and East Penjaliran are presented in Table 3. Based on the Shanon-Wiener index, the diversity in Harapan Island is classified as having low diversity, while in East Penjaliran Island, it is low to moderate. The evenness index on Harapan Island is high, while East Penjaliran Island is in the medium category. The dominance index on Harapan Island is greater than East Penjaliran Island. The species *Holothuria atra* dominated the dominance of Harapan and East Penjaliran islands.

Table 3. The diversity, evenness and dominance index on Harapan Island and East Penjaliran Island.

|                      | Harapan Island | East Penjaliran Island |
|----------------------|----------------|------------------------|
|                      | Site 1 | Site 2 | Site 1 | Site 2 |
| Diversity Index      | 0.937 | 0.868 | 1.093 | 0.937 |
| Evenness Index       | 0.85  | 0.79  | 0.61  | 0.52  |
| Dominance Index      | 0.43  | 0.50  | 0.40  | 0.48  |

East Penjaliran Island has a higher index of sea cucumber diversity than Harapan Island because the number and types of sea cucumbers found are more numerous and varied, although several types of sea cucumbers are found on both islands. Another factor that causes the low diversity index of sea cucumbers on Harapan Island compared to East Penjaliran Island is zoning or differences in protected areas. The Decree of the General of Forest Protection and Nature Conservation of the Ministry of
Forestry Number SK.05/IV-KK/2004 dated January 27, 2004, concerning the Zoning of the Thousand Islands Marine National Park states that Harapan Island is included in the Settlement Island zone while East Penjaliran Island is included in Core Zone II [21]. In addition, differences in diversity indices are also influenced by anthropogenic factors, i.e., catching sea cucumbers by residents on Harapan Island. On the other hand, catching sea cucumbers did not occur on East Penjaliran Island because it is a core zone, so the number and types of sea cucumbers on East Penjaliran Island are still abundant.

The evenness of the sea cucumber population on Harapan Island is classified as large (0.82), while the evenness on East Penjaliran Island is classified as medium (0.57). The high evenness of sea cucumber populations on Harapan Island occurs because the number and types of sea cucumbers found are relatively small, so this shows that the proportion of the number and types of species on the island is balanced, means that there is no dominance on the island. On the other hand, the thing that affects the evenness of the sea cucumber population on the East Penjaliran Island is one species found in relatively abundant but does not dominate in these waters, i.e., *Holothuria atra*.

The total sea cucumbers found on Harapan Island was 15 individuals, while 236 individuals were found on East Penjaliran Island. Anthropogenic factors influence the significant difference. East Penjaliran Island is included in the Core Zone II, which means that the zone is part of a protected national park area, and no changes are allowed by human activities except for education, research, and supporting cultivation. At the same time, Harapan Island is a residential zone whose management can be carried out by various activities such as habitat utilization, marine cultivation, construction of infrastructure, and tourism.

### 3.3. Frequency and density of sea cucumber

Table 4 shows that *Holothuria atra* is a sea cucumber with the highest frequency and density on Harapan Island. Conversely, the lowest frequency and density were *Holothuria scabra*, *Stichopus herrmanni*, and *Bohadchia marmorata*. *Holothuria scabra* is a sea cucumber included in the endangered list, while *Stichopus herrmanni* is a species classified as vulnerable by the IUCN.

**Table 4.** Frequency and Density of Sea Cucumbers on Harapan Island.

| Sea cucumber       | Frequency | Density (ind/m²) |
|--------------------|-----------|------------------|
|                    | Site 1    | Site 2           | Site 1 | Site 2 |
| *H. atra*          | 0.333     | 0.667            | 0.100  | 0.133  |
| *H. scabra*        | 0.111     | -                | 0.033  | -      |
| *H. leucospilota*  | 0.556     | -                | 0.167  | -      |
| *S. herrmanni*     | -         | 0.167            | -      | 0.033  |
| *B. marmorata*     | -         | 0.167            | -      | 0.033  |
| Total              | 1         | 1                | 0.3    | 0.2    |

**Table 5.** Frequency and Density of Sea Cucumbers on East Penjaliran Island.

| Sea cucumber        | Frequency | Density (ind/m²) |
|---------------------|-----------|------------------|
|                     | Site 1    | Site 2           | Site 1 | Site 2 |
| *H. atra*           | 0.355     | 0.513            | 1.000  | 3.304  |
| *H. leucospilota*   | 0.452     | 0.282            | 0.967  | 1.696  |
| *B. marmorata*      | 0.032     | 0.051            | 0.033  | 0.087  |
| *S. ocellatus*      | 0.065     | -                | 0.067  | -      |
| *H. illa*           | 0.065     | 0.026            | 0.100  | 0.043  |
| *S. monotuberculatus* | 0.032 | -                | 0.033  | -      |
| *H. coluber*        | -         | 0.077            | -      | 0.130  |
| *H. pardalis*       | -         | 0.026            | -      | 0.043  |
| *H. fuscocinerea*   | -         | 0.026            | -      | 0.043  |
| Total               | 1         | 1                | 2.200  | 5.348  |
Table 5 shows that *H. atra* is a sea cucumber with the highest frequency and density in East Penjaliran Island. *H. atra*, *H. leucospilota*, *B. marmorata*, and *H. hilla* were found at every station on East Penjaliran Island. Conversely, the lowest frequency and density of sea cucumbers are *H. fuscocinerea*, *H. pardalis*, *S. monotuberculatus*, and *S. ocellatus*; these types only found one individual on the East Penjaliran Island.

There are differences in the frequency and density of sea cucumbers between Harapan Island and East Penjaliran Island. The frequency and density of *H. atra*, which is the most abundant species of sea cucumber on Harapan Island, is less than one, while the frequency and density of Holothuria atra on Penjaliran Island are more than one, so it can be concluded that the frequency and density of sea cucumbers on Harapan Island are lower than with East Penjaliran Island.

*H. atra* had the highest frequency on both Harapan Island and East Penjaliran Island. The density, the number of individuals in a unit area [27], of *H. atra* on Harapan Island was 0.1-0.133 individuals per meter square, while the density on East Penjaliran Island was 1-3.3 individuals per meter square. The density of *H. atra* in East Penjaliran Island is 1-3.3 individuals per meter square, and *Holothuria leucospilota* is 1.6 individuals per meter square. The high density of *H. atra* and *H. leucospilota* in East Penjaliran Island is conceivable because East Penjaliran Island is included in Core Zone II. Anthropogenic influences were not found on East Penjaliran Island so that sea cucumbers could be found in reasonably abundant quantities.

*H. scabra* and *S. hermannii* are types of sea cucumbers found in low numbers on Harapan Island. It is probably because the exploitation of these two sea cucumbers with the highest economic value is already very high in Harapan Island, so their abundance has decreased. *H. scabra* is the most valuable type of sea cucumber on the Chinese market and the most consumed species in Fiji, so it has the greatest exploitation pressure compared to other species [10; 9]. *H. scabra* can be found in coral, mangrove, and seagrass habitats, but it prefers to live in seagrass habitats [28]. *H. pardalis* and *H. fuscocinerea* are sea cucumbers found in the lowest numbers on East Penjaliran Island. Elfidasari et al. [29] found that *H. pardalis* and *H. fuscocinerea* are sea cucumbers that prefer seagrass habitats, while no seagrass habitat is found on East Penjaliran Island that has a substrate in the form of dead coral so that sea cucumbers are difficult to find.

### 3.4. Important value index

The Importance Value Index (IVI) of sea cucumbers on Harapan Island is presented in Table 6. *H. atra* has the highest IVI value of all species at each station because it is a sea cucumber with the highest relative frequency and relative density. The lowest relative frequency, relative density, and IVI were sea cucumbers with the type *H. scabra*.

**Table 6.** The Importance Value Index (IVI) of sea cucumbers on Harapan Island.

| Sea cucumber | Relative frequency | Relative density | Important Value Index |
|--------------|--------------------|-----------------|----------------------|
| *H. atra*    | Site 1: 33,33 | Site 2: 66,67 | Site 1: 33,33 | Site 2: 66,67 | 133,33 |
| *H. scabra*  | Site 1: 11,11 | Site 2: - | Site 1: 11,11 | Site 2: - | 22,22 |
| *H. leucospilota* | Site 1: 55,56 | Site 2: - | Site 1: 55,56 | Site 2: - | 111,11 |
| *S. hermannii* | Site 1: - | Site 2: 16,67 | Site 1: - | Site 2: 16,67 | 33,33 |
| *B. marmorata* | Site 1: - | Site 2: 16,67 | Site 1: - | Site 2: 16,67 | 33,33 |
| Total        | 100               | 100             | 100               | 200            | 200                |

The Importance Value Index (IVI) of sea cucumbers in East Penjaliran Island is presented in Table 7. *H. atra* has the highest IVI value of all species at each station because it is a sea cucumber with the highest relative frequency and relative density. The lowest relative frequency and relative density were sea cucumbers with the types *H. pardalis* and *H. fuscocinerea* found at Station 2 on East Penjaliran Island, so the lowest IVI was *H. pardalis* and *H. fuscocinerea*.
Table 7. The Importance Value Index (IVI) of sea cucumbers in East Penjaliran Island.

| Sea cucumber | Relative Frequency Site 1 | Relative Density Site 1 | Important Value Index Site 1 | Relative Frequency Site 2 | Relative Density Site 2 | Important Value Index Site 2 |
|--------------|---------------------------|-------------------------|-------------------------------|---------------------------|-------------------------|-------------------------------|
| H. atra      | 35.48                     | 49.30                   | 80.94                         | 50.00                     | 51.28                   | 113.07                        |
| H. leucospilota | 45.16                    | 40.85                   | 59.91                         | 27.50                     | 28.21                   | 59.91                         |
| B. mamorata | 3.23                      | 1.41                    | 4.74                          | 5.00                      | 5.13                    | 6.75                          |
| S. ocellatus | 6.45                      | 2.82                    | 9.48                          | -                         | -                       | -                             |
| H. hilla     | 6.45                      | 4.23                    | 11.00                         | 2.50                      | 2.56                    | 3.38                          |
| S. monotuberculatus | 3.23                  | 1.41                    | 4.74                          | -                         | -                       | -                             |
| H. coluber   | -                         | -                       | -                             | 10.00                     | -                       | 10.13                         |
| H. pardalis | -                         | 2.56                    | 3.38                          | -                         | -                       | -                             |
| H. fuscocinerea | -                      | 2.56                    | 3.38                          | -                         | -                       | -                             |
| Total        | 100                       | 100                     | 200                           | 100                       | 100                     | 200                           |

There is a difference in the Important Value Index (INP) between Harapan Island and East Penjaliran Island. The relative frequency and relative density of *H. atra* which is the most abundant species of sea cucumber on Harapan Island and East Penjaliran Island, however, there is a significant difference between the Important Value Index figures on each island. The Importance Value Index (INP) in East Penjaliran Island is higher than the Important Value Index (INP) in Harapan Island.

The results showed that *H. atra* had the highest Importance Value Index (IVI) value on the two islands, which means that *H. atra* has a significant role in the ecosystem. It is in accordance with the results of research by Hartati et al. [30] that *H. atra* is one of the most abundant and widespread species of sea cucumbers in most of the Indo-Pacific region and can be found at various depths and various habitats ranging from coral reefs, mudflats, and seagrass beds. In addition, the high value of the IVI of *H. atra* also indicates that the species can grow and develop very well and has an effect on the environment in the two islands. On the other hand, *H. scabra* shows the lowest IVI in Harapan Island due to exploitation. *H. scabra* is a sea cucumber with a relatively high price, so its presence affects people’s interest to exploit it [10; 31]. These invertebrate species are an essential component of food webs [32] and play a significant ecological role in the sea. The lowest IVI in East Penjaliran Island was *H. pardalis* and *H. fuscocinerea* species. Sea cucumbers like *H. pardalis* and *H. fuscocinerea* prefer seagrass ecosystems. However, there is no seagrass habitat on East Penjaliran Island, making sea cucumbers challenging to discover.

The dominance index on both islands was low; however, *H. atra* was the most common species found. It is because *H. atra* can adapt to various habitats from tidal to subtidal areas. *Holothuria atra* is also referred to as a species that can survive in all habitats [33]. In addition to having a relatively high environmental tolerance, the *H. atra* species can also reproduce asexually and sexually [33; 12]. Another reason to cause the high abundance of *H. atra* is that the species has a low selling price, so it is no longer in great demand [31].

3.5. Sea cucumber distribution index

The distribution index of the sea cucumbers of Harapan Island and East Penjaliran Island is presented in Table 8. The distribution of sea cucumbers on the two islands is classified as uniform, so there is no difference in the distribution of sea cucumbers between islands.

Table 8. The distribution index of the Sea Cucumbers of Harapan Island and East Penjaliran Island.

| Species  | Harapan Island | East Penjaliran Island |
|----------|----------------|------------------------|
|          | Site 1         | Site 2                 |
|          | Site 3         | Site 4                 |
| H. atra  | Uniform        | Uniform                |
| H. scabra| Uniform        | -                      |
|          | Uniform        | -                      |
|          | Uniform        | -                      |
The sea cucumbers found on Harapan Island and East Penjaliran Island have a completely uniform distribution pattern. Sea cucumbers on the East Penjaliran Island have a uniform distribution index due to fierce individual competition. The content of organic matter in East Penjaliran Island is lower than in Harapan Island, and this causes competition between individuals to get their food so that indirectly there will be a division of space in the ecosystem. On the other hand, Harapan Island has a higher organic matter content than East Penjaliran Island, so the distribution of sea cucumbers should be more random because food distribution is more even. The uniform index on Harapan Island is influenced by anthropogenic factors (fishing) so that sea cucumbers are found in small quantities. In addition, the uniform index was also caused by other factors, namely the dominance of certain species, in this case, *H. atra*, which was found in abundance on both islands. It is in accordance with Amaral et al. [34] that sea cucumbers with a uniform or even distribution pattern can occur if in an area there is tough individual competition so that it will encourage the division of space, even though there are some species that are more dominant than other species.

3.6. Physical and chemical parameter of waters

The average water parameters observed in Harapan Island and East Penjaliran Island are shown in Table 9.

| Parameter  | Harapan Island | Penjaliran Timur Island |
|------------|----------------|------------------------|
| Water temp. (°C) | 30.3 | 28.9 | 31.3 | 30.3 |
| Air temp. (°C) | 27.3 | 25.6 | 27.7 | 28.3 |
| Depth (cm) | 14.2 | 13.8 | 16.8 | 34.7 |
| Salinity (ppt) | 31.8 | 32.9 | 29.0 | 31.4 |
| pH | 6.7 | 6.6 | 6.7 | 6.5 |
| DO (ppm) | 4.7 | 5.3 | 5.0 | 4.1 |
| BO (ppm) | 46.81 | 49.12 | 44.7 | 43.64 |

The range of temperature, salinity, pH, organic matter, brightness, and DO measured on the two islands shows a number that is not much different. However, significant differences are seen in the average depth of sampling locations in the two islands. For example, East Penjaliran Island has a depth of 34.75 cm at Station 2. Hasanah et al. [35] argue that, in general, the distribution pattern of sea cucumbers is influenced by environmental conditions related to adaptability, food availability, and protection against predatory influences, as well as currents and waves. Harapan Island and East Penjaliran Island have waves that are not large enough so that sea cucumbers can be found with a uniform distribution pattern. The ability of physiological adaptation, especially tolerance to the increasing water temperature, needs to be a concern because, according to Dong et al. [36], the death of sea cucumbers on a large scale occurs when the water temperature reaches
more than 30 °C. In general, the water conditions in Harapan Island and East Penjaliran are still suitable for the life of sea cucumbers. The chemical composition and nutrients contained in sea cucumbers are strongly influenced by environmental changes [37]. The existence of seagrass in Harapan Island and East Penjaliran Island also needs to be maintained because seagrass serves as a habitat and provides an indirect food source for sea cucumbers [38].

4. Conclusion
Sea cucumber *H. atra* has the highest density and dominates on Harapan Island and East Penjaliran Island. The diversity of sea cucumbers on Harapan Island is low, while in East Penjaliran Island is moderate. The distribution pattern of sea cucumbers on both islands is uniform. The difference in the structure of sea cucumber communities on Harapan Island and East Penjaliran Island is due to differences in location status, exploitation, and environmental influences on both islands.

Acknowledgement
This research was funded through RTA grant from Universitas Gadjah Mada in 2021. The data from this publication are sourced from undergraduate thesis research on behalf of Tesya Ranma Yuniarga.

References
[1] Masre SF 2018 Profiles and biological values of sea cucumbers: a mini Review *Life Sci., Med. & Biomed.* 2(4): 25. doi.org/10.28916/lsmb.2.4.2018.25.
[2] MacTavish T, Stenton-Dozey J, Vopel K and Savage C 2012 Deposit-feeding sea cucumber enhance mineralization and nutrient cycling in organically-enriched coastal sediments *PLoS ONE* 7(11) e50031. doi:10.1371/journal.pone.0050031.
[3] Agusta OR, Sulardiono B and Rudiyanti S 2012 Kebiasaan makan teripang (Echinodermata: Holothuriidae) di perairan Pantai Pulau Pramuka, Kepulauan Seribu *J. Manag. Aquat. Resour.* 1(1):1-8.
[4] Thruong T and Le T 2019 Characterization of six types of dried sea cucumber product from different countries *Internat. J. Food Sci. & Agric.* 3(3):220-231.
[5] Bordboar S, Anwar F and Saari N 2011 High value components and bioactives from sea cucumber for functional foods-A Review. *Mar. Drugs* 9: 1761-1805. doi:10.3390/md9101761.
[6] Widianingsih, Zaenuri M, Anggoro S, Kusumaningrum HPS 2016 Nutritional value of Sea cucumber [Paracaudina Australis (Semper, 1868)]. *Aquat. Procedia* 7:271-276.
[7] Dakrory AI, Fahmy SR, Soliman AM, Mohamed AS and Amer AM 2015 Protective and curative effect of the sea cucumber Holothuria atra extract against DMBA-Induced Hepatorenal in Rats. *Biomed Res. Internat.* Article ID 563652, 11 pages. dx.doi.org/10.1155/2015/563652.
[8] Pangestuti R and Arifin Z 2018 Medicinal and health benefit effects of functional sea cucumber. *J. Trad. & Complement. Med.* 8: 341-351. dx.doi.org/10.1016/j.jtcmce.2017.06.007.
[9] Purcell SW, Ngalufo P, Foale SJ, Cocks N, Cullis BR and Lalavanua W 2016 Multiple factors affect socioeconomics and wellbeing of artisanal sea cucumber fishers *PLoS ONE* 11(12): e0165633. doi:10.1371/journal.pone.0165633.
[10] Purcell SW 2014 Value, Market Preferences and Trade of Beche-De-Mer from Pacific Island Sea Cucumbers *PLoS ONE* 9(4): e95075. doi:10.1371/journal.pone.0095075
[11] FAO 2020 The state of World Fisheries and Aquaculture 2020 Sustainability in action. Rome. https://doi.org/10.4060/ca9229en.
[12] Jasmadi, Wirawati I, Suryaningtyas IT and Permadi S 2020 Study on community structure of commercial sea cucumber in intertidal zone, Southeast Mollucas, and Tual, Mollucas. J. Ilmiah Perik. & Kel. 12(1): 31-47. doi.org/10.20473/jipk.v12i1.15460.

[13] Rumlus R, Semangun H, Karnaradjas O and Mangimbulude JC 2015 Keanekekaragaman jenis teripang di Fafanlap dan Gamta, Kepulauan Misool, Kabupaten Raja Ampat, Papua Barat dan uji aktivitas kandungan senyawa kimianya. Bonorowo Wetlands. 5(1): 1-10.

[14] Setyastuti A, Wirawati I, Permadi S, Vimono IB 2019 Teripang Indonesia: Jenis, Sebaran, dan Status Nilai Ekonomi. Lembaga Ilmu Pengetahuan Indonesia. Jakarta. PT. Media Sains Nasional.

[15] Yusron E 2013 Keanekekaragaman jenis Echinodermata di perairan Likupang Minahasa Utara, Sulawesi Utara J. Ilmu Kel. 15(2):85-90.

[16] Yusron E and Widianarti P 2004 Struktur komunitas teripang (Holothuroidea) di beberapa perairan Pantai Kai Besar, Maluku Tenggara J. Makara Sains 8(1): 15-20.

[17] Wulandari N, Krisanti M and Elfdasari D 2012 Keragaman teripang asal Pulau Pramuka, Kepulauan Seribu Teluk Jakarta J. Life Sci. 3(1):108-115.

[18] Vindia WI, Julyantoro PGS and Wulandari E 2019 Asosiasi Echinodermata pada ekosistem padang lamun di Pantai Samuh, Nusa Dua, Bali. J. Mar. & Aquat. Sci. 5(1):100-108.

[19] Satria GGA, Sulardiono B and Purwanti F 2014 Kelimpahan jenis teripang di perairan terbuka dan perairan tertutup Pulau Panjang Jepara, Jawa Tengah Manag. Aquat. Resourc. J. 3(1):108-115.

[20] Lagio S, Lumingas LJL and Manu GD 2015 Struktur komunitas teripang (Holothuroidea) di kawasan pantai desa Ondong Kecamatan Siau Barat Kabupaten Siau Tagulandang Bairo J. Ilmiah Platax. 2(3): 99-109.

[21] Directorate of Conservation of Areas and Fish Species. 2015. Profil Kawasan Konservasi DKI Jakarta. Jakarta.

[22] Taurusman AA, Shafrudin D, Nurani TW and Komaradin D 2018 Pemulihan stok tangkapan perikanan teripang di Kepulauan Seribu: Suatu pendekatan ekosistem J. Mar. Fish. 9(2):235-244.

[23] Conand C, Polidoro B, Mercier A, Gamboa R, Hamel JF and Purcell S 2014 The IUCN Red List assessment of Aspidochirotida sea cucumbers and its implications SPC Beche-de-mer Inform. Bull. 34(5): 3-7.

[24] Hair C, Mills DJ, McIntryre R and Southgate PC 2016 Optimising methods for community-based sea cucumber ranching: Experimental releases of cultured juvenile Holothuria scabra into seagrass meadows in Papua Guinea. Aquac. Reports 3:198-208.

[25] Isnin D, Noriko N, Wulandari N and Perdana AT 2012 Identifikasi jenis teripang Genus Holothuria asal perairan sekitar Kepulauan Seribu berdasarkan perbedaan morfologi. J. Al-
Azhar Ind. Seri Sains & Teknol. 1(3): 140-146.

[30] Hartati R, Widianingsih A, Trianto M, Zainuri and Ambariyanto 2017 The abundance of prospective natural food for sea cucumber Holothuria atra at Karimunjawa Island waters, Jepara, Indonesia. *Biodiv. J. Biol. Div.* 18(3): 947-953.

[31] Setyastuti A, Wirawati I and Iswari MY 2018 Identification and distribution of sea cucumber exploited in Lampung, Indonesia *Biodiv. J. Biol. Diver.* 19(2): 726-732.

[32] Anderson SC, Mills Flemming J, Watson R and Lotze HK 2011 Rapid Global Expansion of Invertebrate Fisheries: Trends, Drivers, and Ecosystem Effects *PLoS ONE* 6(3): e14735. doi:10.1371/journal.pone.0014735.

[33] Sanvicente-Anorve L, Solis-Marin FA, Solis-Weiss V and Lemus-Santana E 2017 Population density and spatial arrangement of two holothurian species in a coral reef system: is clumping behaviour an anti-predatory strategy? *Cahiers de Biol. Mar.* 58: 307-315.

[34] Amaral MK, Netto SP, Lingnau C and Filho AF 2015 Evaluation of the Morisita index for determination of the spatial distribution of species in a fragment of Araucaria forest *Appl. Ecol. & Env. Res.* 13:361-372.

[35] Hasanah U, Suryanti and Sulardiono B 2012 Sebaran dan kepadatan teripang (Holothuroidea) di perairan pantai Pulau Pramuka, Taman Nasional Kepulauan Seribu, Jakarta *Manag. of Aquat. Resourc.* J. 1(1): 6-12.

[36] Dong Y-w, Yu S-s, Wang Q-l and Dong S-l 2011 Physiological Responses in a Variable Environment: Relationships between Metabolism, Hsp and Thermotolerance in an Intertidal-Subtidal Species. *PLoS ONE* 6(10): e26446. doi:10.1371/journal.pone.0026446

[37] Vergara W and Rodriguez A 2016 Nutritional Composition of Sea Cucumber Isostichopus sp. *Nat. Resourc.* 7:130-137. http://dx.doi.org/10.4236/nr.2016.73013.

[38] Liu X, Zhou Y, Yang H and Ru S 2013 Eelgrass detritus as a food source for the sea cucumber Apostichopus japonicus Selenka (Echinidermata: Holothuroidea) in coastal waters of North China: an experimental study in flow-through systems *PLoS ONE* 8(3): e58293. doi:10.1371/journal.pone.0058293