Community structure, diversity, and distribution patterns of sea cucumber (Holothuroidea) in the coral reef area of Sapeken Islands, Sumenep Regency, Indonesia

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Abstract. Sea cucumbers (Holothuroidea) are one of the high value marine products, with populations under very critical condition due to over exploitation. Data and information related to the condition of sea cucumber communities, especially in remote islands, like the Sapeken Islands, Sumenep Regency, East Java, Indonesia, is still very limited. This study aimed to determine the species, community structure (density, frequency, and important value index), species diversity index, and distribution patterns of sea cucumbers found in the reef area of Sapeken Islands, using a quantitative descriptive study. This research was conducted in low tide during the day using the quadratic transect method. Data was collected by making direct observations of the population under investigation. The results showed that sea cucumbers belonged to 11 species, from 2 orders: Aspidochirotida, with the species *Holothuria hilla*, *Holothuria fuscopunctata, Holothuria impatiens, Holothuria leucospilota*, *Holothuria scabra, Stichopus horrens, Stichopus variegates, Actinopyga lecanora,* and *Actinopyga mauritiana* and order Apodida, with the species *Synapta maculata* and *Euapta godeffroyi*. The density ranged from 0.162 to 1.37 ind m^{-2}, and the relative density was between 0.035 and 0.292 ind m^{-2}. The highest density was found for *H. hilla* and the lowest for *S. maculata*. The frequency ranged from 0.13 to 0.72, and the relative frequency ranged from 0.037 to 0.206. The highest frequency value was found for *H. hilla* and the lowest for *S. maculata*. The highest Importance Value Index was observed in the case of *H. hilla* (0.498), and the lowest was found for *S. maculata* (0.072). The Shannon-Wiener (H') species diversity index value was 2.38, and the evenness value (E) was 0.992, the community tending to be even (E value close to 1). The Index of Morisita (IM) values range between 1.23 and 2.99, being bigger than 1, meaning that the distribution pattern of all types of sea cucumbers was clumped.
Key Words: commercial value, community structure, *H. hilla*, marine.

Introduction. As one of the largest maritime countries in the world, Indonesia has an enormous potential for coastal and marine resources (Nurkholis et al 2016; CEA 2018; USAID 2018). However, the existence and sustainability of marine biodiversity in Indonesia is increasingly threatened. This is due to the rapid rate of increase in population and the intensity of development. In fact, 60% of the population in Indonesia lives in coastal areas. The coastal and marine environments are at the center of anthropic use and the severe destruction of natural resources occurs (Purwaka & Sunoto 1997; Sukristijono 2002; Asian Development Bank 2014).

Sea cucumbers (Echinodermata: Holothuroidea) are one of the marine commodities that are currently widely traded on the domestic and international markets (Máñez & Ferse 2010; Anderson et al 2011; Purcell et al 2012). Sea cucumbers have long been an international trade commodity, commonly known as "beche-de-mer" (Uthicke & Benzie 2001; Lane & Limbong 2015). The capture and trade of sea cucumbers in Indo-Pacific countries has occurred since the 19th century. In Indonesia, sea cucumber capture has been carried out since the Dutch colonial era (Conand 1993; Kinch et al 2008; Purcell et al 2012). Consumer demand for sea cucumber tends to increase yearly, especially in

Asian markets, where Hong Kong is the primary importer (more than 50% of global sea cucumber imports) (Rawson & Hoagland 2019). The supply of sea cucumber stock is very dependent on the capture of natural stocks by fishermen. Sea cucumber cultivation is still very rare. Increased market demand encourages increased exploitation of sea cucumber from the wild (Natan et al 2016; Rawson & Hoagland 2019). The average volume of sea cucumber production in Indonesia per year until 2015 reached 6000 tons (Sadili et al 2015), whereas from 2012 to 2015 exports of sea cucumbers from Indonesia to the international market, with China as the main customer, reached 900 tons to 1200 tons of dried sea cucumbers (Wirawan 2018).

Sea cucumber catches are carried out by fishermen sporadically, with a continuous intensity. Based on the continuous exploitation, it is suspected that sea cucumber populations are experiencing serious pressure and sustainability threats (Purcell 2010; Chávez et al 2011; Natan et al 2016). Sea cucumber populations are decreasing, being even in critical situations because the rate of increase (reproduction) is not proportional to the rate of capture by fishermen (Kinch et al 2008; Purcell et al 2013). Indications of this condition are the increasing difficulty of finding commercial sea cucumbers, cheap and moderate, and even expensive species (Conand & Muthiga 2007; Pankey et al 2012). The decrease in sea cucumber populations is particularly occurring for high-priced species such as *H. scabra* and *H. nobilis* (Darsono 2002a).

The availability of sea cucumber in the wild has dropped dramatically. This is also influenced by a variety of damage to its habitat commonly occurring in many regions of Indonesia (Yusron & Widianwari 2004). When the population density of sea cucumbers falls below the tipping point, it is very difficult for the population to recover (Darsono 2002a). Therefore, conservation and cultivation efforts are needed to reduce the overexploitation of natural stocks (Varkey et al 2010). Sea cucumber is a commodity included in the Commission of International Trade on Endangered Species/CITES Appendix II List (CITES 2019), concerning international trade. Sea cucumber producing countries were recommended to have utilization rules, to avoid damaging natural resources. According to Purwati (2005), whichever strategy will be used as a regulatory system, Indonesia still needs considerably more data and information about sea cucumbers. According to Yusron (2003), it is necessary to have basic research related to abundance, distribution, density and frequency of their presence to get optimal results.

Another problem faced is the lack of opportunities to examine the condition of sea cucumber communities, especially in remote islands (Yusron & Widianwari 2004). Some previous studies of sea cucumbers in Indonesia have been carried out, namely at Derawan Island, East Kalimantan (Darsono 2002b), Kenjeran Beach, Surabaya (Widianingsih et al 2018; Widianingsih et al 2019), Kakaban Island, East Kalimantan (Massin & Tomascik 1996), the eastern waters of the Natuna Coast of the Riau Islands (Sukmiwati et al 2012), Baluran National Park, East Java (Siddiq et al 2016), South Sulawesi (Aprianto et al 2019), Karimunjawa Island, Central Java (Hartati et al 2017), Timor Sea (Prescott et al 2017), Lampung waters (Putro 2016; Setyastuti et al 2018), Suli Village, Maluku (Manuputty et al 2019), Central Maluku and Southeast Maluku Regency (Natan et al 2016), and Lombok Island, West Nusa Tenggara (Pangestuti et al 2016; Indriana & Firdaus 2020). However, considering that Indonesia is one of the largest archipelago countries in the world, with 17508 islands and 81000 km of coastline (Lasabuda 2013), there is still limited research in several areas, and research in remote areas or islands must be encouraged.

One of the remote areas where natural resource potential has not been studied, specifically related to sea cucumber, are the Sapeken Islands, Sumenep Regency. The majority of the population in this archipelago depends on utilizing sea products. Many use sea cucumbers for economic welfare, from generation to generation. The use of sea cucumber to support the economic welfare of the people of Sapeken Islands is possible, especially because of the high price of sea cucumbers, ranging from 56 to 140 USD per 1 kg of dry weight (Wirawan 2018).

From an initial survey, it is clear that the Sapeken Islands have an extensive area of coral reefs surrounding the islands (Fachruddin & Efendy 2019; Rini et al 2015). Coral reefs are a habitat for coral aquatic biota that can be utilized optimally without damaging

the coral reef environment. In general, the condition of coral reefs in the Sapeken Islands is included in the good category, especially at a depth of 2-3 meters, while at a depth of more than 5 m, it is dominated by sand. The diversity of reef fish is high with 342 species from 33 families and 96 genera. The most common are the Pomacentridae, Labridae, and Chaetodontidae families. The highest abundance was 43516 individual fish per ha (Nurwidodo et al 2017; Nurwidodo et al 2018). However, the existence of coral reefs has begun to be threatened because of the collections of corals to be used as construction materials and, in some cases, because of communities who use explosives when fishing.

Coral reef lifeforms found in the Sapeken Islands are branching, digitata, massive, submassive, mushroom, encrusting, foliouse, tabulate, and soft corals. The species are included in 36 genera from the families of Faviidae, Fungiidae, Poritidae, Mussidae, Pectinidae, Agariciidae, Euphyllidae, Pocilloporidae, Acroporidae, Caryophyllidae, Astrocoeniidae, Merulinidae, Siderastreidae, Tubiporidididae, and Trillushididae. Basic substrate constituents include sea lilies, sea urchins, clams, starfish, zoantids, gorgonians, hydrozoans, sea cucumbers, sponges, algae, anemones, ascidians, seagrasses, bivalves and gastropods (Nurwidodo et al 2017; Nurwidodo et al 2018).

Coral reefs are the main habitat for sea cucumbers, so their presence in coral reefs is prominent (Schneider et al 2011; Mulyono et al 2017). Several previous sea cucumber studies in the Indonesian coral reef areas have been carried out, including in Bunaken Island, North Sulawesi (Tamanampo et al 1989), Tanimbar Waters, Southeast Maluku (Rumahrupete et al 1990), Kakaban Island, East Kalimantan (Massin & Tomascik 1996), West Enjaliran Island, Jakarta Bay (Siena 1996), Derawan Island, East Kalimantan (Darsono 2002b), Kotania Bay, West Seram, Central Maluku (Yusron 2003), Natuna Island, Riau Islands Province (Rajab & Darsono 2004; Sukmiwati et al 2012), East Putri Island, Seribu Islands, Jakarta (Dumilah 2006), Baluran National Park, East Java (Siddiq et al 2016), Banda Sea (Setyastuti & Wirawati 2018), Lampung waters (Setyastuti et al 2018), and Suli Village, Maluku (Manuputty et al 2019). Other research was carried out in the areas of Bira Island (Komala et al 2019), and Pacitan beaches, East Java (Muzaki et al 2019).

On a broader scale, research has been conducted in Singapore sedimented reef (Costelloe & Keegan 1984), windward and leeward fringing coral reef, Guam, Mariana Islands (Kerr et al 1993), Indo-Pacific coral reef (Conand 1993; Skillings et al 2014), five reefs of the South China Sea (Woo et al 2010), coral reef of Reunion Island, south-western Indian Ocean (Kolasinski et al 2010), Indonesian marine park and the wider Indo-Pacific (Lane & Limbong 2015), and the Great Barrier Reef (Thorne & Byrne 2013; Uthicke 1997; Uthicke & Benzie 2000, 2001). It can be said that the potential and data on Holothuroidea in Indonesia have not yet been fully revealed, given the vast territorial waters of Indonesia.

This research was the first step to study the potential and community of sea cucumbers in the Sapeken Islands, Sumenep Regency. The objectives of this study were to find out the species of Holothuroidea, the Holothuroidea ecological parameters, the diversity index of Holothuroidea species, and the distribution pattern of sea cucumbers in the reef flat area of Sapeken Islands. The results of this study are expected to contribute practically in supporting the sustainable utilization, conservation and management of sea cucumber resources, by empowering local communities. The results can be used as a database for local and central government, specifically the marine departments/services for completing the natural wealth information of the islands.

Material and Method

Research type. Descriptive research was conducted to obtain data about the diversity of species and distribution patterns of sea cucumbers in the coral reef areas of Pagerungan Island, Sapeken Islands, Sumenep Regency. The study was conducted in July 2019.

Research area. This research was conducted in the reef flat area of Pagerungan Island, Sapeken Islands, Sumenep Regency (Figure 1). Most of these reefs can be found around the island. Retrieval of data was based on using transect techniques. The starting point of

the transect is from the flat edge of the reef from the coast (the boundary between the seagrass zone and the coral reef zone) towards the reef crest.

Research procedures. Determination of the sampling stations was done by purposive sampling, following the cardinal points (Figure 2). At the sampling stage, the following procedures were carried out: measuring 100 m from the reef edge to the reef crest; at each observation station, 3 transect squares are made. Each quadratic transect consists of 9 plots. Each plot is 1x1 m in size. The distance between plots is 10 m, while the distance between transects is 25 m.

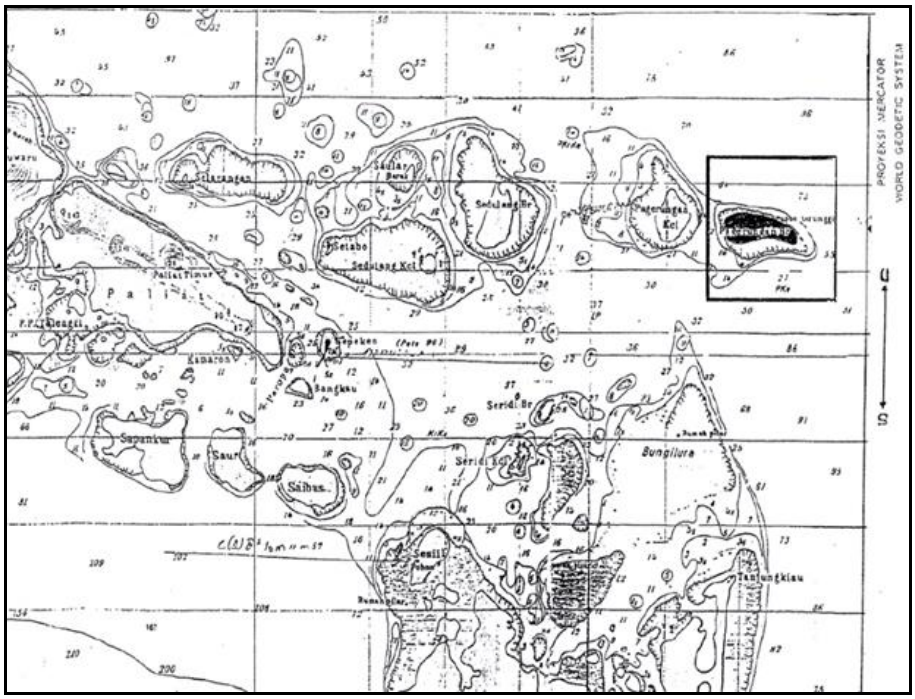

Figure 1. Small Pagerungan Island, Sapeken Islands, Sumenep Regency, Indonesia.

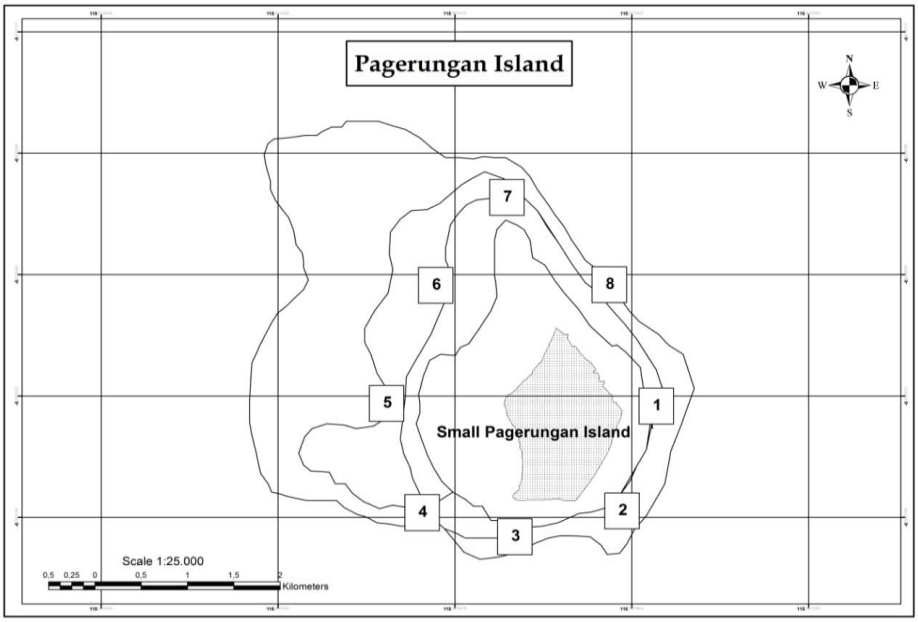

Figure 2. Observed area plan (1:1000000 scale).

Population and sampling. The samples in this study were sea cucumbers found in 216 plots in 24 transects (8 observation stations; 1 station with 3 transects; 1 transect with 9 plots). Sampling was done manually. Each transect takes 1-2 hours to be sampled, so data collection in all points was collected in 1 week. Sampling was done in the morning at low tide. To facilitate and speed up data retrieval, there were 3 people involved in data retrieval.

Identification. Holothuroidea identification was carried out at the Biology Laboratory (Sub-Ecology) of the Universitas Muhammadiyah Malang. The species of sea cucumbers were identified based on the user manuals of Rowe (1969), Clark & Rowe (1971), and Aziz (1995). Identification of sea cucumbers can be carried out by observing morphological characters such as body shape, color variations, distribution of tube legs, distribution of papillae (thorns), protrusions, nodules, and the presence or absence of lymph nodes. Different microhabitats for certain species also helped (Aziz 1995).

Data analysis technique. Analysis of species found in the study area was carried out descriptively. The community structure components analyzed in this study are density, frequency, and important value index.

The density was calculated using the following formula:

$$D=ni/A$$

Where: ni - total number of individuals for species of i; A - the total area of habitat sampled.

Relative density can be seen in the next formula:

$$RD = \frac{ni}{\sum n} \text{ or } \frac{Di}{TD} = \frac{Di}{\sum D}$$

Where: ni - total number of individuals for species of i; ∑n - the total number of all species; Di - density of i; TD - density for all species; ∑D - the total number of densities of all species.

The frequency was calculated using the following formula:

$$F = \frac{Ji}{K}$$

Where: Ji - number of samples where species i was found; K - total number of samples obtained.

The relative frequency was calculated after the formula:

$$Rf = \frac{Fi}{\sum F}$$

Where: Fi - frequency of species i; ∑F - number of frequencies for all species.

Important value index can be seen in the next formula:

$$IVI=RDi+RFi$$

Where: RDi - relative density of species i; RFi - relative frequency of species i.

The species diversity index is determined by using the Shannon-Wiener diversity index (H') and Evenness (E), from the following 2 formulas (Krebs 1969; Magurran 1983):

$$H' = -\sum pi \ln pi$$

E=H'/ln S

Where: S - total number of species; N - the total number of individuals observed; pi - individual number of species i.

For the distribution pattern of each species of sea cucumber at 8 observation stations, the Morisita distribution index was used (Magurran 1983), as follows:

$$IM = n \frac{\sum X^2 - N}{N(N-1)}$$

Where: n - number of species; N - total number of individuals in all stations; $\sum X^2$ - the square of the number of individual stations for the total of all stations.

Results and Discussion. Description of the number and species found in each transect during the study can be seen in Table 1. 11 species of sea cucumbers were found and classified in two orders: Aspidochirotida and Apodida. 9 species constitute the order Aspidochirotida with the genera *Holothuria*, *Stichopus* and *Actinopyga*. Two other species are included in the order Apodida with the genera *Synapta* and *Euapta*.

Table 1

Sea cucumbers from the coral reef of Sapeken Islands, Sumenep Regency

No	*Subclass*	*Order*	*Family*	*Genus*	*Species*	*Total*
1	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Holothuria*	*H. hilla* Lesson	296
2	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Holothuria*	*H. impatiens* Forskaal	60
3	Apodacea	Apodida	Synaptidae	*Euapta*	*E. godeffroyi* Semper	64
4	Aspidochirotacea	Aspidochirotida	Stichopodidae	*Stichopus*	*S. horrens* Selenka	96
5	Aspidochirotacea	Aspidochirotida	Stichopodidae	*Stichopus*	*S. variegatus* Semper	78
6	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Actinopyga*	*A. mauritiana* Quoy & Gaimard	94
7	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Actinopyga*	*A. lecanora* Jaeger	123
8	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Holothuria*	*H. fuscopunctata* Jaeger	65
9	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Holothuria*	*H. scabra* Jaeger	46
10	Aspidochirotacea	Aspidochirotida	Holothuriidae	*Holothuria*	*H. leucospilota* Brandt	55
11	Apodacea	Apodida	Synaptidae	*Synapta*	*S. maculata* Camysso & Eysenhardt	35
			Total			1012

The results of population characteristics calculations, including absolute density, relative density, absolute frequency, relative frequency, and important value index are presented in Table 2. Frequency was used to express the proportion between the number of samples containing a certain species and the total number of samples. The results of data analysis show that the relative frequency has varying values. High relative frequency was observed for *H. hilla* (RF=20.6%), *A. lecanora* (RF=12%), and *S. horrens* (RF=10.2%). The lowest relative frequency was observed for *S. maculata* (RF=3.7%).

Important value index was used to determine the dominance of a species in a community. Based on the analysis results, the highest important value index occurred in the case of *H. hilla*, with the value of 0.498, while for *S. maculata* it was only 0.072.

The analysis shows that the density and relative density have varying values (Table 2). *H. hilla* had the highest density value, with 1.37 ind m^{-2} (RD=29.2%), followed by *A. lecanora*, with 0.57 ind m^{-2} (RD=12.2%), and *S. horrens*, with 0.444 ind m^{-2} (RD=9.5%). Other types of sea cucumbers that have economic or commercial value had density values below 0.444 ind m^{-2}.

Table 2

Population characteristics (D, RD, F, RF, IVI) of sea cucumber from the coral reef of Sapeken Islands, Sumenep Regency

No	*Species*	*D*	*RD (%)*	*F*	*RF (%)*	*IVI*
1	*H. hilla*	1.370	29.2	0.720	20.6	0.498
2	*H. impatiens*	0.278	5.9	0.269	7.7	0.136
3	*E. godeffroyi*	0.296	6.3	0.264	7.5	0.138
4	*S. horrens*	0.444	9.5	0.356	10.2	0.197
5	*S. variegatus*	0.361	7.7	0.310	8.9	0.166
6	*A. mauritiana*	0.435	9.3	0.338	9.7	0.190
7	*A. lecanora*	0.570	12.2	0.420	12	0.242
8	*H. fuscopunctata*	0.301	6.4	0.273	7.8	0.142
9	*H. scabra*	0.213	4.5	0.134	3.8	0.083
10	*H. leucospilota*	0.255	5.4	0.236	6.7	0.121
11	*S. maculata*	0.162	3.5	0.130	3.7	0.072

Note: D - absolute density; F - absolute frequency; RD - relative density; RF - relative frequency; IVI - Important Value Index.

The results of the diversity index calculation and the distribution patterns can be seen in Tables 3 and 4. Based on Table 3, the Shannon-Wiener (H') diversity index of sea cucumbers in the coral reefs of the Sapeken Islands is included in the moderate category (2.38). The highest Evenness (E) value in this area is 0.992.

Table 3

Value of species diversity index

No	*Parameter*	*Value*	*Description*
1	Shannon-Wiener (H')	2.38	Medium categories
2	Evenness (E)	0.992	High categories

If based on the Morisita Index classification, where 1 suggests a random distribution pattern, values less than 1 show an uniform distribution pattern, and values higher than 1 show a clumped distribution pattern, the distribution pattern of all sea cucumbers found in the research is clumped, with an IM value higher than 1.

Table 4

Distribution patterns of various species of sea cucumbers

No	*Species*	*Number of species*	*Number of individuals*	ΣX^2	*Morisita Index*	*Description*
1	*H. hilla*	11	296	11679	1.43	Clumped
2	*H. impatiens*	11	60	534	1.7	Clumped
3	*E. godeffroyi*	11	64	567	1.28	Clumped
4	*S. horrens*	11	96	1374	1.54	Clumped
5	*S. variegatus*	11	78	912	1.53	Clumped
6	*A. mauritiana*	11	94	1776	2.11	Clumped
7	*A. lecanora*	11	123	2652	1.85	Clumped
8	*H. fuscopunctata*	11	65	1194	2.99	Clumped
9	*H. scabra*	11	46	356	1.81	Clumped
10	*H. leucospilota*	11	55	421	1.36	Clumped
11	*S. maculata*	11	35	169	1.23	Clumped

The species of sea cucumber. 11 species of sea cucumber were identified in the coral reefs of the Sapeken Islands in Sumenep Regency. Sea cucumbers found belong to 2 orders, namely the order Aspidochirotida (genera *Holothuria*, *Stichopus* and *Actinopyga*) and the order Apodida (genera *Synapta* and *Euapta*). This was consistent with the statements that Aspidochirotida prefers clear tropical waters (Samyn & Tallon 2005;

Eriksson et al 2012a; Kerr 2013). The West Indo-Pacific region is the richest area in sea cucumbers of the genera *Holothuria*, *Stichopus* and *Actinopyga* (Choo 2008; Bordbar et al 2011). Apodida can be found in deep and shallow seas, including in coral reefs (Choo 2008; Solís-Marín et al 2019). The large number of sea cucumbers in the microhabitat is due to the need for protection from sunlight. Sea cucumber is sensitive to sunlight, so some sea cucumbers present negative phototaxis (Dong et al 2010; Abesamis et al 2018). Meanwhile, according to Yusron (2001), in general, sea cucumbers like clear and clean waters with a fine sandy base with protective plants, protected from the movement of the waves, in a detritus-rich environment.

The species of sea cucumbers found in the flat area of the Kepekuan Sapeken, Sumenep Regency are *H. hilla, A. lecanora*, *S. horrens*, *A. mauritiana*, *S. variegatus*, *H. fuscopunctata, E. godeffroyi*, *H. impatiens*, *H. leucospilota*, *H. scabra* and *S. maculata*. According to Aziz (1995), the species *A. lecanora. A. mauritinia, B. argus, H. impatiens, S. chloronotus,* and *S. horrens* are often found in hard substrates, especially in coral reef ecosystems. Furthermore, it was said that even though sea cucumber preferences for a type of substrate can be distinguished, there is the possibility of sea cucumbers occupying a variety of substrates. Species *H. leucospilota* and *S. variegatus* can occupy various types of substrates.

The diversity of sea cucumbers in the reef of the Sapeken Islands, Sumenep Regency is relatively similar to several other research areas, summarized in Table 5.

Table 5

The diversity of sea cucumbers in several other research areas

No	*Location*	*Number of species*	*Study period*	*Reference*
1	Bunaken Island, North Sulawesi	10	May (1 month)	Tamanampo et al (1989)
2	Tanimbar waters, Southeast Maluku	12	1 month	Rumahrupete et al (1990)
3	Penjaliran Barat Island, Jakarta Bay	13	January (1 month)	Siena (1996)
4	Derawan Islands, East Kalimantan	14	January (1 month)	Darsono (2002b)
5	Morella coastal waters, Ambon	10	August (1 month)	Yusron (2001)
6	Kotania Bay of West Seram Barat, Central Maluku	12	August (1 month)	Yusron (2003)
7	Pulau Timur Timur, Kepulauan Seribu	9	1 Month	Dumilah (2006)
8	Baluran National Park, East Java	21	July until September 2015 (3 months)	Siddiq et al (2016)
9	Suli Village, Maluku	14	September to October 2017 (2 months)	Manuputty et al (2019)
10	Waters of Lampung	8	April 2016 (1 month)	Setyastuti et al (2018)

This shows that this area still has potential as a habitat for sea cucumbers with a high selling price. The number of species found in the coral reef of the Sapeken District of Sumenep Regency can increase because the sampling was conducted only during the day. In fact, according to Aziz (1995), several other types of sea cucumbers such as *H. arenicola, H. perficax* and *H. difficilis* are nocturnal, hiding during the day.

Density. The research of Tamanampo et al (1989) in the coral reefs of Bunaken Island, North Sulawesi, recorded the densities of *S. chloronotus* (1.02 ind m^{-2}), *B. argus* (0.97 ind m^{-2}), and *H. atra* (0.78 ind m^{-2}) sea cucumbers. A study in Morella Ambon coastal waters resulted in the following densities of sea cucumbers *H. edulis*, *H. atra*, *B. marmorata* and *H. scabra*: 1.03 ind m^{-2}, 0.81 ind m^{-2}, 0.71 ind m^{-2}, and 0.69 ind m^{-2}, respectively (Yusron 2001). In the waters of the Gulf of Kotania, West Seram, Central Maluku, the highest density of sea cucumbers *H. scabra*, *H. atra* and *B. argus* were 1.32 ind m^{-2}, 1.24 ind m^{-2}, and 1.02 ind m^{-2}, while other species had a density of under 1 ind m^2 (Yusron 2003). The lowest density value in the reef flat area of Sapeken Islands, Sumenep Regency was that of *S. maculata* (0.162 ind m^{-2}), the relative density being only 3.5%. However, this density is better than the results of the study of Rajab & Darsono (2004), where the density of *S. maculata* in the Natuna Islands, Riau Islands waters was only 0.01 ind m^{-2} although this species is the one most commonly found.

The high density of the species mentioned above is due to their ability to occupy a variety of habitats so that it has more opportunities to develop. Moreover, it has no economic value, so it is not subject to exploitation by the community. According to Rajab (1996), low density and the lack of ability to compete and occupy habitats is caused by over exploitation. However, the density of sea cucumber species in the reef of the Sapeken Islands was still higher than the density of sea cucumbers on the average reef of Putri Timur Island, in the Thousand Islands. According to Dumilah (2006), sea cucumber density in this area is very low, only 0.0013-0.0283 ind m^{-2}.

Frequency. The highest relative and absolute frequencies were calculated for *H. hilla, A. lecanora*, and *S. horrens*. *S. maculata* had the lowest relative and absolute frequency. The 3 species mentioned above have a wider distribution than other species. These species are found in almost all types of substrates or the bottom edge of the reef. Sea cucumbers are benthic animals that have non-selective eating habits. Holothurians that live in the tropics often eat microorganisms that live in the sand, mud and detritus, microcrustacea and Polychaeta.

In North Sulawesi, the highest frequency is obtained for *H. scabra* (0.6), followed by *H. edulis* and *H. leucospilota*, each with 0.537, *H. atra* (0.333), *H. verucosa, B. argus* and *S. horrens* each with a value of 0.267. The frequency of other species was below 0.2 (Rajab & Yusron 1994). In Ambon Morella waters, the highest frequency was observed in the case of *H. scabra* (0.5927), followed by *H. atra* (0.4223), *H. similis* (0.3661), *B. argus* (0.3361), and *B. marmorata* (0.3067). The frequencies of other species were below 0.3 (Yusron 2001). In the waters of the Kotania Bay, West Seram, Central Maluku, the highest frequency was observed for *H. scabra* (0.4886), followed by *H. edulis* (0.3632), *B. marmorata* (0.3072) and *B. argus* (0.2448), while other species had frequency values below 0.2 (Yusron 2003).

Important Value Index. *H. hilla* has the highest important value index compared to other types because it does not yet have a commercial value but also because of the ability of these species to adapt to different habitats and environmental changes. The results of this study further support the results of previous studies which state that the presence of commercial sea cucumbers in Indonesian waters began to diminish and its natural population is relatively very low as explained by Yusron (2001). Sea cucumber scarcity and low density have occurred in almost all regions of Indonesia due to overexploitation (Purcell et al 2009; Jasmadi et al 2018), or due to damage to habitats, like coral reefs (Bryant et al 1998; Teh et al 2013). The scarcity of sea cucumbers is a signal of extinction and it should be met with preservation efforts as soon as possible. It seems that the business continuity of sea cucumbers and their production must be based on aquaculture (Robinson & Pascal 2011; Eriksson et al 2012b; Suryono et al 2019).

Species diversity index. Based on Table 3, the densities of certain species, which were relatively higher than other community members, place the Shannon-Wiener (H') diversity index in the medium category (2.38). However, quantitatively, in the sea cucumber community there was no dominance of one species. This can be seen from the

Evenness (E) index, which was high, 0.992. This shows that the quantitative distribution of density values between community members tends to be evenly distributed (E value approaching 1). The results of this study tend to be the same as the results of the study of Yusron & Widianwari (2004) in some waters of the Great Kai coast, Southeast Maluku, where the diversity index is in the medium category, between 2.2 to 2.5 and Evennes (E) in each location between 0.9 and 0.96.

Distribution pattern. The results of the analysis of the spread patterns are presented in Table 4. The description of the distribution patterns of sea cucumbers per type are presented in Figure 3.

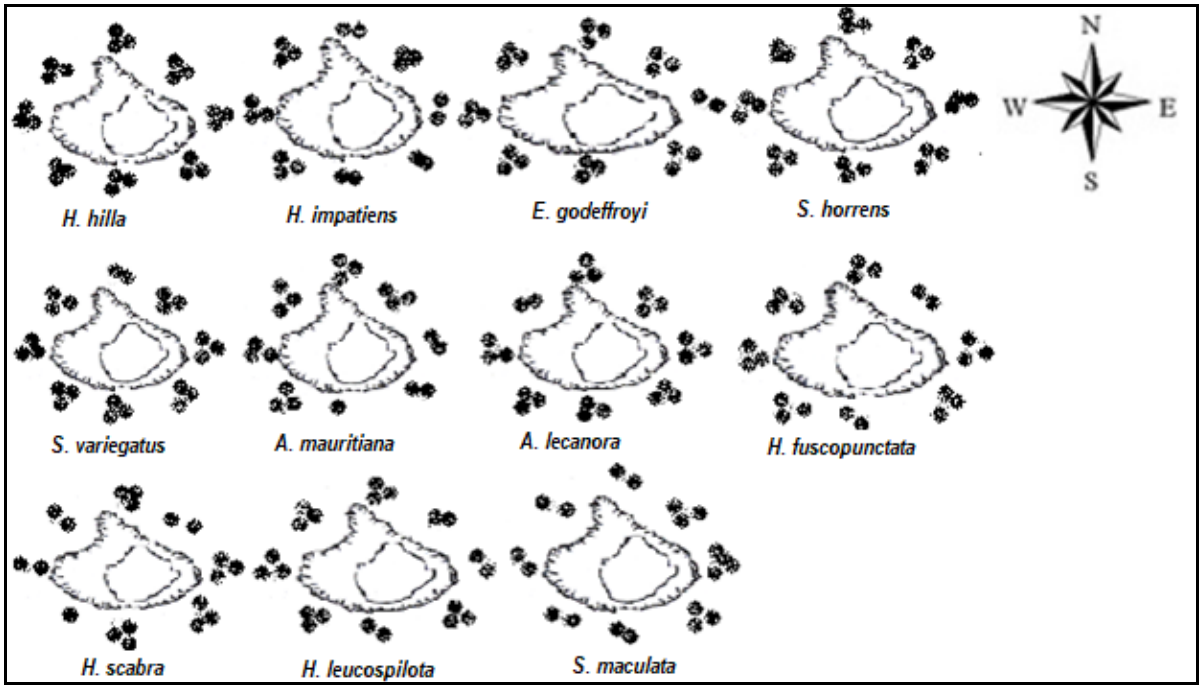

Figure 3. Distribution patterns of each species of sea cucumber in the coral reefs of the Sapeken Islands, Sumenep Regency. 1 dot - low density; 2 dots - medium density; 3 dots - high density.

The results of this study were relatively the same as those of Yuana (2002) in Cemara Kecil and Karimunjawa Islands, which show that the distribution pattern of sea cucumbers on both islands was clustered. The results of this study were very different when compared with some of the results of other studies on the distribution of sea cucumbers in other areas. Yusron (2001) found that the distribution pattern of sea cucumbers in the coral reefs of Morella Beach, Ambon, varied. For example, *H. atra* was evenly distributed (0.88), *H. scabra* and *T. anax* had a random distribution pattern (1), while other species had a group distribution pattern (>1). However, the distribution pattern of *S. variegatus* in the two study areas was the same, in groups (clumped). Tamanampo et al (1989)observed that in the waters of Bunaken Island, North Sulawesi, 2 species of sea cucumber had a pattern of dispersal in groups (*B. argus* and *S. chloronatus*), while *H. atra*, *H. disrepans*, *H. nobilis, H. scabra, A. lecanora*, and *T. ananas* had a random distribution pattern.

Sea cucumber distribution patterns differ depending on the type and nature of sea cucumbers. There are species that live in groups (clumped) and species that are randomly distributed (Eriksson et al 2012a; Husain et al 2017; Stepanov & Panin 2019). Sea cucumber species, substrate conditions, and habitat also determine the distribution pattern of sea cucumbers. There was also a tendency of certain species to prefer certain basic types (Aziz 1995). Sea cucumbers are very dependent on the condition of the surrounding substrate, because the space is relatively limited and their motion is very

slow (Dissanayake & Stefansson 2012; Purcell et al 2016; Yuan et al 2018). A random distribution pattern occurs when environmental conditions were uniform and there was no tendency to make an impression (Tamanampo et al 1989). Random distribution is rare in nature and can occur when the environment is uniform (Avila 1995; Rawat et al 2015). Uniform distribution occurs when competition between individuals is very intense or there is a positive antagonist that encourages the same division of space (Heddy & Kurniati 1994; Amaral et al 2015). As with random distribution, the spread of organisms in nature is rarely found in a uniform pattern (Yadav 2003; Osborne 2012), but grouping with varying degrees is the most common pattern in a population and is almost a rule when viewed from an individual point of view (Heddy & Kurniati 1994; Begon et al 2006; Cassini 2013; Martínez-García et al 2015).

Conclusions. Sea cucumbers (Holothuroidea) found in the flat area of the Sapeken Islands, Sumenep Regency consist of 11 species of two orders, namely the order Aspidochirotida (genera *Holothuria*, *Stichopus* and *Actinopyga*) and Apodida (genera *Synapta* and *Euapta*). The density ranges between 0.162 ind m^{-2} and 1.37 ind m^{-2}. Relative density values ranged between 0.035 and 0.292. The highest density was observed for *H. hilla* and the lowest density for *S. maculata*. Frequencies range from 0.13 to 0.72. The Relative Frequency values range from 0.037 to 0.206, with the highest frequency value for *H. hilla* and the lowest frequency for S. *maculata*. The highest Important Value Index was 0.498, for *H. hilla*, and the lowest was 0.072, for *S. maculata*. The Shannon-Wiener (H ') diversity index value was 2.38, in the medium category and the Evenness (E) value was 0.992, which means that quantitatively the density value among community members tends to be even (E close to 1). Morisita Index (IM) values ranged from 1.23 to 2.99, higher than 1, meaning the distribution pattern of all species of sea cucumbers in the coral reefs area of Sapeken Islands, Sumenep Regency was clumped.

Sea cucumbers of Sapeken Islands, Sumenep Regency, represent a large potential resource. The economic life of the people of Sapeken Islands is highly dependent on the sea, including on various animal species that live in coral reefs, including sea cucumbers. Therefore, it is important to think about efforts to maintain sea cucumber fisheries and their production in fishery-based businesses to reduce overexploitation of natural stocks.

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References

Abesamis N., Meñez M. A., Slater M., 2018 Effects of light and microhabitat on activity pattern and behaviour of wild and hatchery-reared juveniles of *Stichopus* cf. *horrens*. Journal of the Marine Biological Association of the United Kingdom 98(7):1703-1713.

Amaral M. K., Pellico Netto S., Lingnau C., Figueiredo Filho A., 2015 Evaluation of the Morisita index for determination of the spatial distribution of species in a fragment of Araucaria forest. Applied Ecology and Environmental Research 13(2):361-372.

Anderson S., Flemming J., Watson R., Lotze H., 2011 Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12:317-339.

Aprianto R., Amir N., Kasmiati, Matusalach, Fahrul, Syahrul, Tresnati J., Tuwo A., Nakajima M., 2019 Economically important sea cucumber processing techniques in South Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science 370:012082, 7 p.

Avila V. L., 1995 Biology: investigating life on earth. 2nd Edition. Jones & Bartlett, Boston, MA, 979 p.

Aziz A., 1995 [Some notes about the sea cucumbers Aspidochirotida]. Oseana, 20(4):11-

23. [In Indonesian].
Begon M., Townsend C. R. Harper J. L., 2006 Ecology from individuals to ecosystems. 4th Edition. Blackwell Publishing Ltd, Malden, MA, 750 p.
Bordbar S., Anwar F. Saari N., 2011 High-value components and bioactives from sea cucumbers for functional foods - a review. Marine Drugs 9(10):1761-1805.
Bryant D., Burke L., McManus J., Spalding M., 1998 Reefs at risk: a map-based indicator of threats to the worlds coral reefs. World Resources Institute, Washington DC, 56 p.
Cassini M. H., 2013 Distribution ecology: from individual habitat use to species biogeographical range. Springer Science & Business Media, New York, 217 p.
Chávez E. A., Salgado-Rogel M. D. L. Palleiro-Nayar J., 2011 Stock assessment of the warty sea cucumber fishery (*Parastichopus parvimensis*) of NW Baja California, California Cooperative Oceanic Fisheries Investigations Report 52:136-147.
Choo P. S., 2008 Population status, fisheries and trade of sea cucumbers in Asia. In: Sea cucumbers. A global review of fisheries and trade. Toral-Granda V., Lovatelli A., Vasconcellos M. (eds), FAO Fisheries and Aquaculture Technical Paper No. 516, Rome, FAO, pp. 81-118.
Clark A. M., Rowe F. W. E., 1971 Monograph of shallow-water Indo-West Pacific echinoderms. Trustees of the British Museum (Natural History), London, 31 p.
Conand C., 1993 Ecology and reproductive biology of *Stichopus variegatus* an Indo-Pacific coral reef sea cucumber (Echinodermata: Holothuroidea). Bulletin of Marine Science 52(3):970-981.
Conand C., Muthiga N., 2007 Commercial sea cucumbers: a review for the Western Indian Ocean. WIOMSA Boo, Zanzibar, Tanzania, 66 p.
Costelloe J., Keegan B. F., 1984 Feeding and related morphological structures in the dendrochirote *Aslia lefevrei* (Holothuroidea: Echinodermata). Marine Biology 84(2):135-142.
Darsono P., 2002a [Shouls sea cucumbers (Holothurians) be protected]? Oseana 27(3):1-9. [In Indonesian].
Darsono P., 2002b [Sea cucumber resources in Derawan Islands, East Kalimantan]. Oseana 27(1):9-18. [In Indonesian].
Dissanayake D. C. T., Stefansson G., 2012 Habitat preference of sea cucumbers: *Holothuria atra* and *Holothuria edulis* in the coastal waters of Sri Lanka. Journal of the Marine Biological Association of the United Kingdom 92(3):581-590.
Dong G., Dong S., Wang F., Tian X. L., 2010 Effects of light intensity on daily activity rhythm of juvenile sea cucumber, *Apostichopus japonicus* (Selenka). Aquaculture Research 41(11):1640-1647.
Dumilah D. R., 2006 [The abundance of sea cucumbers (Holothuroidea) on the reef flats of Pulau Timur Timur, Kepulauan Seribu]. PhD Thesis, Biologi FMIPA, Universitas Indonesia, 100 p. [In Indonesian].
Eriksson H., Byrne M., de la Torre-Castro M., 2012a Sea cucumber (Aspidochirotida) community, distribution and habitat utilization on the reefs of Mayotte, Western Indian Ocean. Marine Ecology Progress Series 452:159-170.
Eriksson H., Robinson G., Slater M. J., Troell M., 2012b Sea cucumber aquaculture in the Western Indian Ocean: challenges for sustainable livelihood and stock improvement. Ambio 41(2):109-121.
Fachruddin A., Efendy M., 2019 [Potential resource studies in the coastal and marine areas of Sumenep Regency]. Jurnal Ilmiah Perikanan dan Kelautan 3(2):235-239.
Hartati R., Widianingsih W., Trianto A., Zainuri M., Ambariyanto A., 2017 The abundance of prospective natural food for sea cucumber *Holothuria atra* at Karimunjawa Island waters, Jepara, Indonesia. Biodiversitas 18(3):947-953.
Heddy S., Kurniati M., 1994 [Basic ecological principles: a discussion of ecological principles and their application]. Raja Grafindo Persada, Jakarta, Indonesia, 271 p. [In Indonesian].
Husain G., Tamanampo J. F. W. S., Manu G. D., 2017 Community structure of sea cucumber (Holothuroidea) in the coastal area of the Island of Jailolo Subdistrict Nyaregilaguramangofa South Halmahera Regency West Of North Maluku. Jurnal

Ilmiah Platax 5(2):177-188.
Indriana L. F., Firdaus M., 2020 Growth performance of sea cucumber *Holothuria scabra* juvenile in different initial size of pond culture in Lombok, Indonesia. E3S Web of Conferences 147: 01003, 7 p.
Jasmadi J., Wirawati I., Suryaningtyas I. T., Permadi S., 2018 Study on community structure of commercial sea cucumber in intertidal zone, Southeast Moluccas, and Tual, Moluccas. Jurnal Ilmiah Perikanan Dan Kelautan 10(1):106-111.
Kerr A. M., 2013 *Holothuria (Semperothuria) roseomaculata* n. sp. (Aspidochirotida: Holothuriidae), a coral-reef inhabiting sea cucumber from the western Pacific Ocean. Zootaxa 3641(4):384-394.
Kerr A. M., Stoffel E. M., Yoon R. L., 1993 Abundance distribution of holothuroids (Echinodermata: Holothuroidea) on a windward and leeward fringing coral reef, Guam, Mariana Islands. Bulletin of Marince Science 52(2):780-791.
Kinch J., Purcell S. W., Uthicke S., Friedman K., 2008 Population status, fisheries and trade of sea cucumbers in the Western Central Pacific. In: Sea cucumbers. A global review of fisheries and trade. Toral-Granda V., Lovatelli A., Vasconcellos M. (eds), FAO Fisheries and Aquaculture Technical Paper No. 516, Rome, FAO, pp. 7-55.
Kolasinski J., Taddei D., Cuet P., Frouin P., 2010 AChE and EROD activities in two echinoderms, *Holothuria leucospilota* and *Holoturia atra* (Holothuroidea), in a coral reef (Reunion Island, South-western Indian Ocean). Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering 45(6):699-708.
Komala R., Miarsyah M., Wulaningsih R. D., 2019 Holothuroidea as a constituent of benthic communities in the seagrass ecosystems at Bira Island Islands. IOP Conference Series: Earth and Environmental Science 391: 012046, 6 p.
Krebs C. J., 1969 Ecological methodology. University of British Columbia, Harper Collins Publishers, Columbia, SC, 624 p.
Lane D. J. W., Limbong D., 2015 Catastrophic depletion of reef-associated sea cucumbers: resource management/reef resilience issues for an Indonesian marine park and the wider Indo-Pacific. Aquatic Conservation Marine and Freshwater Ecosystems 25(4)505-517.
Lasabuda R., 2013 [Regional development in coastal and ocean in archipelago perspective of the Republic of Indonesia]. Jurnal Ilmiah Platax 1(2):92-101. [In Indonesian].
Magurran A. E., 1983 Ecological diversity and its measurement. Springer Science & Business Media, London, UK, 179 p.
Máñez K. S., Ferse S. C. A., 2010 The history of Makassan trepang fishing and trade. PLoS ONE 5(6):e11346, 8 p.
Manuputty G. D., Pattinasarany M. M., Limmon G. V., Luturmas A., 2019 Diversity and abundance of sea cucumber (Holothuroidea) in seagrass ecosystem at Suli Village, Maluku, Indonesia. IOP Conference Series: Earth and Environmental Science 339:012032, 8 p.
Martínez-García R., Murgui C., Hernández-García E., López C., 2015 Pattern formation in populations with density-dependent movement and two interaction scales. PLoS ONE 10(7):e0132261, 14 p.
Massin C., Tomascik T., 1996 Two new Holothurians (Echinodermata: Holothuroidea) from an anchialine lagoon of an uplifted atoll, Kakaban Island, East Kalimantan, Indonesia. Raffles Bulletin of Zoology 44(1):157-172.
Mulyono M., Apriandeni N. S., Nurbani S. Z., Samsudin A., 2017 Community structure of sea cucumber on coral reefs in Togean Islands national park central Sulawesi, Indonesia. International Journal of Fisheries and Aquatic Studies 5(6):201-204.
Muzaki F. K., Setiawan E., Insany G. F. A., Dewi N. K., Subagio I. B., 2019 Community structure of echinoderms in seagrass beds of Pacitan beaches, East Java, Indonesia. Biodiversitas 20(7):1787-1793.
Natan Y., Tetelepta J. M. S., Uneputty P. A., 2016 Sustainability of sea cucumber fishery at Central Maluku and Southeast Maluku Regency, Indonesia. AACL Bioflux 9(1):34-41.

Nurkholis N., Nuryadin D., Syaifudin N., Handika R., Setyobudi R. H. Udjianto D. W., 2016 The economic of marine sector in Indonesia. Aquatic Procedia 7:181-186.
Nurwidodo N., Husamah H., Rahardjanto A., Mas'odi M., Mufrihah A., 2017 Teacher resilience in remote islands area: a case study in Small Pagerungan Island Sumenep Regency, Indonesia. Journal of Education and Learning 11(1):47-56.
Nurwidodo N., Rahardjanto A., Husamah H., Mas'odi M., 2018 From shark hunter to seaweed and sea-cucumber cultivator: a phenomenology study at Sapeken Islands, Indonesia. American Journal of Humanities and Social Sciences Research 2(10):119-124.
Osborne P. L., 2012 Tropical ecosystems and ecological concepts. 2nd Edition. Cambridge University Press, Cambridge, UK, 522 p.
Pangestuti R., Murniasih T., Putra M. Y., Rasyid A., Wibowo J. T., Ardiansyah A., Untari F., 2016 Free radical scavenging activity of selected sea cucumber species from Mataram-Lombok, Indonesia. Jurnal Teknologi 78(4-2):179-185.
Pankey H., Lantu S., Manuand L., Mokolensang J. F., 2012 Prospect of sea cucumber culture in Indonesia as potential food sources. Journal of Coastal Development 15(2):114-124.
Prescott J., Riwu J., Prasetyo A. P., Stacey N., 2017 The money side of livelihoods: economics of an unregulated small-scale Indonesian sea cucumber fishery in the Timor Sea. Marine Policy 82197-205.
Purcell S. W., 2010 Managing sea cucumber fisheries with an ecosystem approach. FAO Fisheries and Aquaculture Department, Rome, Italy, 157 p.
Purcell S. W., Conand C., Uthicke S., Byrne, M., 2016 Ecological roles of exploited sea cucumbers. Oceanography and Marine Biology 54:367-386.
Purcell S. W., Gossuin H., Agudo N. S., 2009 Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. The WorldFish Center, Nouméa Cedex, New Caledonia, 138 p.
Purcell S. W., Mercier A., Conand C., Hamel J., Toral-Granda V., Lovatelli A., Uthicke S., 2013 Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. Fish and Fisheries 14:34-59.
Purcell S. W., Samyn Y., Conand C., 2012 Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes No. 6, Rome, Italy, 150 p.
Purwaka T. H., Sunoto S., 1997 Coastal resources management in Indonesia: legal and institutional aspects. Institutional Issues and Perspectives in the Management of Fisheries and Coastal Resources in Southeast Asia, ICLARM Technical Report 60, World Fish Center, pp. 60-90.
Purwati P., 2005 [Indonesian sea cucumbers: species composition and history of fisheries]. Oseana 30(2):11-18. [In Indonesian].
Putro K. H., 2016 [Development planning in Papua and demographic bonus 2020]. Jurnal Tata Kelola & Akuntabilitas Keuangan Negara 2(1):49-70.
Rajab A. W., 1996 [Sea cucumbers in Teluk Un Island Dullah Southeast Maluku]. In: Maluku and surrounding waters II. Balitbang Sumberdaya Laut, Puslitbang Oseanologi LIPI, Jakarta, Indonesia, pp. 9-18. [In Indonesian].
Rajab A. W., Darsono P., 2004 [Distribution and density of sea cucumbers (Holothuroidea) in Natuna Islands waters, Riau]. Jurnal Torani 14(2):64-69. [In Indonesian].
Rajab A. W., Yusron E., 1994 [Pengamatan teripang (Holothuroidea) di Perairan Pantai Sulawesi Utara]. Dalam Perairan Maluku dan Sekitarnya, LIPI, Jakarta, Indonesia, pp. 41-46. [In Indonesian].
Rawat M., Dookia S., Sivaperuman C., 2015 Aquatic ecosystem: biodiversity, ecology and conservation. Springer New Delhi, New Delhi, 333 p.
Rawson K., Hoagland P., 2019 Sea cucumbers in a pickle: the economic geography of the serial exploitation of sea cucumbers. Ecology and Society 24(4):35, 7 p.
Rini D. A. S., Pratikto W. A., Sambodo K., 2015 [Identifying the potential of the Kangean Island resource area, Sumenep Madura Regency as a marine tourism area]. Jurnal Kelautan 8(2):60-70. [In Indonesian].
Robinson G., Pascal B., 2011 Sea cucumber farming experiences in south-western

Madagascar. Conference: Asia–Pacific tropical sea cucumber aquaculture, pp. 142-155.
Rowe F. W. E., 1969 A review of the family Holothuriidae (Holothurioidea: Aspidochirotida). Bulletin of the British Museum (Natural History) 18(4):119-170.
Rumahrupete B., Choliq A., Letelay J., 1990 [The density and abundance of sea cucumbers (*Holothuria* spp.) on the beach of Yamdena Island, South Tanimbar District]. Jurnal Penelitian Perikanan Laut 55:41-48. [In Indonesian].
Sadili D., Sarmintohadi S., Ramli I., Rasdiana H., Sari R. P., Miasto Y., Annisa S., 2015 [Sea cucumber conservation national action plan (RAN) period I: 2016-2020]. Darmawan A., Setyastuti A., Hartati S. T. (eds), Indonesian Ministry of Maritime Affairs and Fisheries, Jakarta, 44 p. [In Indonesian].
Samyn Y., Tallon I., 2005 Zoogeography of the shallow-water holothuroids of the Western Indian Ocean. Journal of Biogeography 32(9):1523-1538.
Schneider K., Silverman J., Woolsey E., Eriksson H., Byrne M., Caldeira K., 2011 Potential influence of sea cucumbers on coral reef $CaCO_3$ budget: a case study at One Tree Reef. Journal of Geophysical Research: Biogeosciences 116(G4):G04032, 6 p.
Setyastuti A., Wirawati I., 2018 The Banda Sea: a hotspot of deep-sea echinoderms diversity in Indonesia. IOP Conference Series: Earth and Environmental Science 184:012003, 9 p.
Setyastuti A., Wirawati I., Iswari M. Y., 2018 Identification and distribution of sea cucumber exploited in Lampung, Indonesia. Biodiversitas 19(2):646-652.
Siddiq A. M., Atmowidi T., Qayim I., 2016 The diversity and distribution of holothuroidea in shallow waters of Baluran National Park, Indonesia. Biodiversitas 17(1):55-60.
Siena K., 1996 [Inventory of species of sea cucumbers (Echinodermata, Holothuridea) on the reef flats of Penjaliran Barat Island, Jakarta Bay]. PhD Thesis, Universitas Indonesia, 100 p. [In Indonesian].
Skillings D. J., Bird C. E., Toonen R. J., 2014 Comparative population structure of two edible Indo-Pacific coral reef sea cucumbers (Echinodermata: Holothuroidea), Bulletin of Marine Science 90(1):359-378.
Solís-Marín F. A., Conejeros-Vargas C. A., Caballero-Ochoa A. A., Arriaga-Ochoa J. A., 2019 *Epitomapta simentalae* sp. N., a new species of apodous sea cucumber from the central eastern pacific coast of Mexico (Echinodermata, Holothuroidea, Apodida). ZooKeys 2019(817):1-9.
Stepanov V. G., Panin E. G., 2019 New data about distribution of the sea cucumber *Molpadia musculus* Risso, 1826 (Holothuroidea: Molpadiida: Molpadiidae) in Russian seas. SPC Beche-de-mer Information Bulletin 38:77-78.
Sukmiwati M., Salmah S., Ibrahim S., Handayani D., Purwati P., 2012 [Sea cucumber diversity (Holothuroidea) in the eastern waters of the Natuna Coast of the Riau Islands]. Jurnal Natur Indonesia 14(1):131-137. [In Indonesian].
Sukristijono S., 2002 Integrated coastal zone management (ICZM) in Indonesia: a view from a mangrove ecologist. Southeast Asian Studies 40(2):200-218.
Suryono S., Suryono C. A., Wibowo E., Santoso A., Nur Taufik S. P. J., 2019 Feasibility study of sea cucumber cultivation investment in Karimunjawa Islands, Jepara Regency. IOP Conference Series: Earth and Environmental Science 246:012068, 7 p.
Tamanampo J F. W. S., Rondo M., Salaki M. S., 1989 [Potential and sea cucumber community on the flattened coral reefs of Bunaken Island, North Sulawesi]. Jurnal Fakultas Perikanan Unsrat 1(1):25-32. [In Indonesian].
Teh L. S. L., Teh L. C. L., Sumaila U. R., 2013 A global estimate of the number of coral reef fishers. PLoS ONE 8(6):e65397, 10 p.
Thorne B. V., Byrne M., 2013 Survivorship of post-split fission products of *Holothuria atra* (Holothuroidea: Aspidochirotida) on the southern Great Barrier Reef. Invertebrate Reproduction and Development 57(4):293-300.
Uthicke S., 1997 Seasonality of asexual reproduction in *Holothuria (Halodeima) atra, H. (H.) edulis* and *Stichopus chloronotus* (Holothuroidea: Aspidochirotida) on the Great Barrier Reef. Marine Biology 129(3):435-441.
Uthicke S., Benzie J. A. H., 2000 Allozyme electrophoresis indicates high gene flow

between populations of *Holothuria (Microthele) nobilis* (Holothuroidea: Aspidochirotida) on the Great Barrier Reef. Marine Biology 137(5-6):819-825.
Uthicke S., Benzie J. A. H., 2001 Effect of bêche-de-mer fishing on densities and size structure of *Holothuria nobilis* (Echinodermata: Holothuroidea) populations on the great barrier reef. Coral Reefs 19(3):271-276.
Varkey D. A., Ainsworth C. H., Pitcher T. J., Goram Y., Sumaila R., 2010 Illegal, unreported and unregulated fisheries catch in Raja Ampat Regency, Eastern Indonesia. Marine Policy 34(2):228-236.
Widianingsih W., Hartati R., Zainuri M., Anggoro S., Kusumaningrum H. P., Mahendrajaya R. T., 2019 Morphological ossicles of sea cucumber *Paracaudina australis* from Kenjeran Waters, Surabaya, Indonesia. IOP Conference Series: Earth and Environmental Science 246:012019, 5 p.
Widianingsih W., Zaenuri M., Anggoro S., Kusumaningrum H. P., Hartati R., 2018 Preliminary study on gonad maturity stages of the sea cucumber *Paracaudina australis* from Kenjeran Water, Surabaya, Indonesia. IOP Conference Series: Earth and Environmental Science 116:012035, 8 p.
Woo S. P., Zulfigar Y., Norhanis M. R., Teh C. P., Tan S. H., 2010 The diversity of sea cucumbers (Echinodermata: Holothuroidea) in five reefs of the South China sea, Malayan Nature Journal 62(4):371-377.
Yadav M., 2003 Ecology. Discovery Publishing House, New Delhi, 434 p.
Yuan X., McCoy S. J., Du Y., Widdicombe S., Hall-Spencer J. M., 2018 Physiological and behavioral plasticity of the sea cucumber *Holothuria forskali* (Echinodermata, Holothuroidea) to acidified seawater. Frontiers in Physiology 9:1339, 10 p.
Yuana S., 2002 [Abundance and distribution of sea cucumbers (Holothuroidea) in Karimunjawa coastal waters]. PhD thesis, Universitas Diponegoro, 71 p. [In Indonesian].
Yusron E., 2001 [The structure of the sea cucumber community (Holothuroidea) on the flat coral reefs of Ambon's Morella coast]. Pesisi dan Pantai Indonesia IV, Pusat Penelitian dan Pengembangan Oseanologi, LIPI, Jakarta, Indonesia, pp. 227-233. [In Indonesian].
Yusron E., 2003 [Sea cucumber resources (Holothuroidea) in the waters of the Gulf of Kotania, West Seram-Central Maluku]. Dalam Pesisir dan Pantai Indonesia VIII, P3O-LIPI, Jakarta, Indonesia, pp. 129-133. [In Indonesian].
Yusron E., Widianwari P., 2004 [Sea cucumber community structure (Holothuroidea) in several waters off the coast of Kai Besar, Southeast Maluku]. MAKARA of Science Series 8(1):15-20. [In Indonesian].
***Asian Development Bank, 2014 State of the coral triangle: Indonesia. ADB, Coral Triangle Initiative, and GEF, Mandaluyong City, Philippines, 68 pp.
***CEA, 2018 Trends in marine resources and fisheries management in Indonesia. A 2018 review. California Environmental Associates, California, 145 p.
***CITES, 2019 II Appendices I, II and III valid from 26 November 2019. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Available at: https://www.cites.org/eng/app/appendices.php
***USAID, 2018 State of the sea: Indonesia, volume one: an overview of marine resource management for small-scale fisheries and critical marine habitats in Indonesia. USAID Sustainable Ecosystems Advanced (SEA) Project and the Ministry of Marine Affairs and Fisheries (MMAF), Jakarta, Indonesia, 156 p.
***Wirawan J., 2018 [Indonesia is the world's biggest producer of sea cucumbers, but sea cucumbers are now hard to find]. News BBC Indonesia. Available at: http://www.bbc.com/indonesia/majalah-43207713. [In Indonesian].

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