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Diversity and abundance of sea cucumber (Holothuroidea) resources in the Waters of Duroa Island, Tual City, Maluku, Indonesia

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Abstract. *Kalidi NS, Muskananfola MR, Suryanti S. 2023. Diversity and abundance of sea cucumber* (*Holothuroidea*) *resources in the Waters of Duroa Island, Tual City, Maluku, Indonesia. Biodiversitas 24: 6002-6009.* The people of Duroa Island, Tual City, Indonesia, have been utilizing sea cucumber resources continuously without considering its impact on ecological factors and sustainability. Formulating management initiatives is one possible solution to sustain the stock. However, it is hampered by the lack of information on its current status. This study aims to assess the abundance and diversity as well as the condition of the aquatic environment. In the observation 9 sea cucumbers were found from *Holothuria, Bohadschia, Actinopyga, Stichopus*, and *Thelenota* genera. The density of sea cucumber was highest at station 4 (0.417 ind/m²), and lowest at station 1 (0.083 ind/m²). *Holothuria edulis* dominated the sea cucumber community at a density of (0.450 ind/m^2). Habitat characteristics of sea cucumber observation stations on Duroa Island are dominated by seagrass, rocky sand, rough sand, and sand. Ecological indices such as diversity are classified as moderate, high uniformity, and low dominance. All observation stations have water quality that is still in the optimal range according to water quality standards for marine biota, except at station 1 because the station has a pH value below the national quality standard of <6.5.

Keywords: Abundance, diversity, holothurians

INTRODUCTION

Sea cucumbers are marine invertebrates that belong to the class Holothuroidea, phylum Echinodermata, and live in various aquatic environments ranging from shallow coastal waters to the deep sea (Purcell et al. 2016). Sea cucumbers have important ecological functions in coral reef ecosystems (Purcell et al. 2016), and some benthic species are also commercially valuable (Al-Yaqout et al. 2021). Sea cucumbers are sediment or suspension feeders, depending on species, and consume a combination of bacteria, diatoms, and detritus (Madduppa et al. 2017). For example, *Holothuria atra*, as deposit-feeding sea cucumber, digests and utilizes organic components released from sediments (Viyakarn et al. 2020). *Holothuria atra* has also been shown to have efficiency in foraging by utilizing the high TOM (Total Organic Matter) content and abundance of microphytobenthos organisms in its natural microhabitat (Hartati et al. 2020). Therefore, the higher *H. atra*, the greater its ability to reduce microalgal biomass in the sediment, which also benefits microalgae (Viyakarn et al. 2020). Sea cucumbers not only have ecological value but also have high economic value in the world of trade. Generally, the high demand as a food ingredient is due to their high nutrient content, essential amino acids, and low-fat content (Vergara and Rodriguez 2016; Guerrero and Forero 2018). In addition, sea cucumbers are usually processed by *trepang* cooking, salting, and drying, which is considered a delicacy in most Asian countries (Purcell 2014).

Data and information show pressure on sea cucumber populations due to rapidly rising prices, increasing demand, and increasingly limited sea cucumber stocks from sea cucumber-producing countries (Purcell et al. 2018). Overfishing has occurred in many sea cucumber-producing locations, including Indonesia, Thailand, Vietnam, and Malaysia (Hamel et al. 2013; Khatulistiani et al. 2022). Based on several sea cucumber studies between 2015 and 2019 in Indonesia, such as on Karimun Jawa Island in Jepara, Tanjung Tiram in South Konawe, and Numfor Island in Biak. The research result in these locations show a sea cucumber population that is relatively less than 1 ind/m^2 (Arafat et al. 2021).

The coastal area of Duroa Island is one of the islands in Tual City, Maluku Province. The waters of Duroa Island are rich in fisheries resources. This can be seen in various ecosystems, such as seagrass ecosystems, coral reefs, mangroves, and associated organism. Sea cucumber is a marine organism that utilizes seagrass as a food source, nursery, and spawning ground (Muzaki et al. 2019). According to Uneputty (2017), seagrass beds in shallow waters are important as primary producers, nutrient and carbon cycles, spawning and nursery grounds for benthic organisms and fish, sediment stabilizers, feeding, and shelter.

Sea cucumber fishery in Duroa Island is done by picking up sea cucumbers from the bottom of the water and at low tide, usually referred to as *bameti*; some fishermen in catching sea cucumbers have used compressors. The catch of sea cucumbers is usually sold fresh to collectors living on the island, then sold to the city (Makassar, South

Sulawesi, and Surabaya, East Java). The people of Duroa Island have been utilizing sea cucumber resources continuously without considering the impact on ecological factors and sustainability. Formulating management initiatives is one possible solution to maintain the stock, but it is hampered by the lack of information on its current status. This study aims to assess the abundance and diversity of sea cucumbers and the environmental conditions of the waters of Duroa Island, Tual City, Maluku Province, Indonesia.

MATERIALS AND METHODS

Data collection

Sea cucumber sampling was conducted from January to February 2023 in Duroa Island, Tual City, Maluku Province, Indonesia (Figure 1). The area of Duroa Island is 1,180.35 ha and is divided into 2 areas, namely Dullah Laut Village (Islamic area) and Duroa Hamlet (Catholic area).

Sampling was conducted at high and low tide to get a better perspective while inventorying the benthic sea cucumber ecosystem. Sampling was conducted during the day because the night weather at the research site was less favorable. This study used a line transect technique with a modified reef check for mega-benthic animals (English et al. 1997; Uneputty et al. 2017). Transects were established perpendicular to the shoreline at each station (Table 1), with 1x1 meter^2 quadrants placed to the left and right of the transect line and placed along the transect line (Figure 2). Several different individuals were collected for identification. Samples preserved with 70% alcohol were identified by looking at the outer of the sea cucumber as per guidelines by (Purcell et al. 2023).

In addition to the above, this study also examined the parameters of water conditions at each station that support sea cucumber life, including salinity, pH, and temperature. The tools used to measure salinity were (a Brix meter refractometer handheld portable), a digital pH meter (Ladycare, Indonesia), and temperature (Thermometer rod brand Pharmacy and Healthy Tools Center, Indonesia). Sampling was conducted in situ with three repetitions and then averaged to obtain water quality values.

Data analysis

The following formula determines the diversity indices and density of sea cucumbers on Duroa Island, analyzing data using Microsoft Excel software.

Table 1. Sampling coordinates of the study

Station	Coordinate point
Station 1	5°31'43.6 "S 132°44'02.8 "E
Station 2	5°31'51.9 "S 132°42'53.7 "E
Station 3	5°32'13.3 "S 132°41'56. 2 "E
Station 4	5°33'03.2 "S 132°41'51.7 "E
Station 5	5°33'06.8 "S 132°43'28.9 "E
Station 6	5°33'07.6 "S 132°44'14.5 "E

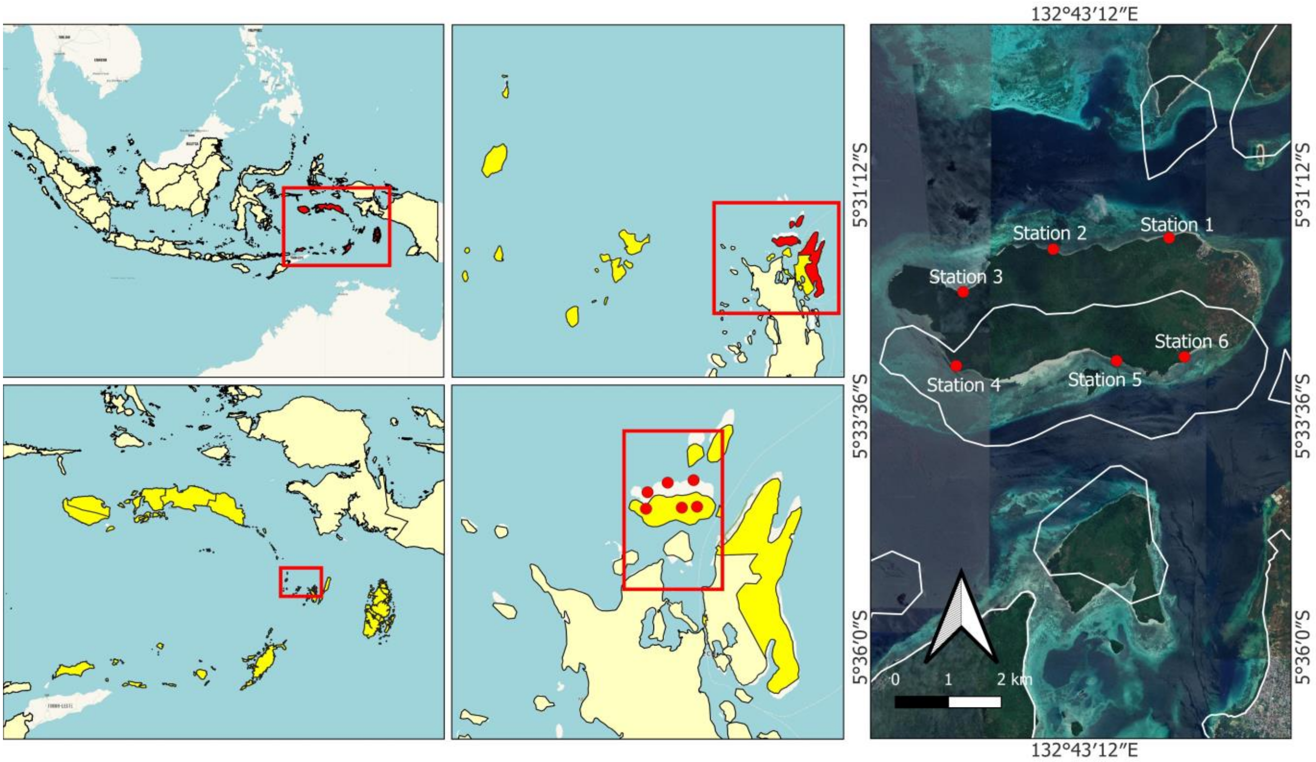

Figure 1. Research station in Duroa Island, Tual City, Maluku, Indonesia

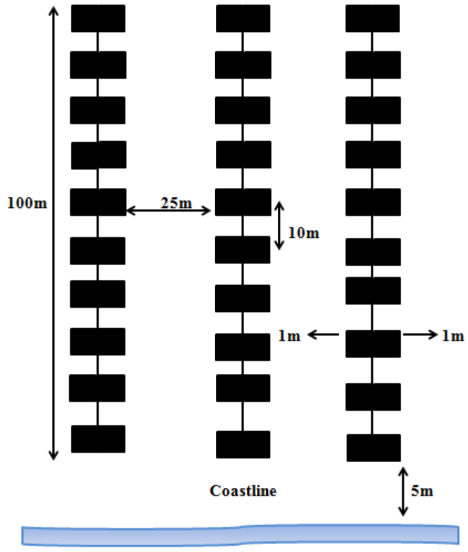

Figure 2. Transect station design for sea cucumbers using quadrats (black square)

Dominance index

The following calculation was used to calculate Simpson's Dominance Index (D) (Simpson 1949; Siburian 2023).

$$D = \sum (Pi)^2$$

Where Pi is the number of individuals of species-i

Dominance index values are grouped into three criteria, namely: 0<D≤0,5 low dominance, 0.5<D≤0.7 moderate dominance, and 0.75<D≤ 1 high dominance.

Species diversity

Sea cucumber species were analyzed based on the Shannon-Wiener diversity index (H') approach calculated as follows (Magurran 1991; Dhahiyat et al. 2003; Muzaki et al. 2019).

$$H' = -\Sigma Pi \ln Pi$$

The diversity index criteria are H´<1.0 as low diversity, 1 <H´<3 as moderate diversity, and H´>3 as high diversity.

Uniformity index

The uniformity index referred to here is the balance and individual composition of each species found in a community. We used the evenness formula in this study for the uniformity index (Ulfah et al. 2019; Siburian et al. 2023).

$$J = \frac{H'}{\ln (S)}$$

Where:
ln : Natural logarithm
S : Number of species

The criteria for the uniformity index are as follows: J value <0.4 as small population uniformity, value 0.4<J<0.6 as moderate population uniformity, and J value >0.6 as large population uniformity.

Density

Species density is the number of individuals per unit area; the density of each species at each station is calculated using the following formula (Aulia et al. 2021).

$$Di = \frac{ni}{A}$$

Where:
Di : Species density value
ni : Total number of individuals of the species
A : Area sampled

Habitat characteristics

Spatial analysis of habitat characteristics was done using ArcGIS 10.8 application by combining sea cucumber abundance data and coordinate points of sea cucumber abundance using combination of available bands on Landsat 9 furthermore, based on field observations, the methods also create training to distinguish between sediment types and seagrass beds. Next, organize the map and add map attributes such as scale, cardinal direction, legend, and grid default ArcGIS 10.8 application, used to represent latitude and longitude on maps.

RESULTS AND DISCUSSION

Identification of sea cucumber species in Duroa Island waters

Based on the research conducted at 6 stations, the identification results showed that the sea cucumber community in Duroa Island, Tual City, consisted of 9 species (Table 2). They are four *Holothuria* species (*Holothuria atra*, *Holothuria edulis*, *Holothuria scabra* and *Holothuria fuscogilva*), one *Actinopyga species* (*Actynopyga lecanora*), two *Bohadschia* species (*Bohadschia argus* and *Bohadschia koellikeri*), one *Stichopus species* (*Stichopus horrens*), and one *Thelenota* species (*Thelenota ananas*). These species are commonly found in the South China, Sulu, and Sulawesi Seas (Woo et al. 2013).

Water quality

The quality of healthy aquatic environment and following the carrying capacity for sea cucumber organisms are needed because they affect their survival (Tanjung et al. 2019) and limit marine biota's spread. Besides that, it can be used to recommend the feasibility of sea cucumber cultivation in the waters of Duroa Island. The physico-chemical parameters of the waters measured in this study include temperature, salinity, and pH. The water quality analysis (physics and chemistry) in the waters of Duroa Island is presented in Table 3.

Table 2. Photographic list of sea cucumbers found in Duroa Island, Tual City, Maluku, Indonesia

Sea cucumber	**Description of sea cucumber**
	Scientific name: *Holothuria* (*Halodeima*) *atra* (Jaeger, 1833) Local name: *Black trepang, keling* Found in sandy, rocky sand and seagrass areas
	Scientific name: *Holothuria* (*Halodeima*) *edulis* (Lesson, 1830) Local name: *Cera dada, lakling merah* Found in sandy, rocky sand, and seagrass areas
	Scientific name: *Holothuria* (*Metriatyla*) *scabra* (Jaeger, 1883) Local name: *Trepang gosok, pasir* Found in sandy, rocky sand, and seagrass areas
	Scientific name: *Holothuria* (*Microthele*) *fuscogilva* (Cherbonnier, 1980) Local name: *Susu putih, Bissawa* Found in rocky sand areas
	Scientific name: *Actinopyga lecanora,* (Jaeger, 1833). Local name: *Trepang kapok* Found in rocky sand
	Scientific name: *Bohadschia argus,* (Jaeger, 1833). Local name: *Bintik, Patola, Cempedak* Found in seagrass and rocky sand areas
	Scientific name: *Bohadschia koellikeri,* (Semper, 1868) Local name: *Bintik* Found in seagrass and rough sand areas
	Scientific name: *Stichopus horrens,* (Selenka, 1868) Local name: *Kacang goreng* Found in seagrass and rocky sand areas
	Scientific name: *Thelenota ananas,* (Jaeger, 1833) Local name: *Nanas, Pandan, Plum flower trepang* Found in rocky sand and rough sand areas

Table 3. Water quality parameters in Duroa Island, Tual City, Maluku, Indonesia

Parameters	**ST1**	**ST2**	**ST3**	**ST4**	**ST5**	**ST 6**
Temperature (°C)	30	32	29	28	29	29
Salinity (‰)	25	30	30	30	30	30
pH	5.6	7.5	7.5	7.6	7.6	7.6

Note: ST: Observation Station

In general, the average value of physical and chemical variables is still within the range of quality standards that support marine biota based on the Ministry of Environment of the Republic of Indonesia (2004). At station 1 the salinity value (25‰) is still within the quality standard tolerance limits range, namely 19-<28‰. Good water quality for marine organisms has a temperature tolerance of 26-30°C, salinity tolerance of 15-35‰ (Al Rashdi et al. 2013; Cleary et al. 2016). While the pH value at station 1 is below the quality standard, namely <6.5. Tolerance of pH according to quality standards is in the range of 6.6-8.5 (Directorate of Conservation and Marine National Parks 2004; Rumlus et al. 2015). Komala et al. (2018) stated that the optimum pH range for echinoderms is between 7.5-8.6. While other stations have pH values that are still in the optimal range (Table 3). The low pH value at station 1 is due to its location close to residential areas (Figure 5). It is known that the local community has been throwing organic and inorganic waste into the waters of Duroa Island, because there is no regulation governing the disposal of waste. Leite et al (2014) stated that the global and local impacts of pollution are caused by humans. The contamination occurs in liquid and solid waste; several examples of solid waste are plastic, metal, paper, glass, and paper waste that pollute beaches, shallow seas, and open seas.

Diversity (H'), Evenness (J), and Dominance (D)

The results of the Ecological Index analysis of sea cucumber resources on Duroa Island are presented in Table 4. A review of diversity data (H') following the criteria (Krebs 1999; Siburian et al. 2023) shows that at station 1, the diversity is low because the value of H'<1.0. While for other stations, the value of diversity is moderate. According to Sumekar and Widayat (2021), a value of 1.0<H'<3.22 means moderate diversity, productivity, and a balanced ecosystem. Species diversity is usually used to observe ecological health or stability, indicated by species richness and evenness of individuals within a species (El-Naggar et al. 2017).

The results of the uniformity analysis (J), following the uniformity index criteria (Ulfah et al. 2019; Siburian et al. 2023), show that station 5 has low uniformity because the value of J<0.4. While at other stations, the uniformity value is high because J>0.6. According to Syukur et al. (2020), a community is said to be stable if the value is close to 1, and less stable if the value is close to 0 (zero).

Furthermore, the Dominance Index (D) research following the dominance index criteria (Sumekar and Widayat 2021) shows that at station 1, the dominance is moderate because D = 0.5<D<0.7. While at other stations, the dominance is low because D<0.5. The closer to the value of 1, the higher the dominance structure and vice versa. Low dominance in an area is caused by high diversity and competition between species, so it does not allow high dominance in a particular species (Muzaki et al. 2019). At station 1, there are only 2 types of sea cucumbers, namely *H. atra* and *H. edulis*, while at other stations there are more than 2 types of sea cucumbers (Figure 3).

Table 4. Results of Diversity (H'), Uniformity (J) and Dominance (D) analysis of sea cucumbers on Duroa Island, Tual City, Maluku, Indonesia

	Ecological Index					
	ST 1	**ST 2**	**ST 3**	**ST 4**	**ST 5**	**ST 6**
H' Category	0.67 (low)	1.24 (moderate)	1.17 (moderate)	1.32 (moderate)	1.09 (moderate)	1.43 (moderate)
J Category	0.97 (high)	0.89 (high)	0.84 (high)	0.82 (high)	0.27 (low)	0.9 (high)
D Category	0.5 (moderate)	0.32 (low)	0.36 (low)	0.30 (low)	0.40 (low)	0.27 (low)

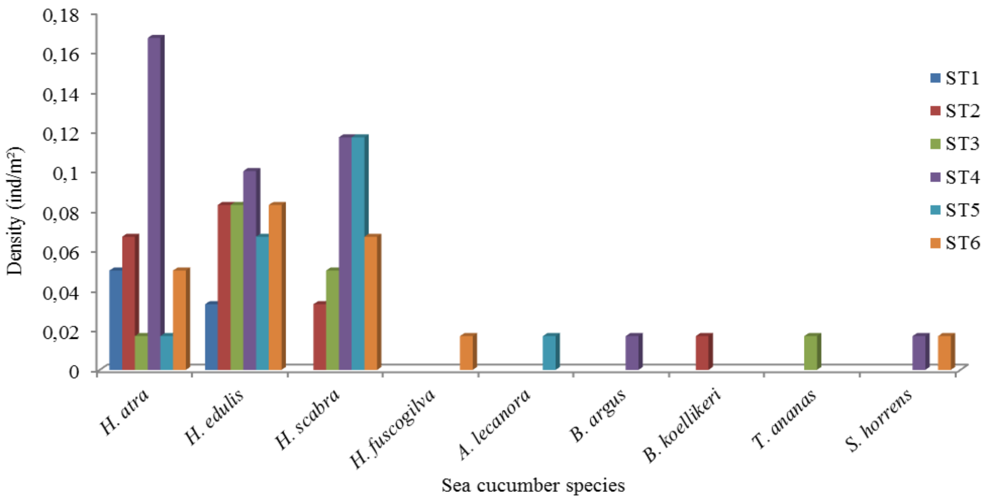

Figure 3. The density of sea cucumber species in the waters of Duroa Island, Tual City, Maluku, Indonesia

The density of sea cucumber resources

The density of sea cucumber species at each station is presented in Figure 3. The results of the density analysis of sea cucumber species in the waters of Duroa Island, *H. atra* were found in all observation stations. The highest density of *H. atra* species was at station 4 (0.167 ind/m^2), while the lowest was at station 3 and station 5 (0.017 ind/m^2). *Holothuria edulis* sea cucumbers are scattered in all observation stations, with the highest density at station 4 (0.1 ind/m^2) and the lowest at station 1 (0.033 ind/m^2). *Holothuria scabra* sea cucumbers were distributed in almost all observation stations except station 1, with the highest density at stations 4 and 5 with a value of (0.117 ind/m^2) and the lowest at station 2 (0.033 ind/m^2). Furthermore, *H. fuscogilva* sea cucumbers were only found at station 6 (0.017 ind/m^2) and *B. argus* at station 4 (0.017 ind/m^2). *Bohadschia koellikeri* at station 2 (0.017 ind/m^2), *A. lecanora* at station 5 (0.017 ind/m^2). *Thelenota ananas* at station 3 (0.017 ind/m^2) and *S. horrens* were found at stations 4 and 6 (0.017 ind/m^2), respectively. Futhermore, sea cucumber density at each research station is presented in Figure 4.

The density of sea cucumbers at each observation station was highest at station 4 (0.417 ind/m^2). The density value on Duroa Island is relatively higher than the density of sea cucumbers in Namatabung Village, Tanimbar Islands, Maluku, which amounted to (0.202 ind/m^2) (Matrutty et al. 2021). In addition, station 1 had the lowest density compared to other stations, which amounted to (0.083 ind/m^2). The low density of sea cucumbers at station 1 was caused by water quality factors (pH) which were below the quality standard (Table 3). In addition to ecological factors, social factors are crucial in sea cucumber density. Station 1, the location is close to settlements, so it is easily accessible by local people to catch sea cucumbers.

Spatial distribution of sea cucumber density and type by habitat

The density of sea cucumber resources in the waters of Duroa Island based on habitat is presented in Figure 5. Sea cucumber density at station 4 (0.417 ind/m^2), and found sea cucumber species *H. atra*, *H. edulis*, *H. scabra*, *B. argus*, and *S. horrens* (Figure 3), with typical habitat characteristics of rocky sand and seagrass. Furthermore, station 6 (0.233 ind/m^2), with sea cucumber species *H. edulis*, *H. scabra*, *H. atra*, *H. fuscogilva*, and *S. horrens* (Figure 3), with characteristics of rocky sand habitat.

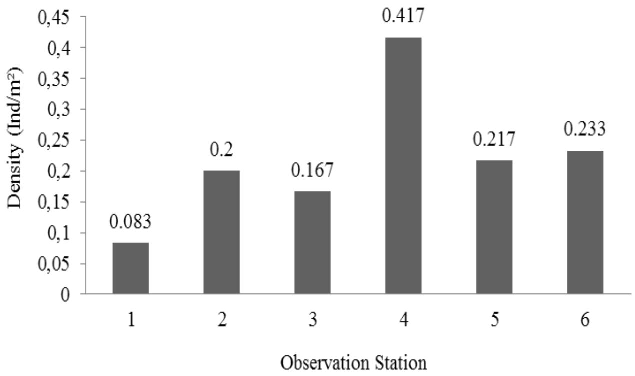

Figure 4. The density of sea cucumber in the waters of Duroa Island, Tual City, Maluku, Indonesia

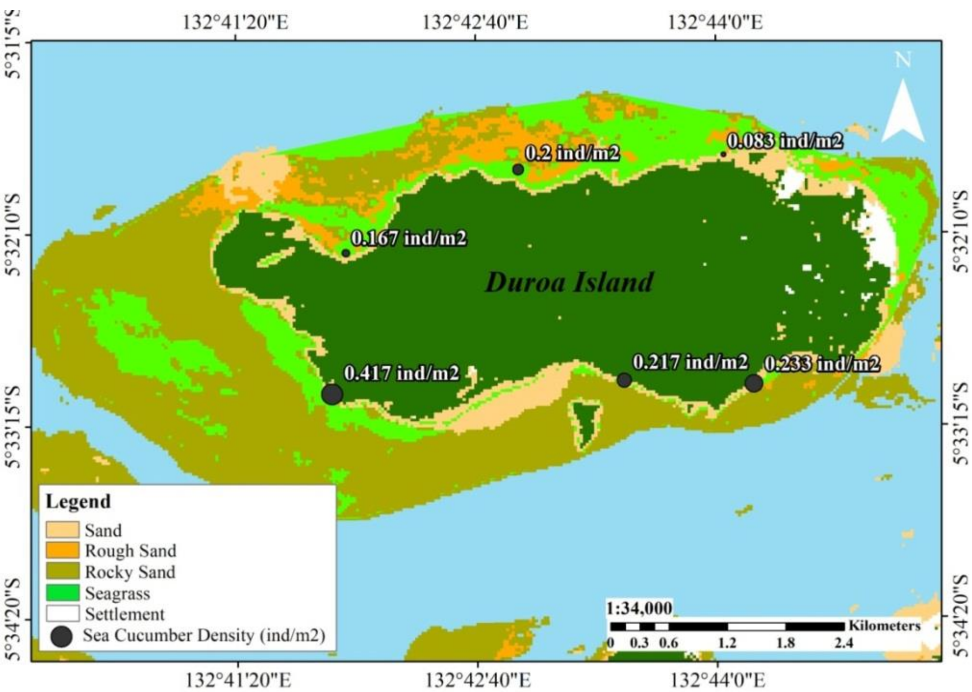

Figure 5. Spatial map of sea cucumber density based on habitat in Duroa Island, Tual City, Maluku, Indonesia

The density of station 5 (0.217 ind/m^2), with sea cucumber species *H. atra*, *H. edulis*, *H. scabra*, and *A. lecanora* (Figure 3), is characterized by rocky sand habitat. The density of station 2 (0.2 ind/m^2), with sea cucumber species *H. atra*, *H. edulis*, *H. scabra*, and *B. koellikeri* (Figure 3), is characterized by seagrass and rough sand habitat. Sea cucumber density at station 3 (0.167 ind/m^2), the types of sea cucumbers found were *H. atra*, *H. edulis*, *H. scabra*, and *T. ananas* (Figure 3), habitat characteristics of seagrass, rocky sand, and rough sand. And the lowest density at station 1 (0.083 ind/m^2), the types of sea cucumbers found were *H. atra* and *H. edulis* (Figure 3), with seagrass and sand habitat characteristics.

In conclusion, the results of research on density, diversity, and physical-chemical factors in the waters of Duroa Island, Tual City, found 9 species of sea cucumber from the genera *Holothuria*, *Bohadschia*, *Actinopyga*, *Theleonota,* and *Stichopus*. The most dominant sea cucumber species were from the *Holothuria* genus (*H. edulis* and *H. atra*). The habitat characteristics of Duroa Island waters are dominated by seagrass, rocky sand, rough sand, and sand. These habitat characteristics support sea cucumbers fiding food, shelter, and spawning. The ecological index of sea cucumber resources on Duroa Island is medium diversity, high uniformity and low dominance. In addition, the water condition of Duroa Island is still within the range of optimal quality standards for sea cucumber life, except for pH at station 1, which is below the national quality standard. The results showed that high-value commercial sea cucumber species began to decline. This is certainly a concern for the sustainability of sea cucumbers in the waters of Duroa Island. Therefore, it is necessary to re-do community-based management fishing for marine biota for a certain period.

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