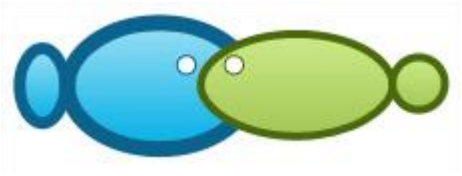

Echinoidea and Asteroidea diversity and abundance in Manado Bay waters, Indonesia

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Abstract. Coastal areas including coral reefs and seagrass beds have a high diversity of fauna. One of the phyla that have a habitat in the coastal area is Echinodermata. The purpose of this study is to determine the type of Echinoidea and Asteroidea, abundance, and diversity found on the coast of Molas Village, Tongkeina Village and Bahowo. The results of the study found 9 species of Echinoidea and Asteroidea at the study sites, namely *Archaster typicus*, *Culcita novaeguineae*, *Linckia laevigata*, *Protoreaster nodosus*, *Diadema setosum*, *Diadema savignyi*, *Echinothrix calamaris*, *Echinometra mathaei*, *Tripneustes gratilla*. The species with the highest abundance value is *D. Setosum*, which has an abundance value of 3.47 ind m^{-2} with a relative abundance value of 35.62%. Based on data analysis using the squared transect method, the values obtained for the Shannon-Wiener index are the following: at Station I (Molas) the value of H' = 1.54, Station II the value of H' = 1.39, and at Station III, the value of H' = 1.33.

Key Words: coastal, echinoderms, identification, transect.

Introduction. Manado Bay is part of the Bunaken National Park (BNP), a conservation area in North Sulawesi, Indonesia (Newman & LeDrew 2005). The northern part of this area, namely the waters of Molas, Tongkeina, and Bahowo, has a fairly complete aquatic ecosystem with coral reefs, mangroves, seagrasses, and seaweed compared to other locations in Manado Bay. However, recent developments show an increase in economic activity and tourism, which have an impact on aquatic ecosystems, including the survival of aquatic biota in the area. One of the aquatic biotas that are susceptible to environmental stress is the phylum Echinodermata. This group of animals has habitats in coastal areas, especially in coral reef areas (Radjab et al 2014).

Echinoderm means an animal that is barb-skinned. All animals belonging to this phylum have a symmetrical radial body shape and most have an endoskeleton of lime (Kimball 1983).

The phylum Echinodermata is divided into five living classes: Crinoidea, Asteroidea, Ophiuroidea, Echinoidea, and Holothuroidea. About 6,500 species of living echinoderms and over 13,000 fossil species in many extinct classes have been described (Hendler et al 1995). The Asteroidea class has the highest diversity in the phylum Echinodermata, which is almost 1,900 species, and about 940 species of Echinoidea are known worldwide (Kohlberg & Schories 2016; Schories & Kohlberg 2016). In the waters of Indonesia and its surroundings (Western Indo-Pacific), for the number of echinoderms recorded, Asteroidea amounted to 87 species, Echinoidea amounted to 84 species, Holothuroidea amounted to 141 species, Ophiuroidea amounted to 142 species, and Crinoidea amounted to 91 species (Yusron 2013).

Echinoderms are one of the main components of marine biodiversity and play an important role in the functioning of ecosystems (Supono & Arbi 2010), especially their role in the food chain in coral reef and seagrass ecosystems as detritus eaters. For example, sea urchins, especially *Diadema setosum*, influence the ecological balance of coral reef ecosystems (Suryanti & Ruswahyuni 2014). Economically, echinoderms have a

high value. Some species are medicinal raw materials, can be consumed, and are used as souvenirs (Suparna 1993).

Several studies on echinoderms in North Sulawesi waters have been carried out, such as research on Basaan Satu waters, Ratatotok sub-district (Budiman et al 2014), Tanamon waters, Sinonsayang sub-district (Tahe et al 2013), Likupang waters, North Minahasa (Yusron 2012). Rompis et al (2013) reported the results of research in Meras waters and inventoried 8 species of echinoderms, Supono and Arbi (2010) found 31 species of echinoderms in Kema waters, Bitung, and Talise waters, North Minahasa. Similar studies specific to the Asteroidea and Echinoidea classes in the waters of Manado Bay and their relationship to habitat characteristics are still minimal. Therefore, the lack of information about diversity became the main basis for this study. The purpose of this study is to determine the type of Echinoidea and Asteroidea, abundance, and diversity found in the coastal areas of Molas Village, Tongkeina Village, and Bahowo.

Material and Method. This research was conducted from March 2022 to August 2022, in the coastal area of Molas Village, Tongkeina Village, and Bahowo, Bunaken District, Manado City. The coordinate point of the sampling stations are 1°32'14''N 124°49'39''E (Molas), 1°34'16''N 124°48'13''E (Tongkeina), 1°35'02''N 124°49'08''E (Bahowo) (Figure 1).

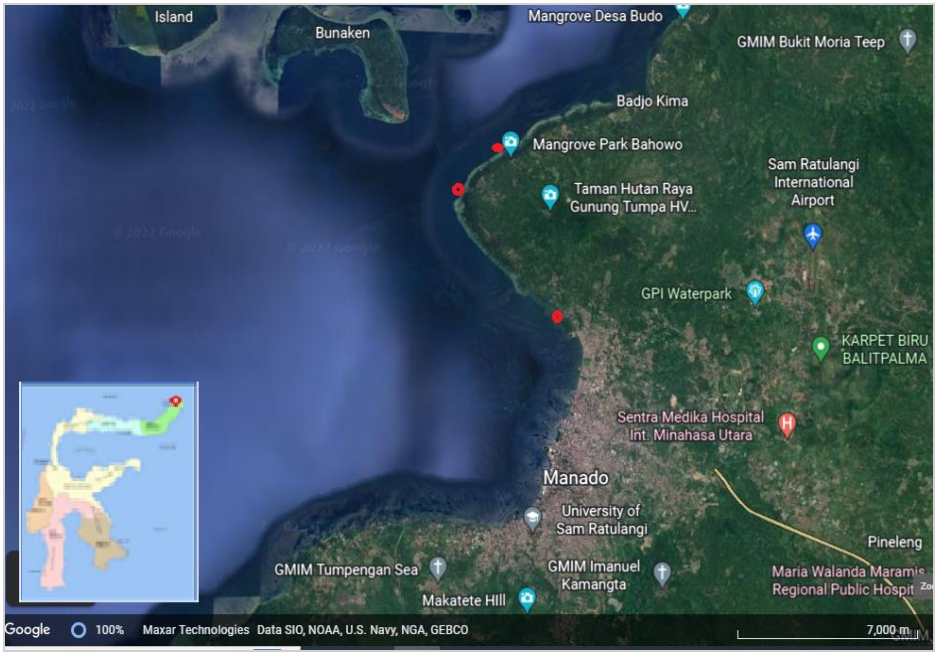

Figure 1. Research locations: Molas Village (bottom red mark), Tongkeina Village (middle red mark), Bahowo (top red mark); map of Sulawesi Island (bottom left) (map generated using Google Earth in March 2022).

The research began with a site survey that aimed to see field conditions (pre-research). The activities include observing the presence of Echinoidea and Asteroidea at the site, the condition of coastal areas, and mangrove vegetation around the mouth of the river as the object of research. Furthermore, when entering the research stage, 3 data retrieval points were set as randomly determined transect locations at each station.

The method used is the line transect quadrat. Three transect lines are placed on each station using a rope pulled from the lowest ebb position towards the sea for 100 meters. The distance between the transects is 100 meters. Squares with some 10 pieces are placed in zig-zag on the transect line with a distance between squares of 10 meters. The squared size is 1x1 meter made of cylindrical pipes measuring 1 meter and half an inch in diameter. Observations are made at the time when the water is approaching low tide. The observed echinoderms are Echinoidea and Asteroidea individuals in the squared plots. During the data collection, measurements of physical parameters were carried out,

namely environmental temperature, and chemical parameters, namely pH, and environmental salinity. The equipment used is a thermometer for temperature, a pH meter for measuring pH, and a refractometer to determine salinity. The sample was then put into a plastic bag and preserved with 70% alcohol, then taken to the Laboratory of Molecular Biology and Marine Pharmaceutics, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Manado to be identified.

Identification of the species of echinoderms is carried out visually by looking at morphological characteristics based on body size, shape, and completeness of organs and body color. Known samples were immediately identified in the field and those that have not been identified were taken for identification at the Marine Biology laboratory of UNSRAT Manado. Identification was carried out using books namely Clark and Rowe (1971), Colin and Arneson (1995), Raghunathan et al (2013), and the WoRMS website (2022). In general, identification refers to the morphology of Asteroidea and Echinoidea, namely body shape, body color, and completeness of body organs. The data obtained was analyzed descriptively and then described in the form of tables and figures. The data was then used to calculate the Shannon-Wiener diversity index (H'), the abundance index (Di), and the relative abundance (RDi) (Odum 1971).

Results. The results of data collection using the line transect method in the form of types and numbers of echinoderms (Asteroidea and Echinoidea classes) are presented in Table 1 below.

Table 1

Types of Echinoidea and Asteroidea found in the intertidal zones of Molas, Tongkeina, and Bahowo

Station	*Class*	*Species name*	*Transect 1*	*Transect 2*	*Transect 3*
I Molas	Echinoidea	*Diadema setosum*	35	41	28
		Echinothrix calamaris	5	9	7
		Echinometra mathaei	18	28	16
		Tripneustes gratilla	2	1	1
	Asteroidea	*Archaster typicus*	2	0	3
		Culcita novaeguineae	1	2	4
		Linckia laevigata	2	3	1
		Protoreaster nodosus	35	21	27
II Tongkeina	Echinoidea	*Echinometra mathaei*	15	8	9
		Diadema setosum	24	12	25
	Asteroidea	*Protoreaster nodosus*	3	3	5
		Linckia laevigata	12	8	12
		Archaster typicus	2	4	3
III Bahowo	Echinoidea	*Echinometra mathaei*	18	5	14
		Diadema savignyi	1	2	0
		Protoreaster nodosus	14	11	17
	Asteroidea	*Linckia laevigata*	2	3	3
		Archaster typicus	8	6	6

The results showed that 9 species of the Echinoidea and Asteroidea classes were found: *Archaster typicus*, *Culcita novaeguineae*, *Linckia laevigata*, *Protoreaster nodosus*, *Diadema setosum*, *Diadema savignyi*, *Echinothrix calamaris*, *Echinometra mathaei*,

Tripneustes gratilla. The most common species found is *Diadema setosum* at Station I (Molas), while the *Linckia laevigata* is the least found.

The description of the species of Echinoidea and Asteroidea present in the waters of Molas, Tongkeina, and Bahowo from the results of this study is as follows. *Diadema setosum* (Leske, 1778) (Figure 2) has a characteristic flattened round body with a body diameter of about 5.3–8.2 cm and a body height of 3.6–5.6 cm (Sese et al 2018), with an orange circle at the end of the anal cone, and has long black spines (Purnami et al 2012). This characteristic is following the results of the study where it was found that *D. setosum* has long, rounded, and slender black color spines and is found in rocky sand areas, seagrasses, and corals.

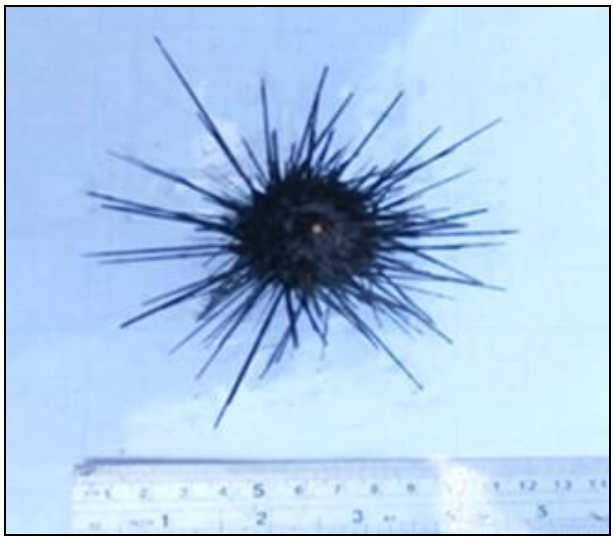

Figure 2. *Diadema setosum* (original image).

Echinometra mathaei (Blainville, 1825) (Figure 3) has a characteristic slightly oval rounded body shape, black body color, there are sharp and yellow primary spines, and in general at the base there is a white ring (Sese et al 2018). This species can be found in rocky areas as well as hiding in holes in rocks (Colin & Arneson 1995). These characteristics are following this study results where *E. mathaei* were found to be round/oval and have pointed spines of pale yellow color.

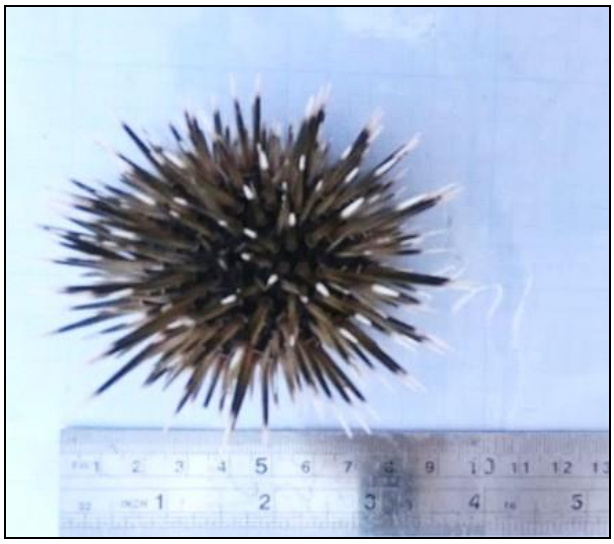

Figure 3. *Echinometra mathaei* (original image).

Echinothrix calamaris (Pallas, 1774) (Figure 4) has characteristic black and white striped long spines (Ningsih et al 2018), a body diameter of 6.2-7.2 cm, and a body height of 4.1-5.4 (Sese et al 2018), and it is found on coral reefs or coral fragments (Alwi et al

2020). These characteristics are following the results of this study where *E. calamaris* found had long black and white striped spines, and blunt thorn tips, and were found in the area of coral fragments.

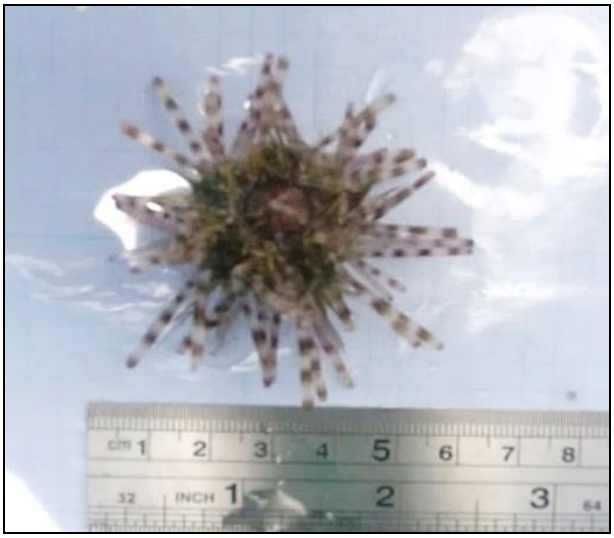

Figure 4. *Echinothrix calamaris* (original image).

Tripneustes gratilla (Linnaeus, 1758) (Figure 5) has a characteristic flattened rounded body shape and has spines of relatively the same size throughout the shell, spines generally have a light orange and white color (Sese et al 2018). This type of starfish is only found in seagrass beds because it is limited by its food preferences (Samyn 2003). These characteristics are following this study results where *T. gratilla* was found to have orange and white fine spines, a slightly flattened round body shape, and is found in seagrass meadow areas.

Figure 5. *Tripneustes gratilla* (original image).

Diadema savignyi (Audouin, 1809) (Figure 6) has characteristics of spines that are larger than the ambulacral part, the shell is generally black and sometimes slightly bluish, and does not have an orange ring line around the anus. Adult specimens have an average diameter of 70 mm and can reach a size of 88 mm (Clark & Rowe 1971; Colin & Arneson 1995). These characteristics are following the results of this study where *D. savignyi* has the presence of spines, a slightly bluish color, and no orange ring around the anus.

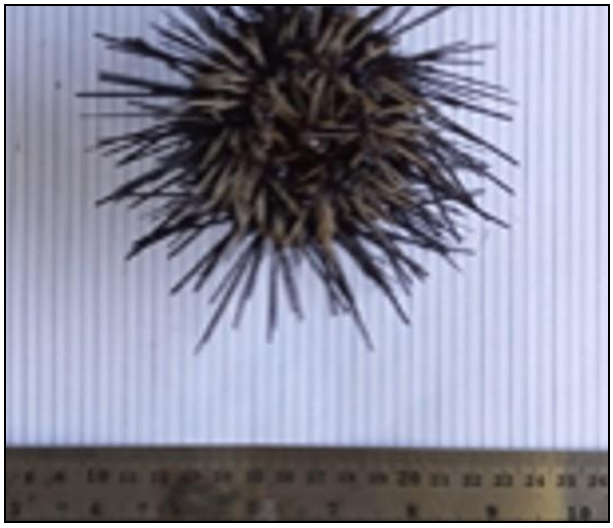

Figure 6. *Diadema savignyi* (original image).

Archaster typicus (dan Troschel, 1840) (Figure 7) has characteristics of 5 arms, having tube feet along the arms, the marginal plate is visible and there is a primary spine, generally light gray and usually burying itself in the sand (Clark & Rowe 1971; Fortaleza et al 2020). These characteristics are following this study results where *A. typicus* was found to have 5 arms, was gray, and was mostly found immersed in the sand.

Figure 7. *Archaster typicus* (original image).

Culcita novaeguineae (dan Troschel, 1842) (Figure 8) does not have arms, its body shape is shaped like a bun, with a body thickness ranging from 6-9 cm, with a diameter of 16-23 cm (Fitriana 2010). It is found on coral reef plains (Purwati & Lane 2004). These characteristics are following this study results where *C. novaeguineae* was found to have no arms, the body was rather thick and was found in the coral reef flat.

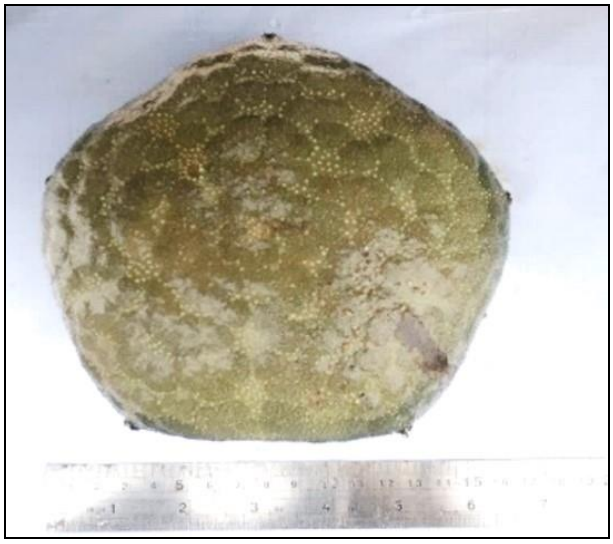

Figure 8. *Culcita novaeguineae* (original image).

Linckia laevigata (Linnaeus, 1748) (Figure 9) has characteristics of a radially symmetrical body shape with a rough body surface, a body size of about 3 cm in diameter, an arm's length of about 12.5 cm (Fitriansyah et al 2018), slender arms with blunt ends, generally blue, and is most often found on reef flats and shallow areas (Clark & Rowe 1971). These characteristics are consistent with this study results where *L. laevigata* was found to have slender arms, the entire body was blue, and was found in coral reef flats.

Figure 9. *Linckia laevigata* (original image).

Protoreaster nodosus (Linnaeus, 1758) (Figure 10) body varies in color from dark red, pink, pale brown, green, and blue to white, body size ranges from 12-17 cm, medium disc size with cranial plates that are shaped like pads, with a flat shape (Clark & Rowe 1971), live in seagrass beds about 2 m (6 ft) deep (Colin & Arneson 1995). These characteristics are consistent with this study results where *P. nodosus* was found to have pale brown body and inhabit seagrass meadows.

Figure 10. *Protoreaster nodosus* (original image).

The results of the species abundance index analysis showed that *D. setosum* had the highest abundance of 3,467 ind m^{-2} (Station I) with a relative abundance value of 35.62%. *T. gratilla* has the lowest species abundance value of 0.13 ind m^{-2} with a relative abundance value of 1.37%. The highest species abundance at Station II (Tongkeina) is for *D. setosum*, namely 2.03 ind m^{-2} with a relative abundance value of 42.07%, while at Station III (Bahawo) *E. mathaei* has a value of 1.23 ind m^{-2} and a relative abundance value of 33.64% (Table 2).

Table 2

Species abundance and relative abundance value from each species

Station	*Species*	*Species abundance (ind m^{-2})*	*Relative abundance (%)*
I Molas	*Diadema setosum*	3.47	35.62
	Echinothrix calamaris	0.70	7.19
	Echinometra mathaei	2.07	21.23
	Tripneustes gratilla	0.13	1.37
	Archaster typicus	0.17	1.71
	Culcita novaeguineae	0.23	2.39
	Linckia laevigata	0.20	2.05
	Protoreaster nodosus	2.77	28.42
II Tongkeina	*Echinometra mathaei*	1.07	22.07
	Diadema setosum	2.03	42.07
	Protoreaster nodosus	0.37	7.59
	Linckia laevigata	1.07	22.07
	Archaster typicus	0.30	6.21
III Bahowo	*Echinometra mathaei*	1.23	33.64
	Diadema savignyi	0.10	2.73
	Protoreaster nodosus	1.40	38.19
	Linckia laevigata	0.27	7.27
	Archaster typicus	0.67	18.18

The results of the analysis of the diversity index of echinoderms are shown in Figure 11. The results of the analysis of the diversity index of classes Echinoidea and Asteroidea at Station I (Molas) obtained the highest value of H' = 1.54, Station II (Tongkeina) obtained a value of H' = 1.39, and Station III (Bahowo) the value of H' = 1.33. These results indicate that the species diversity index at all research stations based on the Shannon-Wiener criteria is at a value of 1.0 < H' <3.0 in the moderate category.

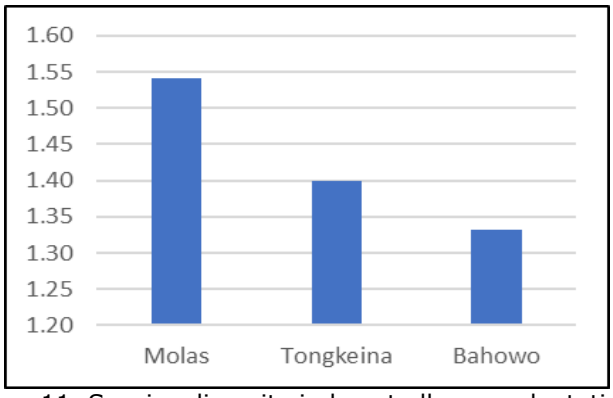

Figure 11. Species diversity index at all research stations.

Based on the results of measurements of physical and chemical parameters that have been carried out at 3 research locations, data on temperature, pH and salinity which are obtained show that the variation in values is not much different at each observation station (Table 3). The water temperature at the three stations ranged from 29-32°C. This shows that the temperature in these waters is in normal conditions so it is appropriate for the life of echinoderms. The results of the salinity measurement ranged from 29-30 (ppt) and the pH was 7-8.

Table 3

Physical and chemical parameters of water at the research sites

Parameter	*Station*		
	I (Molas)	*III (Tongkeina)*	*III (Bahowo)*
Temperature (°C)	32	30	29
Salinity (ppt)	30	29	30
pH	8	7	8

Discussion. Echinoderms are a marine phyla whose populations are generally distributed in benthic ecosystems throughout the world's oceans, including the classes Echinoidea and Asteroidea which are part of the Echinodermata phylum. The results of the research in the waters of Molas, Tongkeina, and Bahowo showed that the Asteroidea class was represented by *Archaster typicus*, *Culcita novaeguineae*, *Linckia laevigata*, *Protoreaster nodosus*, while the Echinoidea class was represented by *Diadema setosum*, *Echinothrix calamaris*, *Echinometra mathaei*, *Tripneustes gratilla*, and *Diadema savignyi*.

Species from Echinoidea and Asteroidea were more evenly found at Station I (Molas), but at the location of Station II (Tongkeina) and III (Bahowo), the species number found decreased. The results of Echinoderms found in this study were higher when compared to studies conducted in the waters of Meras Manado City, where 8 species were found belonging to 3 classes (Asteroidea, Echinoidea and Holothuroidea), Echinoidea class with as many as 4 species and Asteroidea with as many as 3 species (Rompis et al 2013).

Asteroidea looks more dominant at Stations II and III. Asteroidea can be found in various habitats, especially in coral habitats, because ecologically Asteroidea plays a role in coral reef ecosystems, namely as detritus eaters and predators for corals. Asteroidea is also known to have the highest number of species in the phylum Echinodermata, which has almost 1,900 species in the world (Kohlberg & Schories 2016).

The abundance of species of echinoderms can be caused by several factors such as differences in the number of species and the number of individuals. In addition, the composition of the substrate also determines the abundance and diversity of echinoderm species (Setyastuti et al 2018). Echinoidea species *Diadema setosum* has the highest species abundance, especially at stations I and II, indicating that this species can adapt to environmental changes. Stations I and II have substrates that are very supportive to

the life of *D. setosum*. This sea urchin has been known for its role in the balance of the coral reef ecosystem. *D. setosum* spreads in almost all habitats and is evenly distributed in the flat zone of sand, coral, mud, and edge areas (Aziz 1996).

Diversity based on the Shannon-Wiener index can be categorized into three categories, namely low ($H' < 1$), moderate ($1 \leq H' \leq 3$), and high ($H' > 3$), and the level of diversity Echinoidea and Asteroidea in the coastal area of Molas, Tongkeina and Bahowo is in the moderate category. The high or low value of the diversity index can be caused by the number of species or individuals obtained. A community is considered to have high diversity if the number of species found is large, otherwise, if the number of species found is low, the diversity is low (Soegianto 1994).

The results of the measurement of environmental parameters indicate that the physical and chemical conditions of the aquatic environment are classified as normal. This is because the location of the waters is far from human activities and there are no river estuaries around the research site that can bring pollutants into the waters. A good temperature for the life of echinoderms is 20-30°C, while the salinity is in the range of 30-36‰ (Aziz 1994). According to Odum (1971), the safe limit of pH for aquatic life is around 6.5-8.0.

From the results obtained through this study, real efforts are needed to maintain the presence of echinoderms so that their diversity does not decrease. Tongkeina and Bahowo waters are currently conservation areas in Manado City, North Sulawesi which is dominated by lush mangrove forests and have been developed into eco-tourism locations in North Sulawesi.

Conclusions. There are nine species of class Echinoidea and Asteroidea that can be found in the waters of Manado Bay. *Diadema setosum* has the highest species abundance. Based on the Shannon-Weaver diversity index, the coastal waters of Molas, Tongkeina, and Bahowo can be categorized as moderate.

Conflict of interest. The authors declare that there is no conflict of interest.

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