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Echinoidea Community Structure in the Timbul Bone Labunta Sand Waters, Buton Tengah Regency, Southeast Sulawesi

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Abstract

This study aims to determine the types of sea urchins (Echinoidea), the diversity index (H'), uniformity index (E), and dominance index (C) in sea urchins (Echinoidea) in Pasir Timbul Bone Labunta waters, Central Buton Regency. This research is a type of quantitative descriptive research. The determination of stations is carried out using a purposive sampling technique, namely data collection based on the presence of sea urchins (Echinoidea). This research was conducted in April-May 2023 in Pasir Timbul Bone Labunta waters, Central Buton Regency. Observations were made during the day, at the lowest tide, and when sea urchins (Echinoidea) rested in coral crevices or seagrass. The results showed that there were 5 types of sea urchins (Echinoidea), namely Diadema setosum, Echinotrix calamaris, Tripneustes gratilla, Salmacis sphaeroides and Echinometra mathaei. The diversity index at Station I is in the low category, and Stations II and III are in the medium category. Uniformity index at Station I with a low category, Stations II and III with a high category. The dominance index of Station I has a high category, and Stations II and III have a low category index value.

Keywords: Echinoidea; Dominansi; Keanekaraman; Keseragaman; Struktur Komunitas

1. Introduction

The Echinodermata species is divided into 15 orders, 46 families, and 121 genera. Approximately 6,000 types of echinoderms worldwide, an estimated 950 of which are sea urchins (Echinoidea). In Indonesia, there are ± 84 types of sea urchins (Echinoidea) consisting of 31 families and 48 genera. Sea urchins (Echinoidea) have a ball-like shape and have pentagonal (radially symmetrical) body sides (1), with a hard, calcareous shell filled with spines and no arms (2). The body of sea urchins (Echinoidea) consists of three parts: the oral, aboral, and the part between the oral and aboral. The mouth is located in the oral part facing the sea floor. The anus is above (aboral) the top of the shell circle. Sea urchin spines (Echinoidea) are used as protection from predators and as a means of locomotion (3).

Sea urchins (Echinoidea) can be found in intertidal (tidal) areas to a depth of 10 m and even to a depth of 5000 m. The distribution of sea urchins (Echinoidea) depends on substrate factors and food sources around them (4). Sea urchins (Echinoidea) are often found in clear waters with calm currents (5). Around 6 types of sea urchins (Echinoidea) from 4 families are found in the intertidal zone of the waters of Liwutongki Island in South Buton, namely Salmacis bicolor, Tripneustes gratilla, Diadema setosum, Echinotrix calamaris, Echinometra mathaei and Toxopneustes pileolus.

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The diversity of sea urchin species (Echinoidea) is influenced by the habitat type and physico-chemical factors in that environment (6). The local community uses the Pasir Timbul Bone Labunta water area as a tourist attraction, a place to catch fish and other types of animals with high economic value, including sea urchin species (Echinoidea). Community activities in taking and utilizing sea urchins (Echinoidea) in Pasir Timbul Bone Labunta waters because they have a high selling value and their use as food has led to more and more hunting of sea urchins (Echinoidea), which has led to a decline in their population in nature. The decline in the population of sea urchins (Echinoidea) accelerates if the frequency of hunting is higher and is not balanced with population growth.

2. Material and methods

2.1. Time and place

This research was carried out in April-May 2023 in the waters of Pasir Timbul Bone Labunta, Buton Tengah Regency, Southeast Sulawesi. Identification and data analysis were conducted at the Biology Laboratory, Ecology and Taxonomy Unit, Faculty of Mathematics and Natural Sciences, Halu Oleo University, Kendari.

2.2. Tools and materials

The materials used in this research were tissue, absolute formalin, plastic bag, handscoon, label paper, raffia, and petrol. The tools used are stationary, camera, GPS, thermometer, Secchi Disk, pH meter, roller meter, identification book, boat, stakes, jar, and current kite.

2.3. Research Procedure

The transect installation location uses the quadrant method and is carried out at 3 observation stations. The station I is in a sandy substrate area. Station II is in the seagrass meadows, and Station III is in the coral reef area. Observations are made when the lowest tides occur. At each station, 2 transect lines are installed. Transect installation is carried out 20 m horizontally (parallel) from the shoreline with a 35 m long transect. The distance between transects I and 2 is 10 m.

Three observation plots measuring 5 x 5 m were created for each transect line, with a distance between plots of 10 meters, which was expected to represent the community structure of sea urchins (Echinoidea) at the research location. Observations of sea urchins (Echinoidea) were carried out at each station by counting the number of sea urchins (Echinoidea) in each plot, the sea urchins (Echinoidea) found in each plot collected samples and grouped them based on their morphological characteristics and characteristics and counted each type, then identified sample. Sample identification was done using the book Assessing Tropical Marine Invertebrates: a Manual for Pacific Island Resource Management. Water parameter measurements in situ include temperature, salinity, pH, brightness, current speed, turbidity (turbidity), conductivity, TDS, and DO.

2.4. Data analysis

Composition, Abundance, Diversity Index, Uniformity Index, and Dominance Index of Echinoidea Types were calculated using the Shannon-Wienner formula.

3. Results and discussion

Sea urchins, also known as sea urchins (Echinoidea), generally live in coral, seagrass, and sand areas. Sea urchins live in colonies that function to defend themselves, and some live alone, making sea urchins vulnerable to predators (7). The existence of sea urchins in an ecosystem cannot be separated from the influence of physicochemical factors in that environment (8). Sea urchins have physical defenses (spines) that make them suitable for defending and protecting themselves from marine organisms such as mollusks, shrimp, crabs, polychaetes (annelid worms), copepods (small crustaceans), and fish (9). The ecological benefits of sea urchins are diverse, including providing shelter for certain types of fish, food for several types of fish, and determining organisms that play a role in various interactions with other marine biota (10). It is a determining factor in the abundance and distribution of shallow-water marine plants (11). This organism is the main species that controls marine algae communities' structure and seagrass communities' destruction in several tropical and subtropical coastal areas (12). Morphologically, sea urchins are unique animals because they have spines on all parts of their bodies, which function as a means of locomotion and self-protection from predator attacks (13).

Knowledge of morphological characteristics is important to study so that we can differentiate between types with economic value and those that do not have economic value because not all types of sea urchins can be consumed. This

is done to avoid over-exploitation by the community (14). Meanwhile, the ecological index is related to values that describe the stability of organisms in a community with their environment (15). Abiotic and biotic environmental factors greatly influence species interactions and the life cycle patterns of each species in a community (16). Thus, knowledge of ecological indices is very important to study. The results of measuring environmental factors at the three research location stations can be seen in Table 1.

Table 1 Water Quality Parameters at the Research Location

Water Quality Parameters	**Station**			
	Unit	I	II	III
Temperature	°C	27.9	28,2	28,0
Brightness	%	100	100	100
Current speed	m/s	0.04	0,09	0.13
Turbidity	NTU	0.13	0.31	0,13
Conductivity	Umhos	47.6	48.1	40,0
TDS (Total Dissolved Solid)	mg/l	23.8	24.1	23.8
Ph	-	8.2	8.4	8.1
Dissolved Oxygen (DO)	mg/l	7.4	7.3	7.3
Salinity	Ppt	32.1	32.2	29.2
Depth	Meter	0.60	0.75	1
Substrate	-	Sand	Sand and Seagrass	Sand and Coral

The water temperature at stations I to III at the observation location remains normal for the seawater temperature in the sea urchin (Echinoidea) habitat. The normal temperature that supports the existence of sea urchins (Echinoidea) is between 25-33oC. The brightness measurement results show that Stations I, II, and III are quite high, whereas at all observation stations, it can penetrate the bottom of the water. The high level of brightness in the waters is because these waters are generally shallow (17). High levels of brightness support seagrass life and other photosynthetic organisms to carry out the photosynthesis process.

The current speed at the research location is a relatively slow current speed. The water current speed ranges from 0.03 -0.15, a slow current, where sea urchins (Echinoidea) prefer relatively calm waters (18). The results of turbidity measurements at each station are classified as normal. The higher the value of suspended solids in the water, the higher the turbidity value (19). It is thought that the turbidity value at station II is higher because when water sampling occurs, the water and solids are stirred by human activity, which causes the value of suspended solids in the water to become higher.

The conductivity values at each research station still meet the standards for marine biota habitat, especially sea urchins (Echinoidea). The conductivity value that supports marine biota is around 40-200 µmhos. TDS (Total Dissolved Solid) or total dissolved solids are dissolved materials in the form of chemical compounds and other materials (20). Based on the TDS (Total Dissolved Solid) measurements at each station, it is 23.8-24.1 mg/l. TDS values can be influenced by rock weathering, runoff from land, and anthropogenic influences (in the form of domestic and industrial waste) (21).

The pH levels at each station are still normal. Based on the Decree of the Minister of Environment No. 51 of 2004, the pH value obtained in this study shows that the pH tends to be alkaline and is included in the optimum range for the growth of seagrass and sea urchins (Echinoidea), namely 7.0-8.5 (22). The DO or dissolved oxygen conditions at the three locations have a range of DO values at each station that is still within a fairly good range and still supports the life of sea urchins (Echinoidea) because they are classified as normal. Minister of Environment Decree No. 51 of 2004, the DO value based on the standard value of dissolved oxygen in water for living marine organisms is > 5 mg/l. The results of seawater salinity observations show that the salinity range can still support the life of sea urchins (Echinoidea). This is supported by research that sea urchins (Echinoidea) live at 27-32 ppt (23).

The depth at the research location is shallow. The deeper the water, the less light intensity enters the water. Light penetration at the research location reaches the bottom of the waters, making it good for marine plants and photosynthetic organisms (seagrass, zooxhentella algae) to photosynthesize (24). The type of substrate at Station I is sand, Station II is sand and seagrass substrate, while Station III is sand and coral. Sea urchins (Echinoidea) usually occupy sand, seagrass, and coral substrates. The substrate will determine sea urchins' abundance and species composition (Echinoidea) (25). The number of individuals and species composition of sea urchins (Echinoidea) is presented in Table 2.

Table 2 Number of Individuals and Type Composition of Sea Urchins (*Echinoidea*) at each station

Family	**Jenis**	**Station**			**Ni**	**Ki (%)**
		I	II	III		
Diadematidae	*Diadema Sotesumsss*	43	96	66	205	49,03
Diadematidae	*Echinotrix calamaris*	0	0	27	27	6,459
Toxopneustidae	*Tripneustes gratilla*	0	48	19	67	16,028
Temnopleurida	*Salmacis sphaeroides*	0	37	0	37	8.852
Echinometridae	Echinometra mathaei (A)	0	0	23	23	5.503
Echinometridae	Echinometra mathaei (B)	0	0	21	21	5.024
Echinometridae	Echinometra mathaei (C)	0	0	20	20	4.785
Echinometridae	Echinometra mathaei (D)	0	0	18	18	4.306
Total Ni		43	181	194	418	100

Based on Table 2, the number of individual sea urchins (Echinoidea) obtained from this study was 418 individual sea urchins (Echinoidea). Diadema sotesum has the highest composition value, presumably because the Diadema setosum type can be found at all three research stations. This indicates that this type of Diadema setosum can adapt to environmental changes. Diadema sodium can live in coral reefs, sand, and algae growth areas (26). At the same time, Echinomatrix calamari has the lowest composition value, allegedly because station III is in a coral reef area close to the edge area. The abundance of sea urchins (Echinoidea) in the waters of Pasir Timbul Bone Labunta can be seen in Table 3.

Table 3 The abundance of sea urchins (Echinoidea) at the research location

Family	**Type**	**Station**					
		I		II		III	
		Ni	Pi	Ni	Pi	Ni	Pi
Diadematidae	*Diadema Sotesumsss*	43	0,286	96	0,640	66	0,440
Diadematidae	*Echinotrix calamaris*	0	0	0	0	27	0,180
Toxopneustidae	*Tripneustes gratilla*	0	0	48	0,320	19	0,126
Temnopleurida	*Salmacis sphaeroides*	0	0	37	0,246	0	0
Echinometridae	Echinometra mathaei (A)	0	0	0	0	23	0,153
Echinometridae	Echinometra mathaei (B)	0	0	0	0	21	0,140
Echinometridae	Echinometra mathaei (C)	0	0	0	0	20	0,133
Echinometridae	Echinometra mathaei (D)	0	0	0	0	18	0,120
Total		43	0,286	181	1,206	194	1,293

Morphologically, sea urchins (Echinoidea) are divided into two groups: regular sea urchins and irregular sea urchins. The body shape of the regularia sea urchin is pentaradial symmetry, almost spherical, whereas the irregular sea urchin shows varying degrees of bilateral symmetry (27). The body of a sea urchin is round or flat, has no arms, and has long, movable spines. All organs in sea urchins are generally located in the shell (test sceleton), which consists of 10 double plates, usually tightly connected, namely the ambulacra plate. Besides that, there is an ambulacra plate with holes where the tube feet come out. The presence of sea urchins in coral reef ecosystems significantly influences ecological balance.

Sea urchins are often found in coral reef ecosystems, especially the D. setosum type, because the abundance of the population of this species is important for coral reefs as a balance. Sea urchins can be said to be herbivores or grazers because the diet of sea urchins generally eats algae found on coral reefs. The activity of eating algae causes a decrease in the number of macroalgae found in the coral reef ecosystem and rebalances the space where the coral reef can live. Previously, it was known that an increase in macroalgae created a struggle for space for coral animals to grow (28). The results of calculating the diversity index (H'), uniformity index (E), and dominance index (C) can be seen in Table 4.

Table 4 Calculation Results of Diversity Index, Uniformity Index, and Index Dominance

Indeks	**Station**			**Level**
	I	II	III	
Diversity Shannon Wiener (H')	0	1,013	1,817	H'>3 = high diversity, 1<H'>3 = medium diversity H' < 1 = low diversity
Uniformity	0	0,922	1,394	0 < E ≤ 0,5 : Little uniformity, depressed community 0,5 <E ≤ 0,6 : Moderate uniformity, unstable community 0,6 < E ≤ 1 : High uniformity, stable community
Dominance	1	0,282	0,189	0 < C ≤ 0,5 : Low dominance, 0,5 < C ≤ 0,75 : Dominance medium, 0,75 < C ≤ 1 : High dominance

The research results show that each station has varying index values. Station I shows a diversity index value (H') of 0 in the low diversity category, the lowest index value of the three stations. Station II shows a diversity index (H') value of 1.013 in the medium diversity category. Station III shows a diversity index value (H') of 1.817 in the medium diversity category and is the highest index value of the three stations. Based on the Shannon-Wiener criteria, the diversity index value (H') is categorized as if H'<1, namely species diversity, individual distribution, and low community stability. If 1<H'<3 indicates species diversity, individual distribution, medium community stability, and if H'>3 indicates species diversity, individual distribution, high community stability.

The diversity index value (H') at station I is relatively low. This is because there is only one type of sea urchin (Echinoidea). One of the environmental factors that can cause this to happen is the substrate at station I, which is a sandy substrate. Several types of sea urchins (Echinoidea) cannot adapt to sandy substrate areas. Most sea urchins (Echinoidea) live on hard substrates, namely rocks or coral reefs seagrass areas, and only a small portion inhabit sandy substrates (29). This is because it is difficult for the tube feet to find a place to attach in such conditions. The causal factor is that corals can become a habitat for sea urchins (Echinoidea) because the tube feet of sea urchins (Echinoidea) can stick between corals, especially on hard substrates such as coral fragments and dead coral (30). Furthermore, it is thought to be caused by the availability of food sources supporting sea urchins' life (Echinoidea).

The highest uniformity index (E) value is found at station III, with a value of 1.394 in the high uniformity index (E) category, and has a stable community. Station II shows a uniformity index (E) value of 0.922 in the high uniformity (E) value category and a stable community. This is because it is suspected that the distribution of individuals is even at stations II and III. The lowest uniformity index (E) value is at station I, with a value of 0 in the low uniformity (E) value category, and is in a depressed community. It is suspected that station I has an abundance of certain types, whereas at this station, there is only one type of sea urchin (Echinoidea). If the uniformity index (E) value is close to 1 (E>0.5), then the distribution of individuals between types is relatively the same. If the uniformity index (E) value is close to 0 (E<0.5), then there is a group of certain types of species that are relatively abundant compared to other types (31).

The dominance index (C) value at station I is 1, with a high dominance index (C) category. This is thought to be because there is only one type of sea urchin (Echinoidea) at that station, namely Diadema setosum. Station II has a dominance

index value (C) of 0.282 with a low index value category. Station III has a dominance index (C) value of 0.189 with a low index category. This indicates that the sea urchin (Echinoidea) community at Station II and Station III is relatively stable with low dominance. If a particular biota in the waters has a dominance value (C) close to 0, it means that the structure of the biota community is in a stable state. On the other hand, if the dominance value is 1, the community structure is unstable due to ecological pressure (31).

4. Conclusion

Based on the results of the research that has been carried out, it can be concluded that (1) There are 5 types of sea urchins (Echinoidea) found at the research location, namely Diadema setosum, Echinothrix calamaris, Tripneustes gratilla, Salmacis sphaeroides and Echinometra mathaei, which consists of 4 families, namely Diadematidae, Toxopneustidae, Temnopleuridae and Echinometridae, (2). The diversity index (H') at station I shows a low diversity index (H') value, while at stations II and III shows a medium diversity index (H') value. The uniformity index (E) value shows that at station I, the uniformity index (E) value is low, while at stations II and III, the uniformity index (E) value. The dominance index value at station I shows a high dominance index (C) value, while stations II and III show a high dominance index (C) value.

Compliance with ethical standards

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Disclosure of conflict of interest

There are no conflicts of interest in this research, either funding or other organizations that could be detrimental.

References

[1] Weber JN, Raup DM. Fractionation of the stable isotopes of carbon and oxygen in marine calcareous organisms—the Echinoidea. Part II. Environmental and genetic factors. Geochim Cosmochim Acta. 1966 Jul 1;30(7):705–36.

[2] Conor JJ. Gonad growth in the sea urchin, Strongylocentrotus purpuratus (Stimpson) (echinodermata: Echinoidea) and the assumptions of gonad index methods. J Exp Mar Biol Ecol. 1972 Nov 1;10(2):89–103.

[3] Ferber I, Lawrence JM. Distribution, substratum preference and burrowing behaviour of Lovenia elongata (Gray) (Echinoidea: Spatangoida) in the Gulf of Elat ('Aqaba), Red Sea. J Exp Mar Biol Ecol. 1976 Jun 1;22(3):207–25.

[4] Dafni J. Abnormal growth patterns in the sea urchin Tripneustes CF. Gratilla (L.) under pollution (Echinodermata, Echinoidea). J Exp Mar Biol Ecol. 1980 Jan 1;47(3):259–79.

[5] Ernest RG, Blake NJ. Reproductive patterns within sub-populations of Lytechinus variegatus (Lamarck) (Echinodermata: Echinoidea). J Exp Mar Biol Ecol. 1981 Oct 19;55(1):25–37.

[6] Frantzis A, Grémare A, Vétion G. Growth rates and RNA: DNA ratios in Paracentrotus lividus (Echinodermata: Echinoidea) fed on benthic macrophytes. J Exp Mar Biol Ecol. 1992 Apr 16;156(1):125–38.

[7] Guillou M, Michel C. The influence of environmental factors on the growth of Sphaerechinus granularis (Lamarck) (Echinodermata: Echinoidea). J Exp Mar Biol Ecol. 1994 May 16;178(1):97–111.

[8] Gebauer P, Moreno CA. Experimental validation of the growth rings of Loxechinus albus (Molina, 1782) in southern Chile (Echinodermata: Echinoidea). Fish Res. 1995 Jan 1;21(3):423–35.

[9] McClary DJ, Sewell MA. Hybridization in the sea: gametic and developmental constraints on fertilization in sympatric species of Pseudechinus (Echinodermata: Echinoidea). J Exp Mar Biol Ecol. 2003 Jan 29;284(1):51–70.

[10] Villier L, Navarro N. Biodiversity dynamics and their driving factors during the Cretaceous diversification of Spatangoida (Echinoidea, Echinodermata). Palaeogeogr Palaeoclimatol Palaeoecol. 2004 Nov 18;214(3):265–82.

[11] Volpi Ghirardini A, Arizzi Novelli A, Tagliapietra D. Sediment toxicity assessment in the Lagoon of Venice (Italy) using Paracentrotus lividus (Echinodermata: Echinoidea) fertilization and embryo bioassays. Environ Int. 2005 Sep 1;31(7):1065–77.

[12] Attrill MJ, Kelmo F. Opportunistic responses of Diadema antillarum (Echinodermata: Echinoidea) populations following the 1997–98 El Niño event in Bahia, Brazil. Estuar Coast Shelf Sci. 2007 Jun 1;73(1):243–8.

[13] Barbaglio A, Sugni M, Di Benedetto C, Bonasoro F, Schnell S, Lavado R, et al. Gametogenesis correlated with steroid levels during the gonadal cycle of the sea urchin Paracentrotus lividus (Echinodermata: Echinoidea). Comp Biochem Physiol A Mol Integr Physiol. 2007 Jun 1;147(2):466–74.

[14] Böttger SA, McClintock JB. The effects of chronic inorganic and organic phosphate exposure on bactericidal activity of the coelomic fluid of the sea urchin Lytechinus variegatus (Lamarck) (Echinodermata: Echinoidea). Comp Biochem Physiol Part C Toxicol Pharmacol. 2009 Jul 1;150(1):39–44.

[15] Hardy C, David B, Rigaud T, De Ridder C, Saucède T. Ectosymbiosis associated with cidaroids (Echinodermata: Echinoidea) promotes benthic colonization of the seafloor in the Larsen Embayments, Western Antarctica. Deep Sea Res Part II Top Stud Oceanogr. 2011 Jan 1;58(1):84–90.

[16] Brustolin MC, Thomas MC, Mafra LL, Lana P da C. Does Encope emarginata (Echinodermata: Echinoidea) affect spatial variation patterns of estuarine subtidal meiofauna and microphytobenthos? J Sea Res. 2014 Aug 1;91:70–8.

[17] Nobre CR, Santana MFM, Maluf A, Cortez FS, Cesar A, Pereira CDS, et al. Assessment of microplastic toxicity to embryonic development of the sea urchin Lytechinus variegatus (Echinodermata: Echinoidea). Mar Pollut Bull. 2015 Mar 15;92(1):99–104.

[18] Urriago JD, Wong JCY, Dumont CP, Qiu JW. Reproduction of the short-spined sea urchin Heliocidaris crassispina (Echinodermata: Echinoidea) in Hong Kong with a subtropical climate. Reg Stud Mar Sci. 2016 Nov 1;8:445–53.

[19] Iglikowska A, Najorka J, Voronkov A, Chełchowski M, Kukliński P. Variability in magnesium content in Arctic echinoderm skeletons. Mar Environ Res. 2017 Aug 1;129:207–18.

[20] Kim P, Kim D, Yoon TJ, Shin S. Early detection of marine invasive species, Bugula neritina (Bryozoa: Cheilostomatida), using species-specific primers and environmental DNA analysis in Korea. Mar Environ Res. 2018 Aug 1;139:1–10.

[21] Yang Y, Yan Q, Liu Q, Li Y, Liu H, Wang P, et al. An ultrasensitive sandwich-type electrochemical immunosensor based on the signal amplification strategy of echinoidea-shaped Au@Ag-Cu2O nanoparticles for prostate specific antigen detection. Biosens Bioelectron. 2018 Jan 15;99:450–7.

[22] Sadam LO, Emiyarti, Ira. Keanekaragaman Bulu Babi (Echinoidea) Pada Kawasan Lamun Di Perairan Desa Langara, Kecamatan Wawonii Barat Kabupaten Konawe Kepulauan. J Sapa Laut J Ilmu Kelaut. 2019 Sep 28;4(3):113–22.

[23] Noviana NPE, Julyantoro PGS, Pebriani DAA. Distribusi Dan Kelimpahan Bulu Babi (Echinoidea) Di Perairan Pulau Pasir Putih, Desa Sumberkima, Buleleng, Bali. Curr Trends Aquat Sci. 2019 Feb 9;2(1):21–8.

[24] Pereira TM, Gnocchi KG, Merçon J, Mendes B, Lopes BM, Passos LS, et al. The success of the fertilization and early larval development of the tropical sea urchin Echinometra lucunter (Echinodermata: Echinoidea) is affected by the pH decrease and temperature increase. Mar Environ Res. 2020 Oct 1;161:105106.

[25] Plee TA, Pomory CM. Microplastics in sandy environments in the Florida Keys and the panhandle of Florida, and the ingestion by sea cucumbers (Echinodermata: Holothuroidea) and sand dollars (Echinodermata: Echinoidea). Mar Pollut Bull. 2020 Sep 1;158:111437.

[26] Purwandatama RW, Suryanti, Ain C. Kelimpahan Bulu Babi (Sea Urchin) Pada Karang Massive Dan Branching Di Daerah Rataan Dan Tubir Di Legon Boyo, Pulau Karimunjawa, Taman Nasional Karimunjawa. Manag Aquat Resour J MAQUARES. 2013 Jan 29;3(1):17–26.

[27] La Croix AD, Ayranci K, Dashtgard SE. Neoichnology of siliciclastic shallow-marine environments: Invertebrates, traces, and environmental conditions. Earth-Sci Rev. 2022 Oct 1;233:104170.

[28] Wang TT, Wang XD, Wang DY, Fan SD, Wang S, Chen ZB, et al. Aquatic invertebrate diversity profiling in heterogeneous wetland habitats by environmental DNA metabarcoding. Ecol Indic. 2023 Jun 1;150:110126.

[29] Baruadi H, Olii AH, Kadim MK. Kepadatan dan Pola Sebaran Bulu Babi di Desa Lamu | Density and distribution patterns of sea urchin in Lamu Village. NIKe J. 2017;5(2):48–53.

[30] Irianto A, Jahidin J, Sudrajat HW. Kelimpahan Bulu Babi (Echinoidea) Di Intertidal Perairan Pulau Liwutongkidi Kecamatan Siompu Kabupaten Buton Selatan. Ampibi J Alumni Pendidik Biol. 2016 Aug 1;1(2):27–30.

[31] Musfirah NH. Struktur Komunitas Bulu Babi (Echinoidea) Yang Berasosiasi Dengan Ekosistem Lamun Di Pulau Barrang Lompo, Sulawesi Selatan [Internet] [Skripsi]. [Makassar]: Universitas Hasanuddin; 2017 [cited 2023 Oct 9]. Available from: http://103.195.142.59/opac/detail-opac?id=37276