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Abundance and distribution of sea urchins (*Echinoidea* Leske, 1778) on coral reefs in the waters of Latondu Island, Taka Bonerate, South Sulawesi, Indonesia

Prasetia Maulana Malik[1,*], Indah Riyantini[2], Lintang Permata Sari Yuliadi[2], Herman Hamdani[3]

[1]Faculty of Fisheries and Marine Sciences, Padjadjaran University, Sumedang 45363, West Java, Indonesia

[2]Departement of Marine Sciences, Faculty of Fisheries and Marine Sciences, Padjadjaran University, Sumedang 45363, West Java, Indonesia

[3]Departement of Fisheries, Faculty of Fisheries and Marine Sciences, Padjadjaran University Sumedang 45363, West Java, Indonesia

*E-mail address: prasetiam25@gmail.com

ABSTRACT

Sea urchin is one of the key biota of coral reef stability. Research on the abundance and distribution of urchins was carried out from January-August 2019 and field data retrieval occurred in March 2019 on Latondu Island, Taka Bonerate. This study aims to determine the relationship between sea urchin abundance with coral reef conditions and sea urchin distribution patterns in the waters of Latondu Island, Taka Bonerate. Observation of coral reefs and sea urchins was carried out at 3 stations with different criteria of coral reef conditions. Retrieval of coral reef data was done using the Point Intercept Transect (PIT) method, while sea urchin observation came about via a transect belt method. The results showed that in the waters of the island of Latondu, there were 133 sea urchins from 7 species of the Echinoidea class, namely *Diadema setosum, Diadema antillarum, Echinometra mathaei, Echinotrix calamaris, Mespillia globulus, Heterocentrotus mammillatus* and *Echinotrix diadema*. The largest abundance of sea urchins was found in Station 3 on the southern part of Latondu Island with 12 ind / 50 m^2, while Station 1 in the northeast and Station 2 in the northwest part showed 5 ind / 50 m^2. Sea urchin distribution at Station 1 with a value of 0.79 was uniform, Station 2 with a value of 0.80 was also uniform, and Station 3 with a value of 0.91 was uniform as well. The relationship between Sea urchin and coral reef was 0.56, which meant the relationship was moderate and directly proportional.

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Keywords: abundance, distribution, sea urchin, coral reef, Echinoidea, *Diadema setosum, Diadema antillarum, Echinometra mathaei, Echinotrix calamaris, Mespillia globulus, Heterocentrotus mammillatus*, *Echinotrix diadema*, Latondu Island

1. INTRODUCTION

Taka Bonerate National Park is one of the coastal and marine areas in Indonesia that is protected as conservation zone. It is located geographically in the Flores Sea area, at 06° 17' 15" – 07° 06' 45"S, 120° 53' 30" – 121° 25' 00"E. Taka Bonerate National Park is regulated by Ministry of Forestry Decree No. 92/KPTS-II/2001 dated March 15th 2001, and has a total area of 530,765 ha. It is the third biggest atoll reef globally and possesses high biodiversity and numerous habitats of various endangered and protected sea animal species. One of the habitats is Latondu Island. The coral reef ecosystem of this island is in near pristine condition based on the diversity and abundance of its marine biota.

Reef ecosystems play an important role in ocean biodiversity and biota abundance, and coral reefs also act as barriers to protect coasts from waves and currents. Warm water reefs have optimal growth at annual mean temperature that ranges between 23-25 ºC, though they are able to tolerate temperature at the lower limit of 20 ºC and upper limit of 36-40 ºC. One type of biota that lives on them is sea urchin.

Sea urchins are a key species in the diversity of the coral reef community. Their existence greatly depends on detritus and macroalgae, the availability of which is influenced by reef condition. It is strongly suggested that a decrease in sea urchin densities brings about damage to reef ecosystems, due to macroalgae dominating and covering the reefs. Reefs, therefore, live because of the equilibrium between sea urchins and macroalgae. Indeed, a decrease in urchin population will result in an abundance of macroalgae (blooming) and will certainly inflict negative effects on the lives of coral reefs.

The distribution of oceanic organisms is immensely vital because it is one of the biological factors that influence the diversity of marine life in the intertidal zone. The one that affects sea urchin distribution is the substrate. Under different conditions of coral coverage, differences appear in the availability of food for the urchins, which results in differences in urchin abundance and distribution in Latondu Island waters.

2. METHODS

The research was conducted from January to August 2019. Data retrieval was conducted in March 2019 (March 14th, 15th and 16th, 2019). The location was in the waters of Latondu Island, Taka Bonerate District, Kepulauan Selayar Regency, South Sulawesi Province. There were 3 sampling stations (**Figure 1**):

- Station 1 (north-east of Latondu Island): 6°29'35"S, 120°59'38"E
- Station 2 (north-west of Latondu Island): 6°29'46"S, 120°59'07"E
- Station 3 (south of Latondu Island): 6°30'18"S, 120°59'25"E.

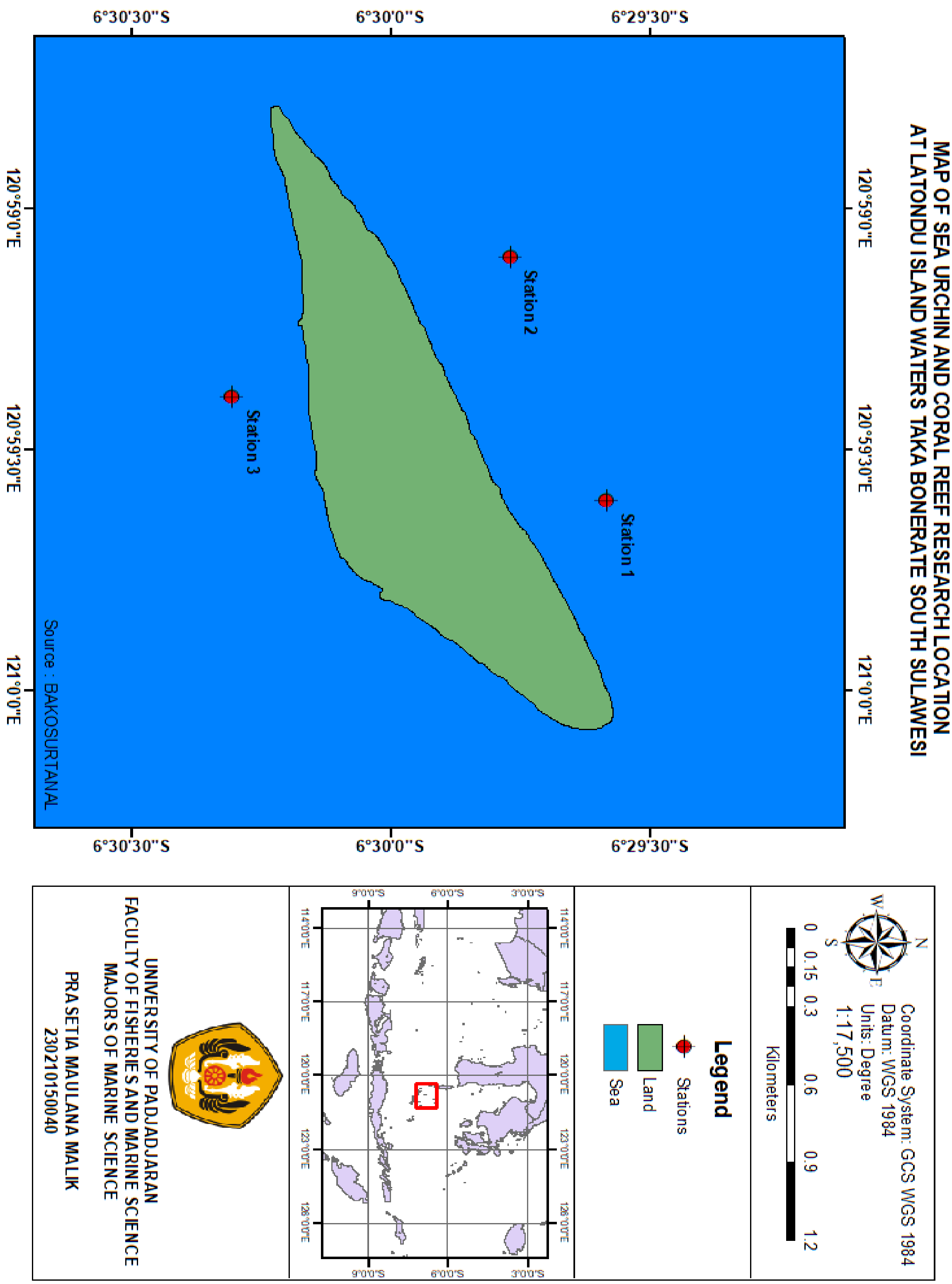

Figure 1. Sampling stations at Latondu Island waters, Taka Bonerate

The tools used in this research were scuba sets, slate paper, thermometer, refractometer, Secchi disk, pH-meter, roll meter, hand-cart, underwater camera, sea urchin identification forms, and reef identification forms (PIT). Physical-chemical parameter data were collected by *in situ* measurements at every station. These parameters include temperature, transparency, salinity, and pH.

The research method used was survey. The survey method is a research technique conducted on large and small populations, wherein the data studied are from samples taken from these populations, so that the distribution and relationships between variables could be determined. The survey data obtained included abundance data, distribution and sea urchin/ coral reef relationship assessments, coral coverage and water quality data. The results were in the form of quantitative and qualitative data which were then processed via data analysis.

Sea urchin data were collected using the Belt Transect method. This method uses a 50 m transect of a 1 m wide corridor. The Belt Transect method can be used to describe biota that has a relatively diverse size or has a maximal size, such as coral reefs and sea urchin presence (**Figure 2**).

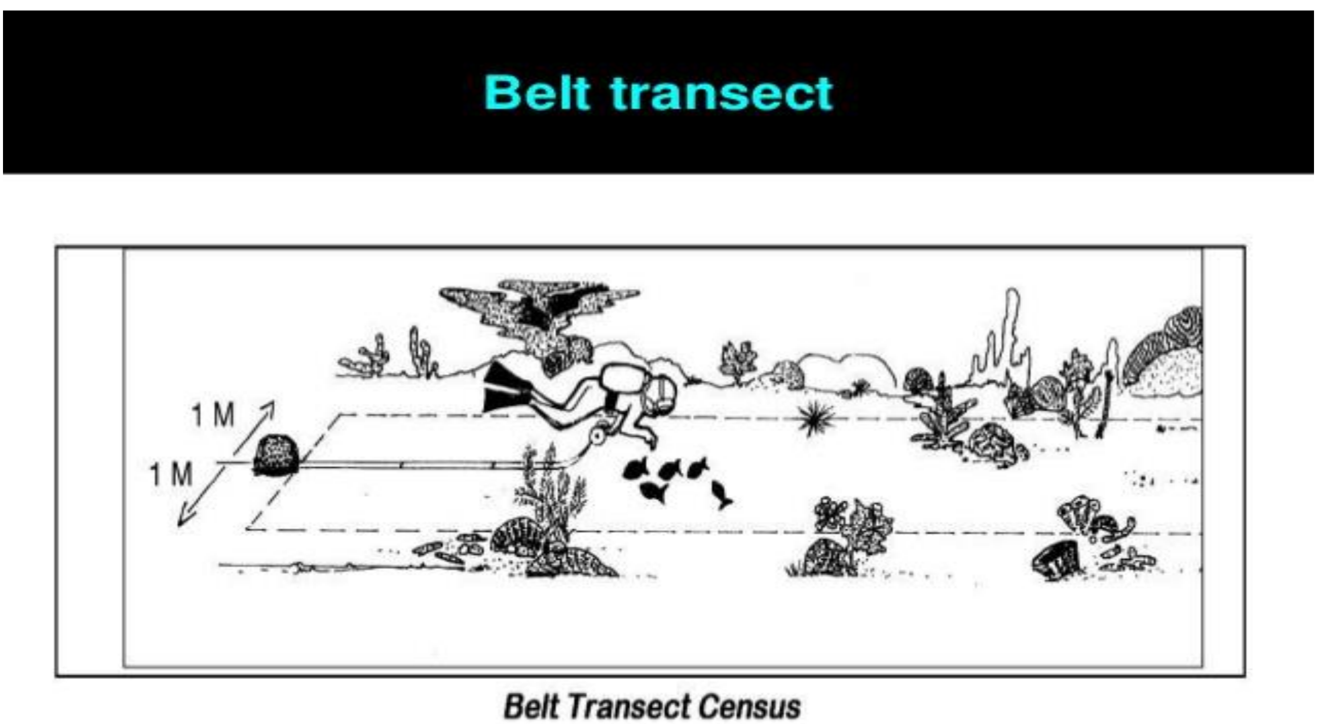

Figure 2. Sea urchin data retrieval scheme

Observation of coral reef condition was accomplished using the Point Intercept Transect (PIT) method by calculating live coral coverage. The Point Intercept Transect (PIT) method was done by pulling a 50 m Line Transect, recording coral reef data under the line at 0.5 meter intervals along the transect, starting at 0.5 meters and continuing up to 50 meters.

Data obtained from the field were data from the transect using the PIT method, and then stored in a computer with the help of the Ms.Excel program. The coral measurement results were processed into the percentage value of coral cover using the formula:

$$L = \frac{Li}{N} \times 100\%$$

with:

L = Percentage of live coral coverage
Li = Sum of each component
N = Total components (50 m).

Reef condition was determined based on percentage of live coral coverage (**Table 1**).

Table 1. Coral reef assessment criteria

Category	Live Coral Coverage (%)
Poor	0 – 24,9
Moderate	25 – 49,9
Good	50 – 74,9
Excellent	75 – 100

Abundance was calculated using the following formula:

$$D = \frac{Ni}{A}$$

with:

D = abundance (ind/m^2)
Ni = total sum of individuals (ind)
A = total sum of transects (m^2).

Data analysis to determine the dispersion of sea urchins applied Morisita Index:

$$Id = n \frac{\sum x^2 - \sum x}{(\sum x)^2 - \sum x}$$

with:

Id = Morisita Index
n = number of sampling quadrats
$\sum$x = sum of individuals in each transect (x_1+x_2+…).

The result of Morisita Index calculation was compared with the following criteria:

Id < 1: Distribution patterns of individual types are uniform
Id = 1: Distribution patterns of individual types are random
Id > 1: Distribution patterns of individual types are clustered.

Data analysis in this study was done using Bivariate Correlation Analysis, via the Ms. Excel program. Bivariate Correlation Analysis was performed to measure the degree of association between two variables.

The implemented formula being:

$$r_{xy} = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}}$$

with:

r_{xy} = coefficient of correlation between two variables
N = number of samples
$\sum X$ = sum of individuals in each station (x_1+x_2+…)
$\sum Y$ = sum of live coral reefs in each station (y_1+y_2+…).

The result is interpreted with the help of a guide (**Table 2**):

Table 2. Interpreted numbers

Interpreted number	Correlation
0 – 0.199	Very Weak
0.20 – 0.399	Weak
0.40 – 0.599	Moderate
0.60 – 0.799	Strong
0.80 – 1.0	Very Strong

3. RESULTS AND DISCUSSION

Based on observations at the three stations, the results obtained for the quality of Latondu Island waters can be seen in **Table 3**.

Temperature is one of the important parameters in the growth and development of sea urchins and coral reefs, as sea urchins will experience death at 35˚C within 12 hours. Water temperature can also affect embryonic development. The temperature measured at each station shows a value that was not much different, namely, 30 °C for stations 1 and 2, 29 °C for Station 3. The temperature being not much different at each station indicates that, during the study, the temperature distribution tended to be homogeneous. Of note, data collection were executed in the morning until noon (Table 3).

Table 3. Physical and chemical parameters

Station	Observed parameters				
	Temperature (°C)	Salinity (ppt)	pH	Depth (m)	Transparency (%)
1	30	30	7	2-7	100
2	30	30	7	2-6	100
3	29	31	7	3-8	100

Salinity measurement results at the site found that salinity ranged from 30-31 ppt. Sea urchins in general are not resistant to low salinity. Exceptions apply to species that live in the tidal area. If the salinity ranges from 23-26 ppt, it will result in changes in color pigments, thorns will fall out and urchins will become inactive, stop eating and eventually die (Table 3).

The results of the measurement of the degree of acidity (pH) found that the pH at each station was 7.2, while the distribution of pH values was homogeneous. For reef organisms, particularly coral and sea urchin, a good pH value is 7-8, thus it can be said in terms of acidity (pH) that the waters of Latondu Island was fit both for reef corals and sea urchins (Table 3).

For Station 1, the depth taken was around 2-7 meters and for Station 2, it was around 2-6 meters, while Station 3 was at 3-8 meters depth (Table 3).

Based on the results of brightness measurement, in Latondu Island waters, the waters brightness was 100%. The high percentage of brightness in Latondu Island waters indicates the level of penetration or entry of sunlight to the bottom of the waters. According to the Ministry of Environment Decree for marine biota, the in water brightness of Latondu Island is considered ideal. In deep and clear waters, the process of photosynthesis and light penetration can reach depths of around 200 meters (Table 3).

3. 1. Coral Coverage

Referring to Minister of Environment Decree No. 51 of 2004 concerning the quality standard of seawater for marine biota, the waters of Latondu Island had waters conditions suitable for viable coral reef ecosystems. However, there were differences in the condition of the coral reef at each station due to other factors such as docking sites, sedimentation and fishing activities.

With reference to **Figure 3**, the percentage of live coral cover in Station 1 was 38.33% and hence, 'moderate', for Station 2, the percentage of live coral cover value was 41.33% and 'moderate', for Station 3, the percentage value of live coral cover was 58.67% and 'good'. The results of live coral cover in Latondu Island waters from the three stations averaged 46.11% and hence, 'moderate'. Based on the Ministry of Environment's Regulation No. 4 of 2001, moderate coral cover ranges from 25% - 49.9% (Figure 3).

Coral fracture at Station 1 in the northeast and Station 2 in the northwest consecutively reached 61.67% and 58.67% in the waters of Latondu Island, caused by the activities of people who catch fish using fish bombs. The damage to coral reefs is largely caused by human activities.

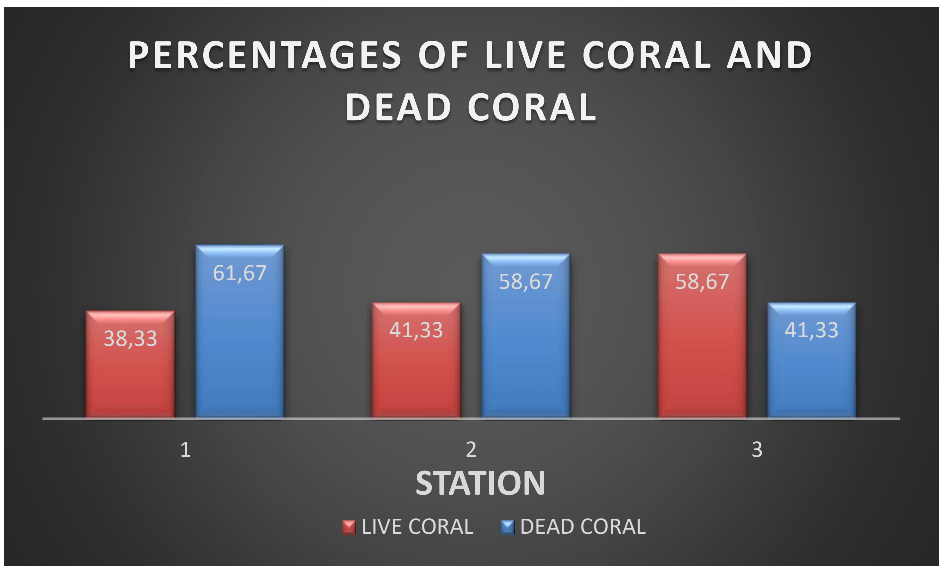

Figure 3. Percentages of Live Coral Coverage

3. 2. Sea Urchin Abundance

The number of sea urchins found in all stations reached 133 individuals that were of 7 different types. The highest abundance of sea urchins (12 individuals / 50 m^2) was found at Station 3, south of Latondu Island and the lowest abundance of sea urchin (5 individuals / 50 m^2) was found both in Station 2, located northwest of Latondu Island and Station 1 which is northeast of Latondu Island. Current speed is one factor for the existence of sea urchins. The strong current is thought to be the cause of the low abundance of sea urchins in these two areas, due to sea urchins preferring calm waters so that their tube feet can attach to hard substrates (**Figure 4**).

3. 3. Distribution of Sea Urchins

The calculation result of the Morisita index at each station showed the same distribution patterns. At the three stations, the results were less than one. This implies that the sea urchin distribution patterns were uniform (Figure 4). Stations 1 and 2 had a higher percentage of coral fractures than Station 3, while there was more food available at Station 2. Sea urchins are generally herbivore, living on algae and sea grasses. However, from the observation results it is suspected that there were not much macroalgae in the three stations, but the distiribution was uniform (**Table 4**).

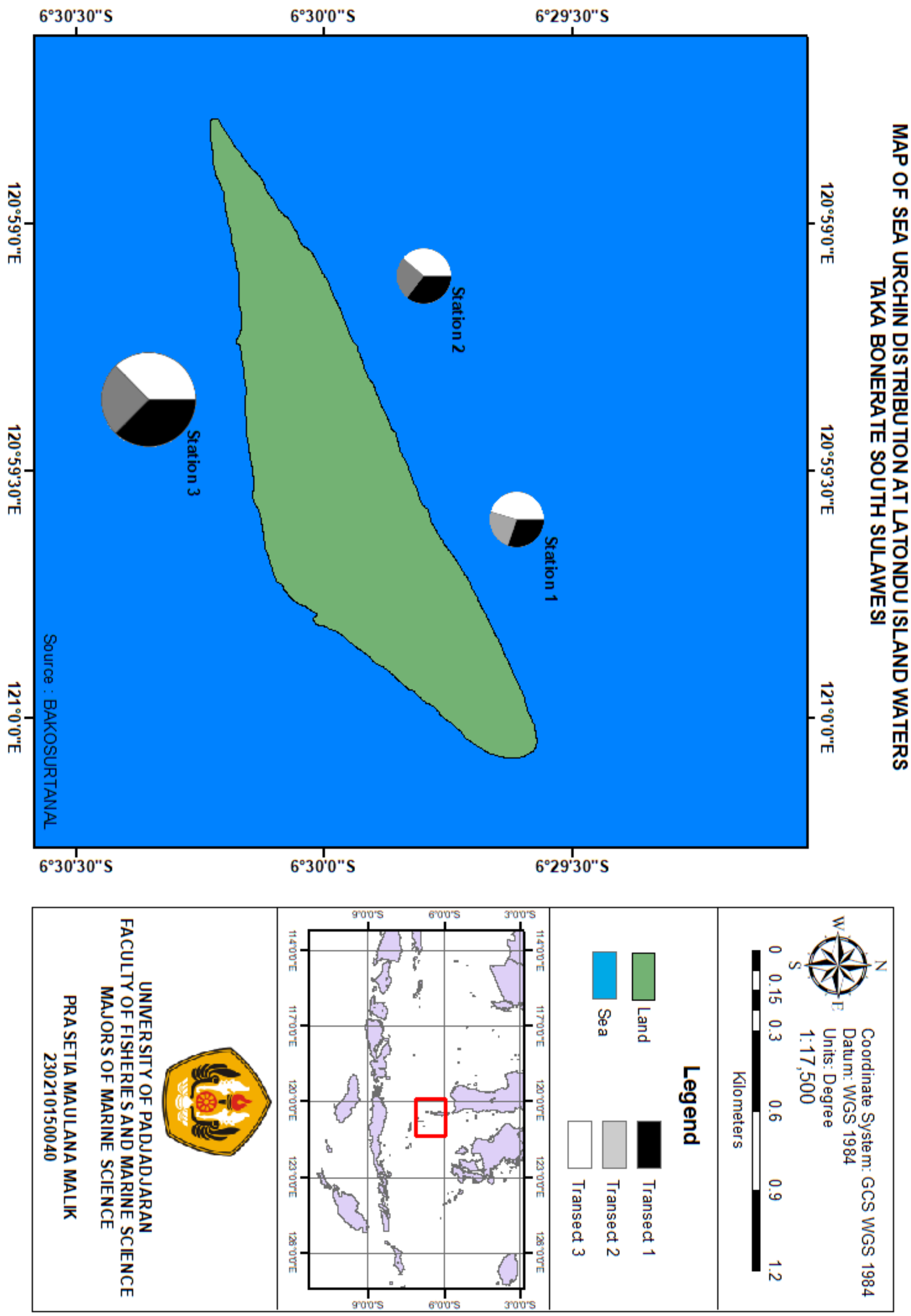

Figure 4. Chart of sea urchin distributions

Table 4. Values of sea urchin distribution

Station	Morisita Index (Ip)	Comparison	Distribution
1	0.79	Ip < 1	Uniform
2	0.80	Ip < 1	Uniform
3	0.91	Ip < 1	Uniform

At the three stations, the calculation results of the Morisita Index were smaller than 1 indicating the sea urchin distribution patterns at that location were uniform. The uniform distribution patterns that occur indicate that there was neither dependence nor competition over food at the location, but that the algae amount was poor. Still, the growth of corals in a current would be better than in calm waters, as the current serves to supply nutrients that are needed by organisms in coral reef areas. Sea urchins found at Stations 1 and 2 were in the coral reef crevices so as to protect themselves from strong currents and strong sunlight exposure. It should be noted that certain types of urchins are sensitive to excessive sun exposure.

3. 4. Relations between sea urchins and coral reefs

The result of the sea urchin correlation analysis with live coral cover in Latondu Island waters obtained from the whole transect was 0.56, which meant that sea urchins have a moderate relationship (Appendix 7), but showed a relationship with a positive relationship direction. A positive correlation coefficient (r) means that there is a relationship between variables X and Y that is directly proportional: Increasing the value of variable X will increase the value of variable Y.

Thus, sea urchin is one of the key species (keystone species) for coral reef communities. This is due to it being one of the macroalgae population controllers. It is strongly asserted that if the density of sea urchins decreases coral reefs will be damaged, because macroalgae will dominate and cover the coral, thus inhibiting the process of coral photosynthesis, eventually resulting in mass coral mortality.

4. CONCLUSIONS AND SUGGESTIONS

4. 1. Conclusions

The number of sea urchins found in Latondu Island waters was 133 individuals of 7 types of sea urchins. Abundance at Station 1 was found to be 5 individuals / 50 m^2, at Station 2 - 5 individuals / 50 m^2, and at Station 3 - 12 individuals / 50 m^2. According to the anaylsis undertaken, sea urchins have a positive relationship to coral reefs with a value of 0.56, which means a moderate correlation. Furthermore, sea urchin distribution in Latondu Island waters is uniform, namely, Sation 1 - 0.79, Station 2 - 0.80, and Station 3 - 0.91.

4. 2. Suggestions

Suggestions from this research are the need to add other parameters, such as quantitative macroalgae data collection, determinants, growth and mortality from sea urchins, as well as water quality parameters such as DO and current speed. Future studies on the economic and biological value of sea urchin would also suffice.

References

[1] Polónia A.R.M., Cleary D.F.R., Freitas R., de Voogd N.J., and Gomes N.C.M. (2015) The putative functional ecology and distribution of archaeal communities in sponges, sediment and seawater in a coral reef environment. *Molecular Ecology* 24: 409, https://doi.org/10.1111/mec.13024

[2] Przeslawski R., Alvarez B., Kool J., Bridge T., Caley M.J., Nichol S., and Bell J. (2015) Implications of Sponge Biodiversity Patterns for the Management of a Marine Reserve in Northern Australia. *PLOS ONE* 10: e0141813, https://doi.org/10.1371/journal.pone.0141813

[3] Schönberg C.H.L. and Fromont J. (2012) Sponge gardens of Ningaloo Reef (Carnarvon Shelf, Western Australia) are biodiversity hotspots. *Hydrobiologia* 687: 143, https://doi.org/10.1007/s10750-011-0863-5

[4] Sutcliffe P.R., Mellin C., Pitcher C.R., Possingham H.P., and Caley M.J. (2014) Regional-scale patterns and predictors of species richness and abundance across twelve major tropical inter-reef taxa. *Ecography* 37: 162, https://doi.org/10.1111/j.1600-0587.2013.00102.x

[5] Tapilatu Y.H. (2015) Status of Drug Discovery Research Based on Marine Organisms from Eastern Indonesia. *Procedia Chemistry* 14: 484, https://doi.org/10.1016/j.proche.2015.03.065

[6] van der Ent E., Hoeksema B.W., and de Voogd N.J. (2016) Abundance and genetic variation of the coral-killing cyanobacteriospongeTerpios hoshinotain the Spermonde Archipelago, SW Sulawesi, Indonesia. *Journal of the Marine Biological Association of the United Kingdom* 96: 453, https://doi.org/10.1017/S002531541500034X

[7] van der Meij S.E.T., Suharsono , and Hoeksema B.W. (2010) Long-term changes in coral assemblages under natural and anthropogenic stress in Jakarta Bay (1920–2005). *Marine Pollution Bulletin* 60: 1442, https://doi.org/10.1016/j.marpolbul.2010.05.011

[8] Phillip L. Davidson, J. Will Thompson, Matthew W. Foster, M. Arthur Moseley, Maria Byrne, and Gregory A. Wray, A comparative analysis of egg provisioning using mass spectrometry during rapid life history evolution in sea urchins, *Evolution & Development*, 21, 4, (188-204), (2019).

[9] Keyne Monro and Dustin J. Marshall, The biogeography of fertilization mode in the sea, *Global Ecology and Biogeography*, 24, 12, (1499-1509), (2015).

[10] Craig R. McClain and Sarah Mincks Hardy, The dynamics of biogeographic ranges in the deep sea, *Proceedings of the Royal Society B: Biological Sciences,* 10.1098/rspb.2010.1057, 277, 1700, (3533-3546), (2010).

[11] G. Desnitskiy, Evolutionary Reorganizations of Ontogenesis in Sea Urchins, Russian *Journal of Developmental Biology*, 10.1007/s11174-005-0023-9, 36, 3, (145-151), (2005).

[12] Guillou, M. and Lumingas, L. (1999). Variation in the reproductive strategy of the sea urchin Sphaerechinus granularis (Echinodermata: Echinoidea) related to food availability. *Journal of the Marine Biological Association of the United Kingdom,* 79(1), 131-136. doi:10.1017/S0025315498000149

[13] Carballo J.L., Cruz-Barraza J.A., Vega C., Nava H., and Chávez-Fuentes Md.C. (2019) Sponge diversity in Eastern Tropical Pacific coral reefs: an interoceanic comparison. *Scientific Reports* 9, 9409, https://doi.org/10.1038/s41598-019-45834-4

[14] Cleary D.F., Polónia A.R., Renema W., Hoeksema B.W, and 12 others, (2016) Variation in the composition of corals, fishes, sponges, echinoderms, ascidians, molluscs, foraminifera and macroalgae across a pronounced in-to-offshore environmental gradient in the Jakarta Bay–Thousand Islands coral reef complex. *Marine Pollution Bulletin* 110: 701, https://doi.org/10.1016/j.marpolbul.2016.04.042

[15] Cleary D.F.R., de Voogd N.J., Polónia A.R.M., Freitas R., and Gomes N.C.M. (2015) Composition and Predictive Functional Analysis of Bacterial Communities in Seawater, Sediment and Sponges in the Spermonde Archipelago, Indonesia. *Microbial Ecology* 70: 889, https://doi.org/10.1007/s00248-015-0632-5

[16] Cleary D.F.R., Polónia A.R.M., Becking L.E., de Voogd N.J., Purwanto , Gomes H., and Gomes N.C.M. (2018) Compositional analysis of bacterial communities in seawater, sediment, and sponges in the Misool coral reef system, Indonesia. *Marine Biodiversity* 48: 1889, https://doi.org/10.1007/s12526-017-0697-0

[17] Ambo-Rappe R. (2014) Developing a methodology of bioindication of human-induced effects using seagrass morphological variation in Spermonde Archipelago, South Sulawesi, Indonesia. *Marine Pollution Bulletin* 86: 298, https://doi.org/10.1016/j.marpolbul.2014.07.002

[18] Becking L.E., Cleary D.F.R., and de Voogd N.J. (2013) Sponge species composition, abundance, and cover in marine lakes and coastal mangroves in Berau, Indonesia. *Marine Ecology Progress Series* 481: 105, https://doi.org/10.3354/meps10155

[19] de Voogd NJ, Cleary DFR (2007) Relating species traits to environmental variables in Indonesian coral reef sponge assemblages. *Marine and Freshwater Research* 58:240, https://doi.org/10.1071/MF06125

[20] Bell J.J. (2007) The use of volunteers for conducting sponge biodiversity assessments and monitoring using a morphological approach on Indo-Pacific coral reefs. *Aquatic Conservation: Marine and Freshwater Ecosystems* 17:133, https://doi.org/10.1002/aqc.789

[21] Bell J.J., McGrath E., Biggerstaff A., Bates T., Bennett H., Marlow J., and Shaffer M. (2015) Sediment impacts on marine sponges. *Marine Pollution Bulletin* 94: 5, https://doi.org/10.1016/j.marpolbul.2015.03.030

[22] Biggerstaff A., Smith D.J., Jompa J., and Bell J.J. (2015) Photoacclimation supports environmental tolerance of a sponge to turbid low-light conditions. *Coral Reefs* 34: 1049, https://doi.org/10.1007/s00338-015-1340-9

[23] Coleman M.A., Vytopil E., Goodsell P.J., Gillanders B.M., and Connell S.D. (2007) Diversity and depth-related patterns of mobile invertebrates associated with kelp forests. *Marine and Freshwater Research* 58: 589, https://doi.org/10.1071/MF06216

[24] de Voogd N.J. and Cleary D.F.R. (2008) An analysis of sponge diversity and distribution at three taxonomic levels in the Thousand Islands/Jakarta Bay reef complex, West-Java, Indonesia. *Marine Ecology* 29: 205, https://doi.org/10.1111/j.1439-0485.2008.00238.x

[25] de Voogd N.J., Cleary D.F.R., Polónia A.R.M., and Gomes N.C.M. (2015) Bacterial community composition and predicted functional ecology of sponges, sediment and seawater from the thousand islands reef complex, West Java, Indonesia. *FEMS Microbiology Ecology* 91, https://doi.org/10.1093/femsec/fiv019

[26] Duckworth A.R. and Wolff C.W. (2007) Patterns of abundance and size of Dictyoceratid sponges among neighbouring islands in central Torres Strait, Australia. *Marine and Freshwater Research* 58: 204, https://doi.org/10.1071/MF06104

[27] Polónia A.R.M., Cleary D.F.R., de Voogd N.J., Renema W., Hoeksema B.W., Martins A., and Gomes N.C.M. (2015) Habitat and water quality variables as predictors of community composition in an Indonesian coral reef: a multi-taxon study in the Spermonde Archipelago. *Science of The Total Environment* 537: 139, https://doi.org/10.1016/j.scitotenv.2015.07.102

[28] Gomes N.C.M., Cleary D.F.R., Pires A.C.C., Almeida A., Cunha A., Mendonça-Hagler L.C.S., and Smalla K. (2014) Assessing variation in bacterial composition between the rhizospheres of two mangrove tree species. *Estuarine, Coastal and Shelf Science* 139: 40, https://doi.org/10.1016/j.ecss.2013.12.022

[29] Helber S.B., de Voogd N.J., Muhando C.A., Rohde S., and Schupp P.J. (2017) Anti-predatory effects of organic extracts of 10 common reef sponges from Zanzibar. *Hydrobiologia* 790:247, https://doi.org/10.1007/s10750-016-3036-8

[30] Henry L.-A., Moreno Navas J., and Roberts J.M. (2013) Multi-scale interactions between local hydrography, seabed topography, and community assembly on cold-water coral reefs. *Biogeosciences* 10:2737, https://doi.org/10.5194/bg-10-2737-2013

[31] Litaay M. (2018) Marine tunicates from Sangkarang Archipelago Indonesia: recent finding and bio-prospecting. *Journal of Physics: Conference Series* 979: 012003, https://doi.org/10.1088/1742-6596/979/1/012003

[32] OOshiro Y., Konjo K., and Makasone K. (2013) Validation of internal reference genes for gene expression analysis in Montipora digitata, Pocillopora damicornis and

Acropora nasuta by quantitative real-time PCR. *Galaxea, Journal of Coral Reef Studies* 15:1, https://doi.org/10.3755/galaxea.15.1

[33] Pearman J.K., Leray M., Villalobos R., Machida R.J., Berumen M.L., Knowlton N., and Carvalho S. (2018) Cross-shelf investigation of coral reef cryptic benthic organisms reveals diversity patterns of the hidden majority. *Scientific Reports* 8, 8090, https://doi.org/10.1038/s41598-018-26332-5

[34] Plass-Johnson J.G., Teichberg M., Bednarz V.N., Gärdes A., and 8 others, (2018) Spatio-Temporal Patterns in the Coral Reef Communities of the Spermonde Archipelago, 2012–2014, II: Fish Assemblages Display Structured Variation Related to Benthic Condition. *Frontiers in Marine Science* 5, 36, https://doi.org/10.3389/fmars.2018.00036

[35] Hoeksema B.W. (2007) Biogeography, Time, and Place: Distributions, Barriers, and Islands. *Topics In Geobiology*. Vol 29, p 117, https://doi.org/10.1007/978-1-4020-6374-9_5

[36] Hoeksema B.W., and de Voogd N.J. (2012) On the run: free-living mushroom corals avoiding interaction with sponges. *Coral Reefs* 31:455, https://doi.org/10.1007/s00338-011-0856-x.