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# Spatial distribution of echinoderms in littoral area of Ambon Island, Eastern Indonesia

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**Abstract.** *Setyastuti A, Purbiantoro W, Hadiyanto. 2018. Spatial distribution of echinoderms in littoral area of Ambon Island, Eastern Indonesia. Biodiversitas 19: 1919-1925.* Echinoderms samples were collected in Ambon Island as part of the marine resource inventories designed to study the biodiversity of Maluku Archipelago. The purpose of this works was to investigate the abundance and genus richness of echinoderms within the five sampling sites using single transect orthogonal to the coast consisted of 10-quadrat plot of 5x5m, the distance between plots was 10m at each site. Furthermore, this study also aimed to understand the relation of substrate type and community composition within those five sites. The substrate was classified into four types (sea-grass, macro-algae, sand, rocks and/or dead coral) noted by presence/absence mark at each plot. The differences in total abundance and genus richness among those sites were analyzed using an Analysis of Deviance following a Generalized Linear Models (GLMs) fitted by Poisson and log link. However, in term of genus composition, the data were visualized using a Principal Coordination Analysis (PCoA) plots calculated from Bray-Curtis dissimilarity based on the log (x+1) transformed abundance data. A total of 910 individuals of echinoderms belonging to 19 genera was successfully recorded. Total abundance of echinoderms was different significantly among sites ($p<0.05$). The most abundant echinoderms were collected from Tanjung Tiram, approximately 68.71 individuals/quadrat, which was almost 1.4 times than those in Liang and even 4 times than those in Suli. The genus composition between sites was significantly different ($p<0.05$). The composition of substrate types among sites was not significantly different ($p>0.05$), however the composition of substrates correlated significantly with the composition of echinoderms genus ($p<0.05$, rho=0.36). In conclusion, more complex the substrate variation in an area will affect the diversity and abundance of Echinoderms community therein.

**Keywords:** Ambon-Maluku, Echinodermata, littoral area, spatial distribution

## INTRODUCTION

The assessment of biodiversity in the marine realms are important for understanding ecological patterns, ecosystem functioning, and conservation management, thus magnetize many ecologist, societies, conservationist and decisions maker. Other importance of biodiversity inventories are to detects, monitor, measures and estimates the fluctuation of diversity list and the implications of its changes to the ecosystem function (Iken et al. 2010; Wheeler et al. 2012).

Echinoderms are the crucial part of marine biodiversity because of its ecological role (Birkeland 1988; Iken et al. 2010; Lampe 2013). For example Holothuroidea is positive as a major bioturbator because they can increase the productivity of benthic microalgae and seagrass system and through their excretory physiology they also can increase local nutrients (Uthicke and Klumpp 1998; Uthicke 2001; Wolkenhauer et al. 2010; Jamieson et al. 2011; Costa et al. 2014; Wolfe and Byrne 2017) and potential to help buffer the effects of ocean acidification (Schneider et al. 2011; Schneider et al. 2013; Wolfe and Byrne 2017). Echinoidea as a herbivore has an important role in controlling the algal cover on hard substrates, and as a bioturbator (or their foraging behavior) they may play a key role as a limiting factor of reef growth (Bak 1994; Mokady et al. 1996; Carreiro-Silva and McClanahan 2001; Fjukmoen 2006). Some species of Asteroidea are a corallivore, their grazing activity can strongly influence the coral reef ecosystem structure and diversity (Yamaguchi 1986; Lane 1996; Wakeford et al. 2008). Ophiuroidea as a dominant taxon in Arctic region may account for a large portion of remineralization (Piepenburg et al. 1995; Ambrose et al. 2001).

Estimation number of echinoderms diversity over the world which already described is roughly 7.291 species, consist of Asteroidea is 1922 species, Echinoidea is 999 species, Ophiuroidea is 2.064 species, Crinoidea and Holothuroidea are 623 and 1.683 species, respectively (Appeltans et al. 2012). Data of Indonesian echinoderms diversity seem to scatter in specific location and most are about Holothuroidea. Supono et al. (2014) listed echinoderms species in Lembeh Strait, North Sulawesi, total species observed were 76 species; Setyastuti (2014) listed 23 species of echinoderms diversity in Nusa Laut Island, Central Maluku; Uneputty et al. (2017) observed 17 species of echinoderms of Ambon, Maluku. Other publications are about Holothuroidea, Massin (1996) enlisted 27 species from Ambon, Maluku; Massin (1999) enlisted 56 species from Spermonde, South Sulawesi; Setyastuti (2009) enlisted 9 species from West Seram, Maluku; Lane and Limbong (2013) successfully reviewed 28 species from Bunaken National Marine Park, North

Sulawesi. Those differences in number of taxa at each publication seem to correlate with different sampling methods they used. However, it is difficult to quantify because complete species inventories require extraordinary efforts (Longino et al. 2002; Shen et al. 2003) and there are undiscovered species in almost every taxonomic survey or species inventory (Shen et al. 2003).

Echinoderms samples were collected in Ambon Island (Figure 1) as part of the marine resources' inventories designed to study the biodiversity of Maluku Archipelago. The purpose of this works were to investigate the abundance and genus richness of echinoderms within the five sampling sites; two sites at outer of Ambon Island (Liang and Suli), three sites at Ambon Bay (Lateri, Halong, and Tanjung Tiram) using sampling technique of quantitative biodiversity assessment that we tried to expand from previous methodologies. Furthermore, this study also aimed to understand the relation of substrate type and community composition within those five sites.

## MATERIALS AND METHODS

### Study area

Liang and Suli beach are located in the outer side of Ambon Island, Maluku, Indonesia, but specific location of both sites are different. Liang beach is interrupted most by oceanic flow from Seram Sea. Suli, however, is located inside the Baguala Bay thus making the area more sheltered than Liang. As a fringing reef area, both sites are characterized by a very vast area of intertidal whereas mangrove, seagrass, and coral reef ecosystem is positioned in adjacent. By visual observation, it can be considered that seagrass density at Liang is lower than Suli. Substrates at Liang are mostly sandy bottom with a few boulders/rubble found. Otherwise, at Suli, the substrates composition are more complex than Liang, sandy bottom of which most areas are mixed with rubble and died corals. Seagrass species found at Liang are dominated by *Thalassia hemprichii,* and *Cymodocea rotundata*, whereas at Suli are *T. hemprichii* and *Enhalus acoroides*.

Halong, Lateri, and Tanjung Tiram are located in the inner of Ambon Bay thus making the current less heavy than Liang/Suli. Halong and Lateri have similar habitat characteristics such as spotty seagrass stands and sandy-muddy substrate. Seagrass species that found at Halong are *E. acoroides* and *T. hemprichii,* while at Lateri is only *E. acoroides.* The intertidal area is approximately less than 100 m perpendicular to the slope. Furthermore, only a few boulders are found at these sites. On the contrary, Tanjung Tiram has a very vast intertidal area as Liang and Suli. Seagrass meadow, sandy, rubble, and boulders bottom are dominance characteristic at the site. *E. acoroides* is the most dominant seagrass species herein.

### Procedures

*Sampling technique*

The fieldwork took place four days during two weeks period in late March and early April 2014 at five sites, two sites at outer of Ambon Island (Liang and Suli beach), three sites at inner Ambon Bay (Lateri, Halong, and Tanjung Tiram beach) (Figure 1). Investigation on echinoderm diversity and abundance used single transect orthogonal to the coast at each site. Each transect consisted of 10-quadrat plot of 5x5m, the distance between plots was 10m. Sampling was conducted during the low tide to get the better view while inventories the echinoderms benthic community. Each individual found within the plot was noted and identified up to genus level using taxonomy references (Rowe 1969; Clark and Rowe 1971; Massin 1996; Vandenspiegel et al. 1998; Massin 1999; Albuquerque et al. 2001; Massin et al. 2002; Purwati and Lane 2002; Fujita and Marsh 2004; Samyn et al. 2006; O'louglin and Rowe 2006; Clark and Jewett 2010; Clark and Jewett 2011; Kim et al. 2013; O'Loughlin and Birbiesca-Contreras 2015). Furthermore, substrates that classified into four types (sea-grass, macro-algae, sand, rocks, and/or dead coral) at each plot were also noted by presence/absence mark.


**Figure 1.** Study sites in Ambon Island, Maluku, Indonesia. 1. Liang, 2. Suli, 3. Halong, 4. Lateri, 5. Tanjung Tiram

**Data analysis**

Since the transect result at Lateri and Halong sites were nil, data analyses included differences in total abundance, genus richness, and genus composition of echinoderms was applied only for three sites, i.e. Liang, Suli, and Tanjung Tiram beach. The composition of substrate types among those sites was also analyzed based on the binomial data, i.e. absent (0) and present (1).

The differences in total abundance and genus richness among those sites were analyzed using an Analysis of Deviance following a Generalized Linear Models (GLMs) fitted by Poisson and log link. A GLMs was used because the data were count data with a lot of zero (Crawley 2015). Pairwise tests were also done to analyses which sites that differ significantly in total abundance and genus richness ($p<0.05$).

In term of genus composition, the data were visualized using a Principal Coordination Analysis (PCoA) plots calculated from Bray-Curtis dissimilarity based on the log (x+1) transformed abundance data. The differences in genus composition among study sites were analyzed using a Per-mutational Multivariate Analysis of Variance (PERMANOVA) calculated from Bray-Curtis dissimilarity based on the log (x+1) transformed abundance data with 999 permutations. A log (x+1) transformation was used because the data variance was higher than those mean (Bakus 2007). Pairwise tests were also conducted to analyses which sites that differ significantly in genus composition ($p<0.05$). The genus contributing to those differences was determined based on the genus vector that had significant correlations with both axes of PCoA plots (i.e. PCO1 and PCO2) ($p<0.05$) and the value of rho >0.6 according to Spearman correlation tests.

Similarly, the composition of substrate types among study sites was also visualized and analyzed using a PCoA and a PERMANOVA, respectively, but those were calculated from Bray-Curtis dissimilarity based on the binomial data. The correlation between genus composition and substrate composition was then analyzed using a Mantel Test for Dissimilarity Matrices.

Data analyses and visualizations were performed using R software (*https: //www.r-project.org*) using various packages. The package of vegan was used to perform PCoA, PERMANOVA, and Mantel Test (Oksanen et al. 2016), while the package of ggplot2 was used to visualize the data (Wickham 2009).

## RESULTS AND DISCUSSIONS

**Results**

A total of 910 individuals of echinoderms belonging to 19 genera were observed in this study. Table 1 present the list of genus obtained at each site except Halong and Lateri which null result. The total abundance of echinoderms was different significantly among sites ($p<0.05$). The most abundant echinoderms that were collected from Tanjung Tiram approximately 68.71 individuals/quadrat, which was almost 1.4 times than those in Liang and even 4 times than those in Suli (Figure 2.A). However, the genus richness was not significantly different among sites ($p>0.05$), around 3-5 genera/quadrat (Figure 2.B).

In term of genus composition, the PCoA plots represented 39.37% of total variations, i.e. PCO1 (23.37%) and PCO2 (16.00%) (Figure 2.C). PERMANOVA and Pairwise tests showed that the genus composition between sites was significantly different ($p<0.05$). Genera contributed to those differences were *Bohadschia*, *Ophiocoma*, and *Synapta*, while *Bohadschia* was only found in Tanjung Tiram. *Ophiocoma* was absent from this site but abundant in Liang. *Synapta* was abundant in both Tanjung Tiram and Liang, but few in Suli (Figure 2.E).

Compared to the genus composition, the PCoA plots represented more variations in the composition of substrate types, about 91.99% of total variations, i.e., PCO1 (91.52%) and PCO2 (0.47%). The composition of substrate types among sites was not significantly different ($p>0.05$) (Figure 2.D). However, the composition of substrates correlated significantly with the composition of echinoderm genera ($p<0.05$, rho= 0.36). The presence of seagrass, rock, and dead corals increased the diversity and abundance of echinoderms in the Ambon Bay.

**Table 1.** Genus distribution at each site in Ambon Island, Maluku, Indonesia

| No. | Genus | Liang | Suli | Tanjung Tiram |
|---|---|---|---|---|
| **Class Holothuroidea** | | | | |
| 1 | *Actinopyga* | - | - | √ |
| 2 | *Bohadschia* | - | - | √ |
| 3 | *Holothuria* | √ | √ | √ |
| 4 | *Stichopus* | - | - | √ |
| 5 | *Synapta* | √ | √ | √ |
| 6 | *Opheodesoma* | √ | - | √ |
| | | | | - |
| **Class Asteroidea** | | | | |
| 7 | *Culcita* | √ | - | - |
| 8 | *Linckia* | √ | - | - |
| 9 | *Protoreaster* | - | √ | - |
| 10 | *Archaster* | - | - | √ |
| | | | | - |
| **Class Ophiuroidea** | | | | |
| 11 | *Ophiocoma* | √ | √ | - |
| 12 | *Ophiarachnella* | √ | - | - |
| 13 | *Macrophiotrix* | √ | - | - |
| 14 | *Ophiolepsis* | √ | - | - |
| | | | | - |
| **Class Echinoidea** | | | | |
| 15 | *Diadema* | √ | √ | √ |
| 16 | *Echinometra* | √ | √ | - |
| 17 | *Echinotrix* | - | - | √ |
| 18 | *Mespilia** | - | - | √ |
| 19 | *Tripneustes** | - | - | √ |
| Total genus | | 11 | 6 | 11 |

Note: √: present, -: absent; *free handpicking collection/not in the transect plot

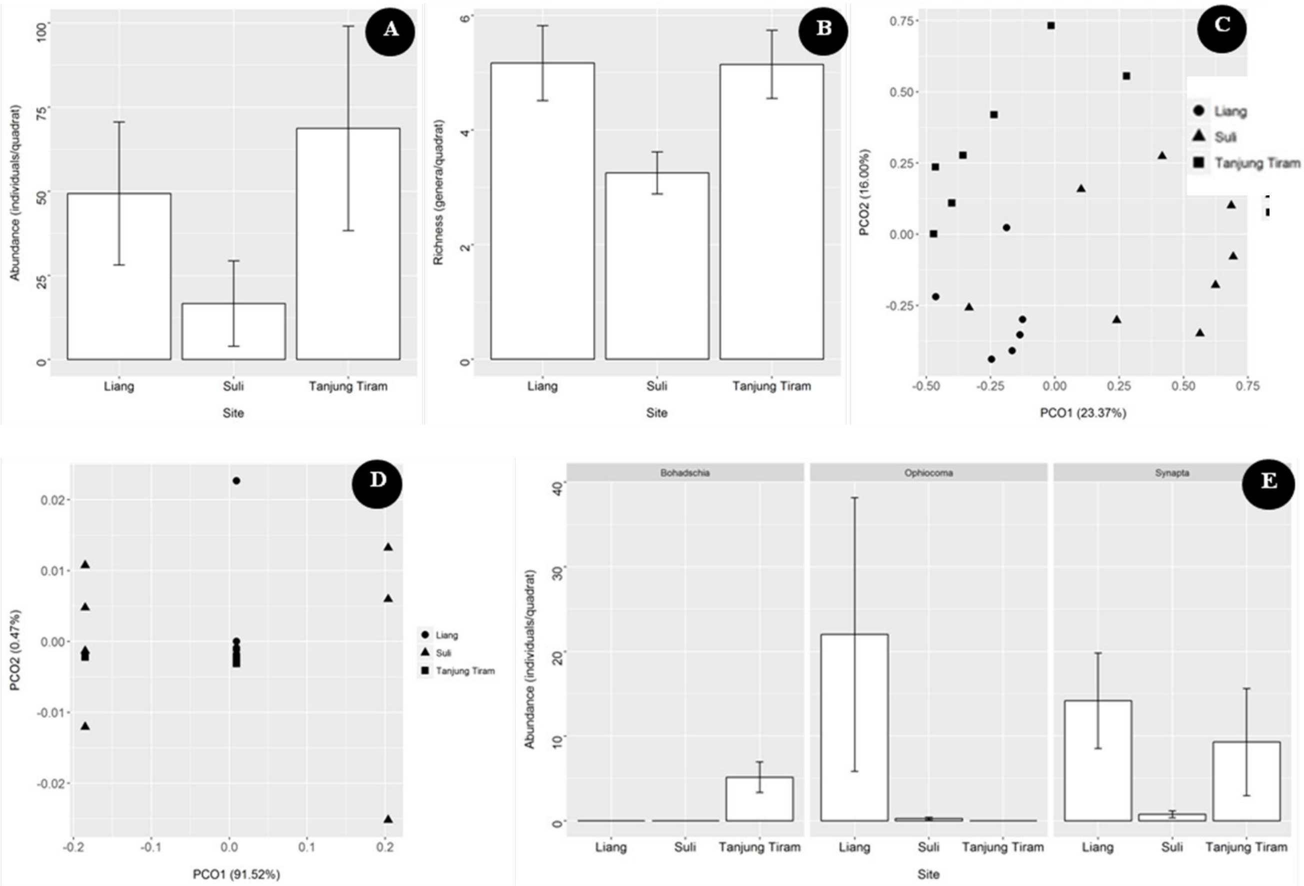


**Figure 2.** A. Total abundance of echinoderms among study sites; B. Genus richness of echinoderms among study sites; C. The ordination of genus composition of echinoderms among study sites; D. The ordination of the composition of substrate types among study sites; E. The distribution of genus contributed to differences in genus composition among study sites

Total abundance of echinoderms was different significantly among sites ($p<0.05$). The most abundant echinoderms were collected from Tanjung Tiram approximately 68.71 individuals/quadrat, which was almost 1.4 times than those in Liang and even 4 times than those in Suli (Figure 2.A). However, the genus richness was not significantly different among sites ($p>0.05$), around 3-5 genera/quadrat (Figure 2.B).

## Discussion

Tracing on publications of echinoderms diversity and density in the intertidal zone or shoreline specifically showed that the methodology used for the sampling were varied. Several publications used standardized protocols of the Census of Marine Life NaGISA program (Natural Geography in Shore Areas, www.coml.nagisa.org), of which transect perpendicular to the coast by using 5-10 plot of 0.0625 $m^2$ (Chenelot et al. 2007; Iken et al. 2010; LIacuna et al. 2016). While other publications used line transect/belt transect of 40 x 40 m /10 x 10 m/50 x 2 m along the beachside or perpendicular to the coast (Massin and Doumen 1986; Darsono et al. 1998; Hasan 2009; Selano et al. 2014; Uneputty et al. 2017). The others used quadrat transect of 0.5 x 0.5 m/1 x 1 m perpendicular to the coast (Yusron 2003, 2003b; Dobo 2009). Each methodology has its own justification. However, the pluses and minuses of each methodology are inevitable. This study tried to expand the methods, considering the middle efforts compare to previous different methods by using the transect plot of 25 $m^2$ perpendicular to the coast.

Out of five sites location, two sites (Halong and Lateri) were excluded from the statistical analyses because of no echinoderms found during the survey. Several causes to explain it could be the habitat condition does not support anymore for the sustainable living of echinoderms. Based on visual observation, the sedimentation occurred in those two areas making the bottom substratum covered most by mud. Moreover, liquid anthropogenic waste from the village surrounding is also recorded very high. At those two areas, we could not find any boulders/rubbles/corrals, and only a few *E. acoroides* stands noted, as ecologically common known either boulders or seagrass stands worthwhile beneficially as shelter area and nutrient trapping respectively (Hereu et al. 2004; Entrambasaguas et al. 2008). The composite of those factors is possibly making the sites not suitable anymore for echinoderms to live, and this condition shows the declining of habitat quality compared to many previous publications that still recorded several echinoderms species on those areas (PPLD-LIPI 2014). However, this kind of habitat degradation may also lead to declining of food supply and the capability of recruitment that affected the patchiness of marine organism (Chenelot et al. 2007).

During the study, we only observed four classes out of five extant classes of Echinodermata, i.e., Holothuroidea, Echinoidea, Asteroidea, and Ophiuroidea. The absence of class Crinoidea is no clear reason. However, from the point of view of habitat preference, it could be a consequence of its habitat restrictions related to food resource and attachment to the stratum that affected it anatomy adaptation (Ausich 1980; Entrambasaguas et al. 2008). Since crinoid itself is an animal group that eats plankton from seawater and nocturnal, it makes them prefer to live in the area with persistent currents such as in the floor of deep sea or coral reef ecosystem (Meyer 1976; Ausich 1980; Kirkendale and Messing 2003). However, several publications noted that crinoid species in Indonesia or the world usually recorded not in the exposed water/shoreline (Clark and Rowe 1971; Meyer 1976; Ausich 1980; Messing 2007).

Genus richness was not significantly different among sites ($p<0.05$) (Figure 2B). Tanjung Tiram and Liang showed the same number of genus diversity even their composition was totally different (Figure 2.C, 2.E). Tanjung tiram and Liang possessed 11 genera each, of which four genera were the same (*Opheodesoma, Synapta, Holothuria,* and *Diadema*). Other genera such as *Bohadschia*, *Actinopyga, Echinothrix, Archaster, Stichopus, Mespilia,* and *Tripnesuates* were exclusively only on Tanjung Tiram. However, statistical analysis showed that genus contributed to those genus composition differences were *Bohadschia*, *Ophiocoma*, and *Synapta* (Figure 2.E). While *Bohadschia* was only found in Tanjung Tiram, *Ophiocoma* was absent from this site but abundant in Liang. *Synapta* was abundant in both Tanjung Tiram and Liang but few in Suli. These findings showed that several genera might have their specific microhabitat preference because different genus responds differently to environmental drivers that contribute to some of the disparate patterns (Iken et al. 2010). However, no single environmental variable was the sole driver. The more complex the habitat in the sites the more favorable places for more organism to live in, since it will provide more places for recruitment, food supply, and shelter from the predator. These findings also supported by the correlation analysis of genus richness and substrates composition at each sites using PcoA that resulted in the composition of substrates correlated significantly ($p<0.05$, rho=0.36) with the composition of echinoderm genus which means that the presence of seagrass, rock, and dead corals increased the diversity and abundance of echinoderms in the Ambon Bay.

Our data showed that total abundance among three observed sites was different significantly ($p<0.05$), of which Tanjung Tiram was the most abundant and then Liang and Suli afterward (Figure 2.A). In Tanjung Tiram was successfully observed 481 inds. echinoderms, meanwhile in Liang and Suli noted about 296 and 133 inds., respectively. Out of those, the highest individual number in Tanjung Tiram was genus *Diadema* (306 inds.). Thoroughly investigation showed that most of this genus individually captured in the area near the slope where the substrates were mostly rubble, coral/dead coral, and algae. This finding supports the information about specific microhabitat of *Diadema* as a herbivore of algal turf that is usually covering the hard substratum (Bak 1994; Aziz 1996; Fjukmoen 2006). It also strengthens the result of (Bechtel et al. 2006) that the presence of *Diadema* is instrumental in initiating the transition from algal to the coral-dominated reef since our result noted that most of its aggregation individuals were discovered on the transition area of seagrass bed and coral reef ecosystem. 

Some notes that we can conclude from our research are: (i) patchily distribution of echinoderms as a megabenthic community is commonly known. Our present results generated the same things, that was in our two sites (Lateri and Halong) did not contain any echinoderms. However, the causes of this patchiness can be numerous, including the physical environment (such as the habitat changing that obviously seen in those two sites because of environmental damage caused by water pollution, sedimentation, and liquid household waste). This kind of condition may lead to habitat degradation that could interrupt the food supply, recruitment process, and shelter area. Another reason might be related to the cryptic behavior of certain species. (ii) Abundance and species richness of echinoderm are correlated significantly with substrate composition. More diverse the substrate composition, more abundance the individual and more varies the diversity of echinoderms will be recorded. 

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