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Mapping of Sea Urchin Abundance as Control of Algae Expansion for the Balance of Coral Reef Ecosystem in Karimunjawa Islands

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ABSTRACT

This study was intended to determine the amount and distribution of sea urchin abundance, algae biomass, percentage cover of corals and zooxanthellae density, and to determine suitable areas of sea urchin abundance as control of algae expansion in Karimunjawa Islands. The study was conducted in May 2016 at 3 stations, i.e. I. Cultivation Zone (Kemujan Island), II. Utilization and inhabited Zone (Karimunjawa Islands), and III. Tourism Zone (Menjangan Kecil Island). A quantitative survey method was used. The results showed that Station I, Kemujan Island, had the lowest sea urchin abundance (21-90 ind/m^2), the highest algae biomass of approximately 0-1,98 gr/m^2, predominantly dead corals and fragments, as well as a high zooxanthellae density. Station III, Menjangan kecil Island, had the highest sea urchin abundance (39-570 ind/m^2), the lowest algae biomass of 0-0,954 gr/m^2, mainly live corals, seagrass and sand meadows; also the lowest zooxanthellae density. The most suitable areas of sea urchin abundance as control of algae expansion in Karimunjawa Islands are station III, Menjangan-kecil Island. This result can be indicator of coastal environmental health and known as the important part of ecosystem that have significant influence of coral.
KEYWORDS: Sea Urchin; Abundance; Algae; Coral Reef; Karimunjawa Islands.

INTRODUCTION

Karimunjawa Marine National Park is located in the Sea which is ± 45 nautical miles from the city of Jepara, including into the administrative area of Karimunjawa District, Dati II Regency of Jepara. Overall it is located between 5 '40 "- 5' 57" LS and 110 '4 "- 110' 40" BT, which has an area of 111,625 Ha, consists of a land area of 7,033 Ha and a news area of 104,592 Ha [1], [2], [3]. One of the important ecosystems in Karimunjawa waters is the coral ecosystem, ecologically useful as nursery ground, feeding ground and spawning ground for various types of fish and marine invertebrates [2]. Coral reefs are marine ecosystems in tropical marine life constructed by the producer of lime in particular species of stony corals and calcareous algae [4]. Coral reef ecosystems from 1991 to 2009 in Karimunjawa Islands have been degraded due to human activities [5]. Also states that numerous human activities on land bring about negative impacts to the marine ecosystems, especially coral reefs [6]. Mentions that high nutrient contents of coral reef ecosystem lead to the growth of macroalgae in place of the corals [7]. Coral reefs are known to have high nutrients from the nitrogen and phosphorus generated and circulated by bacteria and producers [8][9]. As a result of the aforementioned factors, coral reef ecosystems have been in decline [10]. State that one issue that threatens the existence of coral reefs is waste dumped into coral ecosystems [11]. A good coral reef ecosystem has high nutrients that can stimulate the rapid growth of macroalgae, causing coral communities to be replaced by algae and increases sea urchin abundance[12].

Annual rates of change in coral cover and complexity do not covary, and levels of complexity vary greatly among reefs with similar coral cover [13]. Affirms that poor coral reef condition lead to a decrease of biota variety but an increase in sea urchin abundance. Sea urchin abundance is inversely proportional to the condition of coral reef ecosystems and it could hinder algae expansion. Areas with poor coral reef condition have low sea urchin abundance, consequently raising algae expansion which leads to eutrophication, and vice versa [14][15]. Sea urchins are one of the key species of coral reef ecosystems, because they control the population of macroalgae species. There is a mutually beneficial relationship (mutualistic symbiosis) between sea urchin abundance and coral reefs because the sea urchin Diadema antillarum grazes algae within the ecosystem, thus it can be assumed that sea urchins are indicators of the balance of coral reef ecosystems [16]. The sea urchin Diadema antillarum was the most important herbivore on Caribbean reefs until 1983, when mass mortality reduced its populations by more than 97%

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[17]. Mass death of the sea urchin The antillarum diadema of the plague in 1983 and 1991 affected the balance of coral ecosystems [18][19].

Found that in Legon Boyo waters, Karimunjawa islands, sea urchin abundance was higher on live corals (228;116 ind/150 m^2) in comparison to other substrates, such as dead corals, coral fragments, and sand, with an abundance of 60;25 ind/150 m^2, 118;47 ind/150 m^2, 10;5 ind/150 m^2 [20]. The types of sea urchins commonly found in Karimunjawa islands are *Diadema setosum, Diadema antilarum, Echinothrix calamaris , Mespilia globulesa,* and *Echinometra mathaei* [20],[14]. Percentage cover of corals in Pancuran Belakang Karimunjawa was classified as fair (55.29%), with the dominant sea urchin species being *Diadema setosum* [21].

This study is very important because coral reef ecosystem is a complex ecosystem and has a high aesthetic value, and is a habitat by several types of echinoderms that are dominant coral reef residents [22], [23], but some types of sea urchins such as *Diadema setosum* are predators for coral reefs [24], but populations *Diadema antilarum* on Caribbean coral reefs can help restore coral conditions [19]

The objective of this study is to determine the amount and distribution of sea urchin abundance, algae biomass, percentage cover of corals and zooxanthellae density in Karimunjawa Islands, and to determine suitable areas of sea urchin abundance as control of algae expansion in Karimunjawa Islands.

MATERIALS AND METHODS

The study was held on May 13-16th, 2016 and May 27-30th, 2016. Research sites were determined based on zones of Karimunjawa islands, with the sampling stations classified into three stations: I. Cultivation Zone at Kemujan Island, II. Utilization and inhabited Zone at Karimunjawa Island, and III. Tourism Zone at Menjangan Kecil Island.

Each observation stations were divided into three plots, with each plot placed at the depth of where the coral reef ecosystems reside, representing the condition of respective sites. Map of research site is described in Figure 1.

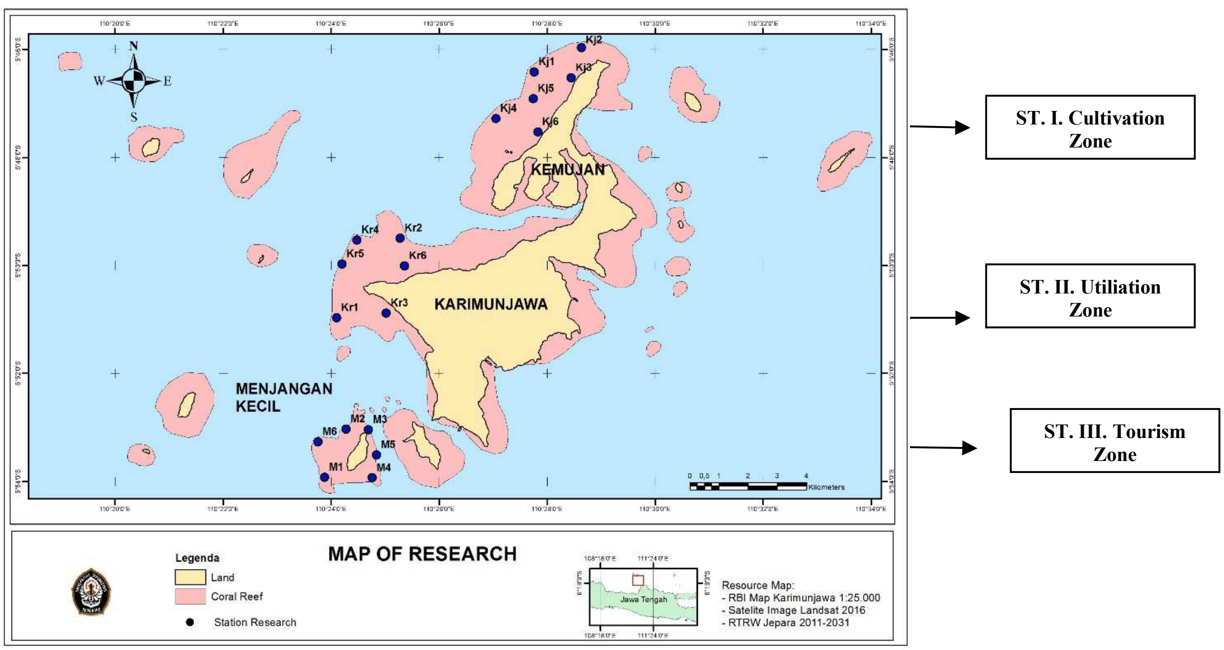


Figure 1. Map of Research Sites

Data Analysis

a. Sea urchin abundance and coral reefs

Sea urchin abundance was measured by direct observation. Coral cover is usually determined on each transect using the percent coral cover equation by [25]. In this study, however, percent coral cover was gauged by Landsat imaging data through Lyzenga analysis [26].

b. Algae biomass of coral reef ecosystem

Algae biomass of coral reef ecosystem is defined as the average dry weight (gr) of biomass for each area of growth site (cm^2) per days of coral algae inhabit in the live coral ecosystem, calculated by means method [27]. Manual analysis was done with images generated by *Image J* software that can provide a score of the area of algae cover (cm^2).

c. Spatial overlay of the observed variables

Each of the measured parameters: sea urchin abundance, algae biomass and percentage cover of corals were analyzed spatially using ArcGIS software by a weigh overlay method. The method is applied to make new layers from a combination of several layers (a combination of several observed variables) [28]

RESULTS AND DISCUSSION

General Description of Research Sites

Karimunjawa Sea National Park is located in the Java Sea waters, approximately 45 nautical miles from Jepara City, and is a part of Karimunjawa sub-district administrative region of Jepara Regency. Geographically, it is positioned between 5' 40" - 5' 57" south latitude and 110' 4" - 110' 40" east longitude, and has an area of 111,625 Ha which consist of 7,033 Ha land and 104.592 Ha water [1];[29]

Research sites were split into three stations according to the degree of utilization of coral reef ecosystem and zoning in Karimunjawa Islands, as following:

a. Station I in Kemujan Island, as an area of utilization of waters, became the cultivation zone. Lands of Kemujan Island are mangrove forests as wide as 194.234 Ha. Based on Inventorying the Distribution of Mangrove in Karimunjawa National Park Program in 2002, it is located at 5º46'24" – 5º59'16" S; 110º26'55" – 110º29'38" E. [3].

b. Station II was set in Karimunjawa Island which was the area of coral reef ecosystem waters and became the utilization zone since it was used for tourism and people's residence. Karimunjawa Island is the largest island of the archipelago, inhabited by up to 8,150 people; and has an area of 3,637.21 Ha which comprised of 2,215.31 Ha of land and 1,421.90 Ha of waters. It is geographically positioned at 5º49'33"-5º48'23" S; 110º24'34"-110º28'37" E. [1]

c. Station III is in Menjangan Kecil Island. The coral reef ecosystem waters of tourism zone in Menjangan Kecil has an area of 46 Ha. The white-sand beaches were formed from coral fragments. The waters around Menjangan Kecil Island was the collection site for data and samples of *Acropora sp* corals in this study. It is dominant in tropical waters, easily grows, and has high resistance for environmental changes. This station is situated at 5^0 53' 15.06"S and 110^0 24' 26.35"E [3]

Observed variables

The results of this study were divided into 3 stations with different location that is station 1 at Kemujan Island, station II di Karimunjawa Island and station III at Menjangan Kecil Island. Samples were taken twice from each station at three plots, first sampling was on May 13-16th, 2016 whereas the second sampling was on May 27-30th, 2016; generating a total of six data for each station. The results from the measurement of observed variables namely sea urchin abundance, algae biomass and zooxanthellae density are presented in Table 1.

Table 1. Results on Measurements of Observed Variables

Station	Sea urchins	Algae	Zooxanthellae
I.1	21	1.4776	19.27282
I.2	55	1.98	62.76489
I.3	33	0.483	40.85973
I.4	36	1.3	36.54409
I.5	65	0.3784	46.08132
I.6	90	0	27.29385
II.1	132	0	38.34694
II.2	87	1.866	35.10548
II.3	92	0	38.75544
II.4	64	0.5	45.18508
II.5	224	0	53.88309
II.6	296	0	44.44684
III.1	570	0	35.19081
III.2	39	0	54.84003
III.3	126	0	52.46928
III.4	62	0	44.66067
III.5	75	0	93.98762
III.6	86	0.954	82.25999

a. Sea urchin abundance

Results on sea urchin abundance are displayed on Figure 2.

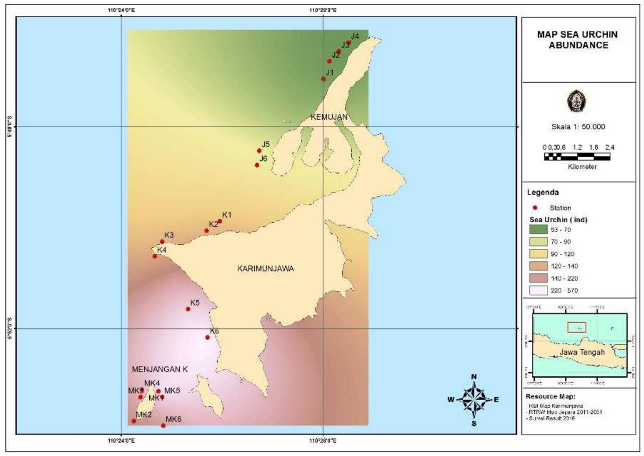


Figure 2. Sea urchin abundance at Karimunjawa

The results on sea urchin abundance (Figure 2) showed that station I Kemujan island had the lowest sea urchin abundance of about 21-90 ind/m^2, whereas the highest sea urchin abundance was found in Station III Menjangan Kecil island, having around 39-570 ind/m^2. In station II Karimunjawa Island, the sea urchin abundance was considered moderate with approximately 64-296 ind/m^2. Station I had the lowest sea urchin abundance because it is a cultivation zone. Moreoever, station I Kemujan Island also had low algae biomass. On the other hand, station III Menjangan Kecil islands was discovered to have the highest sea urchin abundance, for the island has undergone coral reef transplantation from BTNKJ on 2008, in addition to being well-managed for tourism. The island had low algae biomass as well. Theoretically, the habitat of sea urchins is within coral reef ecosystems. Sea urchin abundance in that station was categorized as "fair" because Karimunjawa islands is a part of tourism zone and has inhabitants.

b. Algae biomass

Results on algae biomass are presented in Figure 3. The results on algae biomass (Figure 3) showed that the lowest algae biomass was found at station III Menjangan Kecil Island, only up to 0-0.954 gr/m^2. In contrast, station I Kemujan Island had the most algae biomass of about 0-1.98 gr/m^2. The distribution pattern of algae biomass was inversely proportional with the distribution pattern of sea urchin abundance, owing to algae being foodstuff for sea urchins.

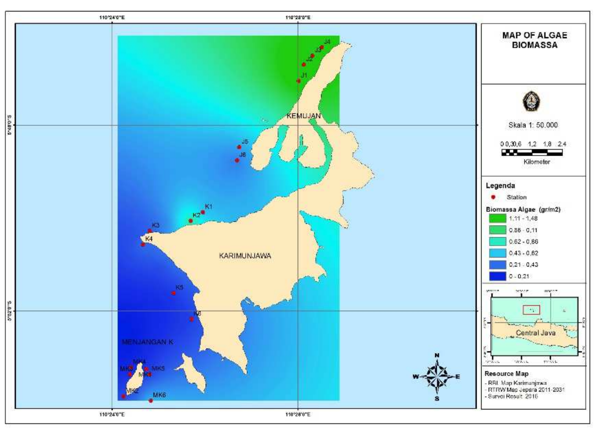
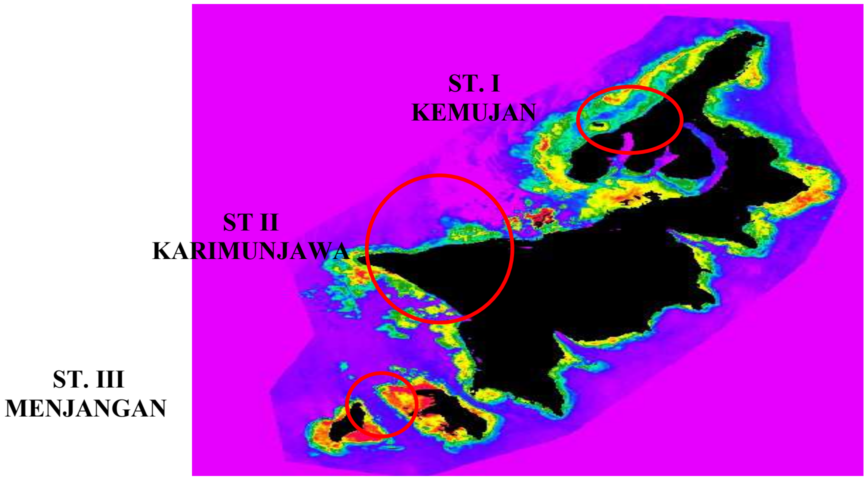


Figure 3. Algae biomass at Karimunjawa Islands

c. Percentage cover of corals

Results on percentage cover of corals that was calculated with lyzenga algorithm combination and 80% accuracy using lands at imaging of Karimunjawa islands are displayed in Figure 4.

Based on the interpretation of coral cover at research sites (Figure 4), station II Karimunjawa Island as the utilization zone has several coral reef surface covers that consisted of live corals, dead corals, coral fragments, seagrass meadows, and sand; with live corals and seagrass meadows being the dominant biota. On station III tourism zone, there were live corals, dead corals, coral fragments, seagrass meadows, and sand, it was mostly live corals, seagrass meadows, and sand. In contrast, station I of cultivation zone was mainly dead corals and coral fragments.



Notes: Interpretation keys 1. Light green: live corals; 2. Dark green: dead corals; 3. Yellow: coral fragments; 4. Orange: seagrass meadows; 5. Red-pink: sand; 6. Black: land

Figure 4. Percentage Cover of Corals at Karimunjawa Islands

Coral reef surface covers are habitats to sea urchins and become a proving point of the theory that states good coral reef ecosystems with high nutrients may stimulate rapid growth of macroalgae, further leading to a shift in community from coral communities into maroalgae and increased sea urchin abundance. This is due to sea urchin abundance at coral reef ecosystem that functions to maintain balance and is a form of a mutualistic symbioses relationship.

The implications of these changes for reef-associated human activities, such as fishing and tourism, can be substantial [30].

d. Zooxanthellae density

Results on zooxanthellae density are described in Figure 5. As shown by Figure 5, the lowest zooxanthellae density was found at Station III Menjangan Kecil Island, whereas the highest density was at station I Kemujan Island. Density of zooxanthellae in the study sites in good category, it will have an impact on the distribution of algae that will affect the extent of coral cover. This is in accordance with the statement zooxanthellae is strongly associated with primary production in reef ecosystems and coral polyps can also form algae biomass [31],[32],[33],[34]. The distribution pattern of zooxanthellae density was the same as the distribution pattern of algae biomass [6],[35]. Density of zooxanthellae and chlorophyll, strongly associated with algae abundance and will affect coral conditions [36],[37].

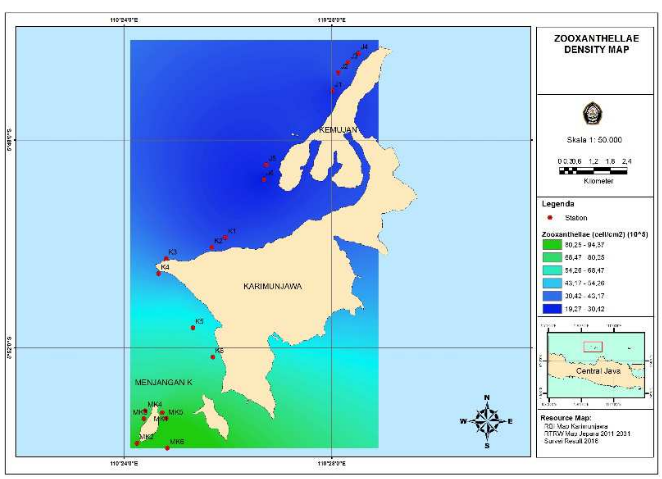


Figure 5. Zooxanthellae Density at Karimunjawa Islands

e. Spatial overlay of the observed variables

The observed variables, i.e. sea urchin abundance, algae biomass, percentage cover of corals and zooxanthellae density were combined (overlay) using weigh overlay analysis into a map of sea urchin abundance as a control of algae expansion, as presented in Figure 6.

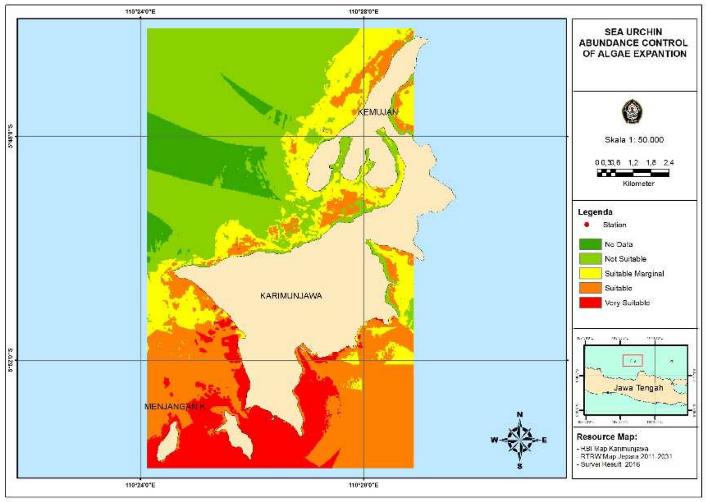


Figure 6. Map of Sea Urchin Abundance as Control of Algae Expansion

The result of overlaying the observed variables by ArcGis software (Figure 6) showed that sea urchin abundance as control of algae expansion at Karimunjawa islands was at Station III Menjangan Kecil Island, whereas at Station I Kemujan Island and Station II Karimunjawa Island, it was considered relatively suitable and it fit the marginal. it is in accordance with opinion [38] In the Caribbean states, Diadema appears to be effective in increasing the recruitment and growth of scleractinian corals and can be used as an important manipulative tool to restore coral reefs. [39] sea urchin Diadema antillarum reduces algae cover and enhances coral recruitment.

CONCLUSION

It can be concluded from this study that that Station I Kemujan island had the lowest sea urchin abundance (21-90 ind/m^2), the highest algae biomass of about 0-1,98 gr/m^2 that was predominantly dead corals and coral fragments, and had high zooxanthellae. Conversely, Station III Menjangan Kecil Island had the highest sea urchin abundance (39-570 ind/m^2), the lowest algae biomass of around 0-0.954 gr/m^2 that was mainly live corals, seagrass meadows, and sand; as well as the lowest zooxanthellae density. The most suitable area to apply sea urchin abundance as control of algae expansion at Karimunjawa islands was at Station III Menjangan Kecil Island, whereas at Station I Kemujan Island and Station II Karimunjawa Island, it was considered relatively suitable and it fit the marginal. The relationship between the abundance of sea urchins, Percentage cover of Corals and algae is mutualism so that if one of them in unstable condition it will affect the condition of the ecosystem in it.

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