Spatial Structure Analysis of Benthic Ecosystem Based on Geospatial Approach at Parang Islands, Karimunjawa National Park, Central Java, Indonesia

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Spatial Structure Analysis of Benthic Ecosystem Based on Geospatial Approach at Parang Islands, Karimunjawa National Park, Central Java, Indonesia

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Abstract

This research examines the spatial structure of live coral based on its patches on a geospatial data. Spatial structure is a part of the landscape ecology approach that has been applied on terrestrial and applied on marine ecosystems on this research. It is including Mean Shape Index (MSI), Number of Patches (NumP), Mean Patch Size (MPS), Total Seascape Area (TLA) and Class Area (CA). Live coral patches were extracted based on GeoEye-1 satellite image with several tasks, such as ortho-rectification, atmospheric calibration, water column correction; Lyzenga transform and supervised classification. A field survey was done in 2015 - 2016 with 38 verification sites and 16 sites of manta tow. Live coral patches produced a significant accuracy (overall accuracy=84.1%, user accuracy= 81.8%, producer accuracy = 90%, and Kappa Index k = 0.81%). Live coral was found 35% (CA: 201.99 ha) of seascape TLA area 814.19 ha and spread over a large number of patches (NumP: 5613-21087 patches). The live coral had a mean shape index (MSI) between 1.23 to 1.25 and the average size of patches (MPS) between 0.0029 - 0.0082. This approach could be applied to reef ecosystems and becomes a baseline data to anticipate future damage.

Keywords: *Spatial structure, benthic ecosystem, patches, live coral, and Karimunjawa*

INTRODUCTION

Coral reef ecosystems scattered across the world's coral reef triangle are under serious threats and anthropogenic is identified as the main issue of such damage (Burke et al., 2012). The threat of this damage is influenced by the climate change impact (Sunaryo, et al. 2018), especially the rise in sea surface temperature that affects the coral bleaching. In Indonesia, the status of coral reef condition shows that 60% is severely damaged (LIPI, 2107). Parang and Kumbang islands are part of Parang Island consist of coral reef ecosystems that form an ecological unity. Parang Islands of Karimunjawa Islands National Park has extensive coral reef ecosystem (Helmi et al, 2018a). Residents already live in this area before the national park establish. Most of the inhabitants depend on coral reef ecosystems for fishing, aquaculture, tourism, sailing and marine transport (Helmi et al, 2018b). The mapping of reef ecosystems is done periodically to determine the existing status and extent of damage as a basis for planning and management in the region. This research aims to 1) conduct a mapping of variations of shallow water habitats existing in coral reef ecosystems; 2) to examine the coral reef ecosystems covering percent live coral cover and spatial structure of living corals; and 3) trends in sea surface temperature rise and the potential for coral bleaching. Shallow water habitat mapping is conducted using GeoEye-1 multispectral satellite data with 1.8m x 1.8 m resolution that has not been done before. Data collection existed give information about

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status of live coral cover and quantitative coral reef structure with ecological landscape approach. Implementation of the landscape ecology approach to coral reef ecosystems is the novelties of this study. The landsc structure is part of an ecological characteristics based on a strongly spatial form of an ecosystem (McGarigal and Marks, 1995). The landscape spatial structure applied are Total Sescape Area, CA (Class Area), MSI (Mean Shape Index), NumP (Numb of Patches), MPS (Mean Patch Size). A detailed map of shallow water habitats, quantitative spatial structures of living coral reefs and rising sea surface temperature trends are becoming complementary data collection of coral reefs that have not been integrated previously.

DATA AND METHOD

Digital satellite data processing was performed for radiometric correction (Weragodathenna et al., 2000; Werdell et al., 2003; and Reshitnyk et al., 2014). Rectification for geometric cor tion was done using Polynomial and Nearest Neighbor methods (Lillesand and Kiefer, 9 94; Pineda et al., 2005; and Hamylton et al., 2011, Hartoko, et al., 2016, and Satriadi et al., 2018). To improve the visual display quality of satellite data, we used the Contrast Enhancement Method, Composite Color and Image Data Fusion.

Coral reef ecosystem mapping was conducted using a water attenuation model for water column correction (Mumby et al., 1998; Kabiri et al., 2014; El-Askary et al., 2014; and Wahidin, et al., 2015), the Lyzenga Transform Method to highlight the spectral response of shallow water substrate (Lyzenga. 1978) and Green et al. 2 0). Shallow water ecosystem mapping was performed using Supervised Classification Method (O'Neill et al., 2013; Mustapha et al., 2014; Valle et al., 2015, and Setyawidati, et al., 2017) and contextual editing (Green et al. 2004).

Manta tow survey was carried out at 16 locations to verify the results of the mapping and to determine the condition of coral reefs. Manta Tow was conducted using two minute observations, visibility 10-12m, a speed of 1.5 knots, parallel observations on the reef crest and reef slope (Munasik. 2009). Accuracy tests of shallow coral reef ecosystem (Green et al. 2004) used the Confusion Matrix and Kappa Index methods.

Confusion Matrix is an objective method and accuracy because the accuracy can be obtained overall and each accuracy of object that was mapped (Sutanto. 2013). Kappa index is discrete multivariate techniques to study accuracy using statistical analysis Khat (Cohen, 1960 in Sutanto, 2013) with the following algorithm.

$$K = \frac{N\sum_{i=1}^{r} x_{ij} - N\sum_{i=1}^{r}(x_{i+}.x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+}.x_{+i})}$$

Where:

r	= Number of lines in the confusion matrix
x_{ij}	= Number of observations on the first line and on the main diagonal
x_{i+}	= Number of observations on the first line (the number of right edges of the matrix)
x_{+i}	= Number of observations in the strip I (the number at the bottom of the matrix)
N	= The total number of observations (pixels) on the matrix (the number in the lower right corner)

K value is between 0 -1. If both accuracy value of each be close to 1, imply the possibility of such accuracy occurred by chance is 0 (not purely coincidental). If the negative value of K obtained, that means the mapping and modeling produced is very poor.

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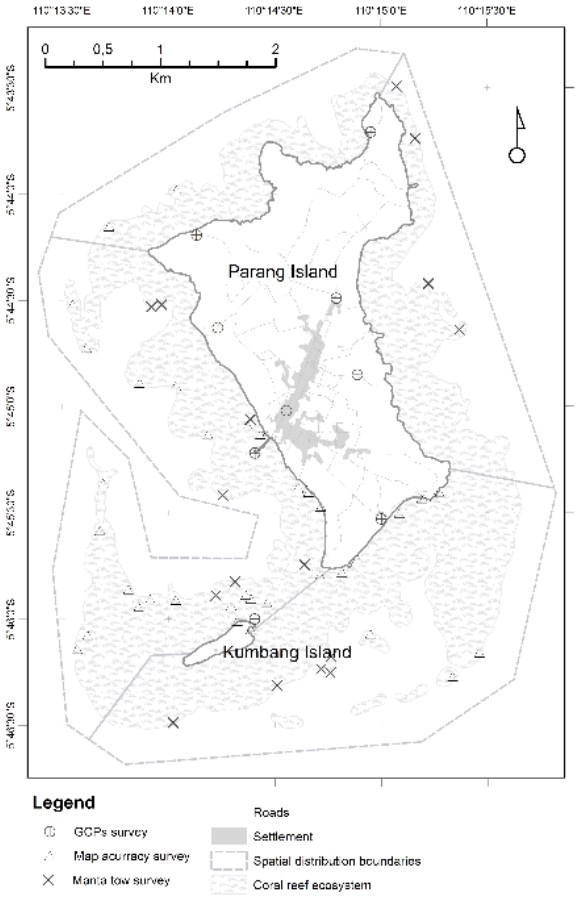

Figure 1. Study area

The spatial structure studied was live coral using the approach developed by McGarigal and Marks, 1994 and McGarigal and Marks, 1995 include: Total Seascape Area, CA (Class Area), MSI (Mean Shape Index), NumP (Numb. of Patches), MPS (Mean Patch Size).

The spatial structure is part of the ecological approach from the ecological scientific development (Stow, 1993). The spatial structure of living coral reefs in the study area was divided into four parts, namely the north, east, west and south. And subscripts algorithm for calculation of spatial structure as follows;

$$TA = \mathrm{A}\left(\frac{1}{10.000}\right)$$

$$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10.000}\right)$$

$$\mathrm{NP} = n_i$$

$$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}\left(\frac{1}{10.000}\right)$$

$$MSI = \frac{\sum_{j=1}^{n} \left(\frac{P_{ij}}{2\sqrt{\mu . a_{ij}}}\right)}{n_i}$$

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Where;
i = 1, ... , m or n : patch types (classes)
1, ... , n patches
$P_{i,j}$= perimeter (m) of patch ij

$a_{i,j}$ =area (m^2) of patch ij
A = Total landscape area (m^2)
n = n_i number of patches in the landscape of patch type (class) i

TA equals the area (m2) of the coral reef ecosystem, divided by 10,000 to convert to hectares). TA excludes the ar of any background patches within the coral reef ecosystem Sum of areas of all patches in the landscape. CA equals the sum of the areas (m^2) of all live coral patches of the corresponding patch type, di ded by 10,000. NP equals to the number of live coral patches of the corresponding patch type (class). MPS equals the sum of the areas (m^2) of all live coral patches of the corresponding tch type, divided by the number of patches of the same type, divided by 10,000 (to convert to hectares). MSI equals the sum of live coral patch perimeter (m) divided by the square root of patch area (m) for each patch of the corresponding patch type, adjusted by a constant to adjust for a circular standard (vector).

RESULTS AND DISCUSSION

GeoEye-1 Satellite Data has coverage of clouds 0%. Geometry Correction of GeoEye-1 satellite imagery (0.5m spatial resolution) has been done using 7 GCPs produce a significant geometric accuracy RSME= 0.87 with 0,4m accuracy in the field.

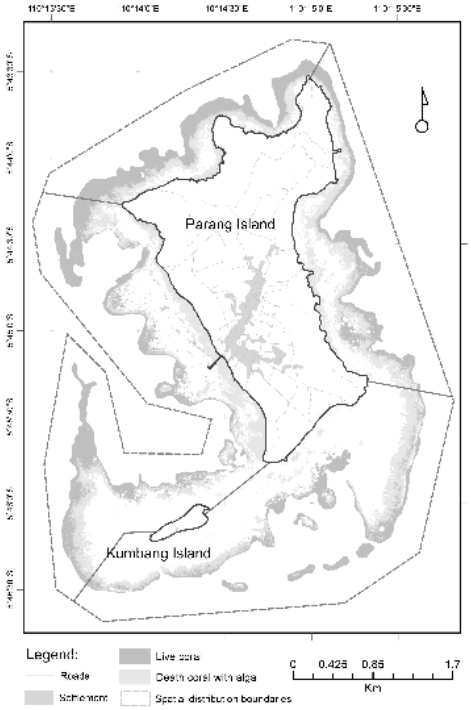

Figure 2. Spatial distribution of Live Coral and DCA (Dead Coral with Alga)

Results for reef mapping are shown in Figure 2. The results of the survey conducted give you a map of coral reef ecosystems that have quality over all accuracy = 84.1% or higher than the tolerable accuracy (80%). Producer Accuracy and User Accuracy in each category are mapped according to the ecosystem

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with has high accuracy (above the rated tolerable accuracy = 80%). Statistical analysis shows that the coral reef ecosystem maps produced in the area of Parang Island is accurate and can be used for studies that require high accuracy of the mapping results. Kappa Value Index (k = 0.81) was obtained in the results of this analysis shows that this mapping accuracy is positive or considered as good and closed to the value of high accuracy (highest score = 1).

Coral reef habitat area obtained is 814.22 ha. There is live coral reef of 202.01 ha (49.75%) and coral reefs die 204 ha (50.25%) that were found in the area of coral reefs. The results of this study indicate that the area of Live and Death Coral is the 49.86% (406.01 ha) of coral reef ecosystems in the study area.

Table 3. Spatial distribution of live and death coral in four areas at Parang Islands

No.	Area	Live Coral (ha)	%	Death Coral (Ha)	%	Coral Reef Ecosystem (ha)	%
1.	Western area	33,95	16,81	47,13	23,11	136,68	16,79
2.	Southern area	78,21	38,72	81,8	40,11	305,17	37,48
3.	Eastern area	46,07	22,81	29,4	14,42	94,5	11,61
4.	Northern area	43,76	21,66	45,59	22,36	277,84	34,12
		201,99		203,92		814,19	

The table shows that coral reefs live and dead coral reefs are spread almost evenly across the water of Pulau Parang diversity is relatively complex spatial structures in particular on the number of patches, mean patch size and class area.

Table 4. Live coral spatial structure.

No.	Area	MSI (Mean Shape Index)	NumP (Numb. Of Patches)	MPS (Mean Patch Size)	TLA (Total Lanscape Area) ALL Class Area	CA (Class Area)
1.	Western area	1,25	21087,00	0,0037	305,12	78,21
2.	Southern area	1,26	14888,00	0,0029	277,81	43,76
3.	Eastern area	1,24	8529,00	0,0040	136,54	33,95
4.	Northern area	1,23	5613,00	0,0082	94,48	46,07

The dead coral (50.25%) is found more dominant than live coral (49.75%). The largest living coral reef is located in the western part of the islands (78.2 ha) spread at 2.1087 patches with Mean Shape Index Irregular (MSI=1.25) and very small size of Mean Patch Size (MPS=0.0037ha). Karimunjawa national park needs to improve the integrated surveillance and rehabilitation efforts in Parang Island. These rehabilitation priority areas could be focused on the area of dead coral and surveillance at live coral on this research. Surveillance and rehabilitation needs to be done in an integrated manner involving Pokmaswas (Community Watch Group), Polhut (Forest Police), and related with stakeholder, which are under the coordination of BTN Karimunjawa Central Java.

CONCLUSIONS

GeoEye-1 satellite imagery (spatial res. 5m) can be used for detail mapping of live and death coral with significant accuracy (over all accuracy=84.1 %, user accuracy= 81.8%, producer accuracy = 90%, and Kappa Index k = 0.81%). Dead coral (50.25%) is found more dominant than live coral (49.75%). At the western side of Parang Islands, was found the most widespread of seabed habitat (305.17 ha) and also

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found the most extensive of live (78.21 ha) and dead coral (81.8 ha). The largest living coral reef found in the western islands of 78.2 ha spread over 21087 patches with the Irregular Mean Shape Index (MSI = 1.25) and has a very small Mean Patch Size (MPS = 0.0037 ha).

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

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PROFICIENT	The essay supplies relevant, accurate qualitative and/or quantitative data and evidence related to the scientific topic or text(s) to support its claim and counterclaim.
DEVELOPING	The essay supplies some qualitative and/or quantitative data and evidence, but it may not be closely related to the scientific topic or text(s), or the support that is offered relies mostly on summary of the source(s), thereby not effectively supporting the essay's claim and counterclaim.
EMERGING	The essay supplies very little or no data and evidence to support its claim and counterclaim, or the evidence that is provided is not clear or relevant.

REASONING

Explain how or why each piece of evidence supports the claim.

ADVANCED	The essay effectively applies scientific ideas and principles in order to explain how or why the cited evidence supports the claim. The essay demonstrates consistently logical reasoning and understanding of the scientific topic and/or text(s). The essay's explanations anticipate the audience's knowledge level and concerns about this scientific topic.

PROFICIENT	The essay applies scientific reasoning in order to explain how or why the cited evidence supports the claim. The essay demonstrates logical reasoning and understanding of the scientific topic and/or text(s). The essay's explanations attempt to anticipate the audience's knowledge level and concerns about this scientific topic.
DEVELOPING	The essay includes some reasoning and understanding of the scientific topic and/or text(s), but it does not effectively apply scientific ideas or principles to explain how or why the evidence supports the claim.
EMERGING	The essay does not demonstrate clear or relevant reasoning to support the claim or to demonstrate an understanding of the scientific topic and/or text(s).

FOCUS

Focus your writing on the prompt and task.

ADVANCED	The essay maintains strong focus on the purpose and task, using the whole essay to support and develop the claim and counterclaims evenly while thoroughly addressing the demands of the prompt.
PROFICIENT	The essay addresses the demands of the prompt and is mostly focused on the purpose and task. The essay may not acknowledge the claim and counterclaims evenly throughout.
DEVELOPING	The essay may not fully address the demands of the prompt or stay focused on the purpose and task. The writing may stray significantly off topic at times, and introduce the writer's bias occasionally, making it difficult to follow the central claim at times.
EMERGING	The essay does not maintain focus on purpose or task.

ORGANIZATION

Organize your writing in a logical sequence.

ADVANCED	The essay incorporates an organizational structure throughout that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence. Effective transitional words and phrases are included to clarify the relationships between and among ideas (i.e. claim and reasons, reasons and evidence, claim and counterclaim) in a way that strengthens the argument. The essay includes an introduction and conclusion that effectively follows from and supports the argument presented.
PROFICIENT	The essay incorporates an organizational structure with clear transitional words and phrases that show the relationship between and among ideas. The essay includes a progression of ideas from beginning to end, including an introduction and concluding statement or section that follows from and supports the argument presented.
DEVELOPING	The essay uses a basic organizational structure and minimal transitional words and phrases, though relationships between and among ideas are not consistently clear. The essay moves from beginning to end; however, an introduction and/or conclusion may not be clearly evident.
EMERGING	The essay does not have an organizational structure and may simply offer a series of

	ideas without any clear transitions or connections. An introduction and conclusion are not evident.

LANGUAGE

Pay close attention to your tone, style, word choice, and sentence structure when writing.

ADVANCED	The essay effectively establishes and maintains a formal style and objective tone and incorporates language that anticipates the reader's knowledge level and concerns. The essay consistently demonstrates a clear command of conventions, while also employing discipline-specific word choices and varied sentence structure.
PROFICIENT	The essay generally establishes and maintains a formal style with few possible exceptions and incorporates language that anticipates the reader's knowledge level and concerns. The essay demonstrates a general command of conventions, while also employing discipline-specific word choices and some variety in sentence structure.
DEVELOPING	The essay does not maintain a formal style consistently and incorporates language that may not show an awareness of the reader's knowledge or concerns. The essay may contain errors in conventions that interfere with meaning. Some attempts at discipline-specific word choices are made, and sentence structure may not vary often.
EMERGING	The essay employs language that is inappropriate for the audience and is not formal in style. The essay may contain pervasive errors in conventions that interfere with meaning, word choice is not discipline-specific, and sentence structures are simplistic and unvaried.