7. BENTHIC DIVERSITY MAPPING AND ANALYSIS BASE ON REMOTE SENSING AND SEASCAPE ECOLOGY

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International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 11, November 2018, pp. 227–235, Article ID: IJCIET_09_11_023
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=11
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

BENTHIC DIVERSITY MAPPING AND ANALYSIS BASE ON REMOTE SENSING AND SEASCAPE ECOLOGY APPROACH AT PARANG ISLANDS, KARIMUNJAWA NATIONAL PARK, INDONESIA

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ABSTRACT

Mapping of coral reef ecosystem by using remote sensing either from satellite platform has been acknowledging as an essential tool. Seascape ecology is the study of seascape patterns, interaction among patches within a seascape mosaic and how these patterns and interactions change over time. The objectives of this study are to produce a benthic map, measure the benthic diversity matrix and to compare the diversity matrix among different seascape area at Parang Islands shallow waters in the eastern part of Karimunjawa National Park, Indonesia. The high-resolution satellite image that has been used in this study was from GeoEye-1 to map the benthic. Fragstats is used to measure and analyze the diversity metric values for the benthic consist of live coral, DCA, seagrass, etc. This research produces benthic ecosystem map consists of eight benthic classes. The diversity metric index shows that the southern seascape region of this island has the highest diversity.

Keywords: Remote sensing, seascape ecology, benthic, Fragstats, and Karimunjawa

Cite this Article: Muhammad Helmi, Purwanto, Warsito Atmodjo, Petrus Subardjo and Afrina Aysira, Benthic Diversity Mapping and Analysis Base On Remote Sensing and Seascape Ecology Approach at Parang Islands, Karimunjawa National Park, Indonesia, International Journal of Civil Engineering and Technology, 9(11), 2018, pp. 227–235.

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1. INTRODUCTION

Corals are one of the valuable benthic ecosystems. One of the complex yet valuable marine habitats in the world isa coralreef, which left only approximately to 1% in the marine benthic environment [16]. Coral reef is known as shoreline protector [5] as well as supplying marine resources in the fisheries sector and making it essential to ecosystem balance. Besides, coral reef grants more than 10 billion USD of annual net income globally in the tourism industry [18]. However, this marine benthic are threats by anthropogenic activities and to natural disaster [7].

Karimunjawa National Park consists of 27 islands with protecting several ecosystems, such as coral reefs, seagrass, mangroves, beach forest, and low land tropical forest. These islandsare known as a complex ecotourism area and main tourist destination [19] in Indonesia. Moreover, Karimunjawa National Park a natural habitat of diverse marine organisms [6]. Parang and Kumbang islands are the part of its national park on the western area. Both small islands in the form of a group of islands with one shallow aquatic ecosystemconsist of coral reef ecosystems that form an ecological unit. Residents already live in Parang Island before the establishment of Karimunjawa Islands National Park. Inhabitants in this area mostly depend on the coral reef ecosystem for fishing, aquaculture, tourism, sailing, and marine transport.

The determination of existing status and extent of damage is done by mapping of benthic class periodically as a basis for planning and management in the region.

The aim of this study is to map a benthic class based on the high resolution of satellite image; measure the benthic diversity matrix using spatial structure modeling software, and to compare the diversity matrix at four seascape area.

The significance of this study is the implementation of the landscape ecology approach to the benthic ecosystem at the shallow marine area. According to [10], landscape structure is part of ecological characteristics based on the strongly spatial form of an ecosystem. In this study, the landscape metrics was applied to the Seascape area. Seascape metrics that were used are Patch Richness (PR), Shannon's Diversity Index (SHDI), Simpson's Diversity Index (SIDI), Shannon's Evenness Index (SHEI) and Simpson's Evenness Index (SIEI). There is no study previously on a detailed map of benthic class, andmeasure the diversity metrics of each benthic class. Thus, it becomes complementary and baseline data collection of the benthic ecosystem on the study area.

2. METHODOLOGY

2.1. Study area

The study area is located at Parang and Kumbang Islands, Jepara Regency, Central Java, Indonesia as shown in Figure1.

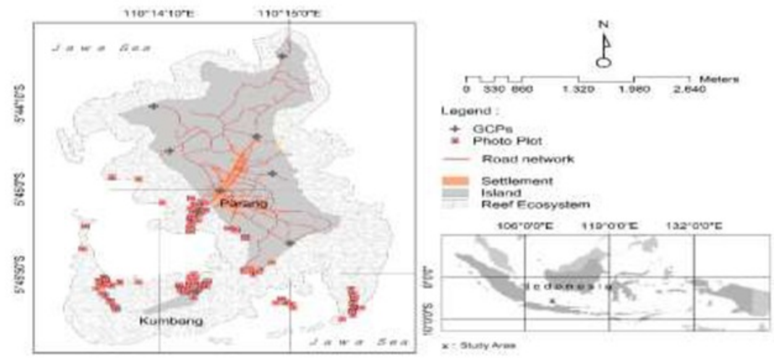

Figure 1 Study Area at Parang and Kumbang Islands.

2.2. Pre-processing of GeoEye-1 Satellite Image

In this study, the satellite image that has been used was from GeoEye-1 with acquisition date July 16th, 2011 (GeoEye Inc, USA). The image has a technical specification of four multispectral bands, 1.84m of spatial resolution, 11 bits, 4500 columns and 6394 rows of pixels in GeoTIFF format. The pre-processing involved radiometric and geometric correction of the GeoEye-1 satellite image.

Scattering, absorption and minimizing the light attenuation interference by atmospheric constituents can be done by using radiometric correction [11, 25]. This correction was done by using Dark Object Subtraction (DOS) method which to correct or remove the additive haze component or path radian on each band of the GeoEye-1 image. Dark target is the optically deep-water pixels produced by this correction. Meanwhile, orthorectification method was used in geometric correction based on input data including GeoEye-1 RPC (rational polynomial coefficient) sensor model, 10m resolution of DEM (Digital Elevation Model) from spot height and contour line interpolation of topography map and GCPs (Ground Control Points) from GPS Survey. Topographic maps used are 1:25000 scales, and published by BIG (Indonesian Geospatial Information Agency) on 2012. Geometry reference was developed from nine GCPs that measure using Garmin76 GPS Map using Datum WGS84 and projection SUTM49 as shown in Figure 1.

2.3. Mapping of Coral Reef Ecosystem

The specular reflectance in the form of sun glinton satellite image was corrected by using infrared sun glint correction on the visible band [21]. Water column impact [1, 3, 11, 21, 25] on each satellite image band was normalized with apply the Depth Invariant Index [1, 11] and Inverse Model [21]. This correction was done to prepare the multispectral input band for benthic habitat classification.

2.3.1. Field Survey

Photo plot technique was used during a field survey conducted at 98 sampling sites in 2015 and 2016 using the underwater camera as Figure 1. The sampling sites were selected based on variation classes of benthic habitat map. Types of benthic habitat at the field were recorded and its position was marked using Garmin76 GPS.

2.3.2.Accuracy Assessment

Accuracy assessment was done for all benthic habitat using Overall Accuracy method, and for each class of benthic habitat, accuracy assessed using User and Producer Accuracy [1, 2, 12, 22, 23 and 25].Overall, user accuracy and producer accuracy need to undergo a statistical test to ensure that the value of resulting test does not happen by chance. The test was Kappa Index [3, 22],which is one of the discrete multivariate techniques to study accuracy used statistical in analysis Khat, as shown in the algorithm below:

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

K equation represents that *r:* Number of rows 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; x_{+i}: Number of observations in the first row; and *N:* Total number of observations (pixels) of the matrix.

2.3.3. Analyzing by using Fragstats

Fragstats is software developed to compute a wide variety of landscape metrics for categorical map patterns that has successfully been applied for seascape ecology [8, 9, 10, and 15]. Landscape metrics can be estimated by Fragstats based on the disposition of the patches within the landscape [20]. In this study, a set of metrics defining diversity was selected based on its relevance to seascape ecology composition that is represent by Diversity Metric Index as Table 1.

Table 1 Diversity Metric Index.

Metric	Index	Equation	Description
Density	Patch Richness (PR)	$PR = m$	Patch types number present in the seascape
	Shannon's Diversity Index (SHDI)	$SHDI = -\sum_{i=1}^{m}(P_i x\ LnP_i)$	Represent the amount of "information" per morphological class; larger values indicate a greater number of patch types and/or greater evenness among types
	Simpson's Diversity Index (SIDI)	$SIDI = 1 - \sum_{i=1}^{m} P_i^2$	The probability that any two pixels selected at random would correspond to different patch types; the larger the values the greater the likelihoodthan any two randomly drawn pixels would be different patch types
	Shannon's Evenness Index (SHEI)	$SHEI = -\frac{\sum_{i=1}^{m}(P_{i\,x}\ lnP_i)}{\ln m}$	The proportion of maximum Shannon's Diversity Index based on the distribution of area among patch types any typically given as the observed level diversity divided by the maximum possible diversity given the patch richness. SHEI=1 when the area is distributed evenly among patch types.
	Simpson's Evenness Index (SIEI)	$SIEI = \frac{1 - \sum_{i=1}^{m} P_i^2}{1 - \left(\frac{1}{m}\right)}$	The proportional abundance of each patch type squared or the observed Simpson's Diversity Index divided by the maximum Simpson's Diversity Index of patch types.

Note:The metric descriptions are based on landscape analysis obtained from Fragstats [10]. Patch refers to each of the grid cluster falling within a given morphological class.

3. RESULT AND DISCUSSION

The mapping in this study produced a spatial distribution of benthic consists of live coral, DCA, seagrass, sand, rubble, associate sand and rubble, associate rubble and seagrass, associate rubble and DCA. The spatial distribution pattern of benthic from high resolution of GeoEye-1 satellite data are shown in Figure 2.

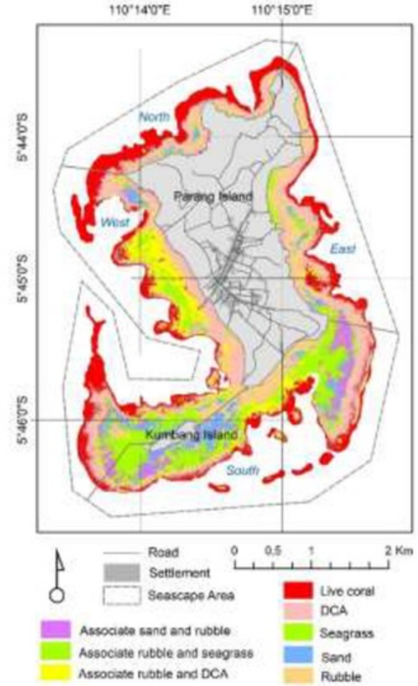

Figure 2 Maps show the spatial distribution of benthic

From the figure above, there were eight classes of coral reef have been identified from different part (north, east, south, and west) of the Seascape area. The eight classes of benthic habitat were chosen based on 98 photo plots survey of benthic types.

The benthic map's accuracy test that has been done for 98 survey sites shown in Figure 3.2. The Overall Accuracy of this map is 83.7%, which slightly higher than tolerable accuracy (80%) that categorized as good. From the accuracy test, it shows that overall mapping results are in accordance with the conditions in the field. Meanwhile, the contingency matrix indicates the compatibility of the benthic habitat in the map and field.

Table 2 Contingency matrix of accuracy assessment.

	Benthic Map										**Map Accuracy**			
	Benthic Class	1	2	3	4	5	6	7	8	Total	Producer accuracy	User accuracy	Overall accuracy	Kappa index (k)
Field Data	1	9			1	1	1			12	75.0	75.0	83.7	0.81
	2		9		1					10	81.8	90.0		
	3		1	10	1					12	83.3	83.3		

	4	1		1	11					13	78.6	84.6		
	5	1		1		8	1			11	88.9	72.7		
	6	1					5	1		7	71.4	71.4		
	7							14	1	15	87.5	93.3		
	8	16	1					1		18	94.1	88.9		
	Total	28	11	12	14	9	7	16	1	98				

Note: Benthic class (1) Live coral, (2) DCA, (3) Seagrass, (4) Rubble, (5) Sand,(6) Associate of rubble and seagrass, (7) Associate of sand and rubble, and (8) Associate of rubble and DCA.

The table above shows the statistical analysis result using the Confusion Matrix method. From this method, User Accuracy and Producer Accuracy can be generated. The Confusion Matrix method produces User Accuracy and Producer Accuracy on each class by considering omission and commission error. Calculation of producer accuracy is more reliable because associated with a correct number of pixels x. However, user accuracy result is not necessarily true due to calculation associated with the number of pixels *x* interpretation. The value of k is between 0-1. From the result of this study, the value of *k* is not zero that shows accuracy value of this habitat benthic classification does not occur by chance. Furthermore, the value of k is not negative indicates that the resulting classification is good. High accuracy of this habitat benthic mapping shows by the value k=0.81 which close to the value 1. The result shown which obtained from all accuracy tests indicate that multispectral GeoEye-1 satellite image can be used for benthic mapping with significant accuracy.

Table 3 The benthic class at different seascape area.

Benthic Class	Area (ha)				
	North	East	South	West	Total
Live coral	46.08	33.97	43.79	75.21	199.05
DCA	29.43	47.16	45.34	83.57	205.5
Seagrass	1.24	6.22	0.62	1.33	9.41
Sand	2.83	4.77	28.44	17.07	53.11
Rubble	13.62	33.45	38.31	37.45	122.83
Associate rubble and DCA	0.68	3.52	19.57	41.47	65.24
Associate rubble and seagrass	0.6	5.25	72.2	41.23	119.28
Sand and rubble	0.07	2.24	29.63	8.08	40.02
Total (ha)	94.55	136.58	277.9	305.41	814.44

Table 3 shows the area of benthic habitat with the total classes that reaching 814.4 ha. High biodiversity indicates by the number of benthic habitat types found in Parang Islands. The largest area of seagrass found was 6.22 ha which located at the eastern part of the island. Moreover, the DCA and live coral have the largest area that located at the west of the island with an area of 83.57 ha and 75.21 ha respectively. Wet season (NW) causes high waves influenced by high winds blowing from the west with strong ocean currents. The presences of live coral in the west part of the island contribute to the reduction of waves. DCA also found in the western part of Parang Islands as highest wave during wet season occurred in the area. However, seagrass population can be found in the eastern part due to seagrass are vulnerable to physical disturbances such as storm and waves.

Table 4 Diversity metric index obtained on eachbenthic area

Diversity	Coral Reef Seascape Index			
	North	East	South	West
Patch Richness (PR)	9	9	9	9
Shannon's Diversity Index (SHDI)	1.23	1.6	1.89	1.78
Simpson's Diversity Index (SIDI)	0.64	0.75	0.84	0.81
Shannon's Evenness Index (SHEI)	0.56	0.73	0.86	0.81
Simpson's Evenness Index (SIEI)	0.71	0.85	0.94	0.91

Diversity Type	Diversity Metric Index				
	North	East	South	West	Average
Patch Richness (PR)	9	9	9	9	9
Shannon's Diversity Index (SHDI)	1.23	1.6	1.89	1.78	1.63
Simpson's Diversity Index (SIDI)	0.64	0.75	0.84	0.81	0.76
Shannon's Evenness Index (SHEI)	0.56	0.73	0.86	0.81	0.74
Simpson's Evenness Index (SIEI)	0.71	0.85	0.94	0.91	0.85

Based on table 4, it shows that the number of patch types present in the seascape is 9 (PR=9) for all part of the island. This shows that none of the sampling designs considered in this study capture the total number of different patch types present within the seascape. From the SHDI and SIDI value, the southern part of Parang Islands has a greater number of patch types and/or greater evenness. The value of SHEI and SIEI for all part of the island almost reaching to 1 which indicates the distribution of area among patch types almost distributed evenly. Overall, from the all metrics obtained, indicate that the coral reef is diverse and its area is proportionally distributed in accordance with their presence within the seascape.

4. CONCLUSION

Based on the analysis of GeoEye-1 satellite data, it is known that Parang and Kumbang Island has a single benthic ecosystem with an area of 814.4ha.This shallow marine ecosystem consists of eight benthic class, consist of live corals (199.05 ha), DCA (205.5 ha), seagrass (9.41 ha), sand (53.11 ha), rubble (122.83 ha), associate sand and rubble (40.02 ha), rubble associates and seagrass (119.28 ha), associate rubble and DCA (65.24 ha).

The largest benthic is found in the western part of the seascape area which reaches 41.47 ha.This benthic mapping has a good accuracy with overall accuracy = 83.7%, and kappa index = 0.81. The diversity metric index shows that the southern seascape region of this islands has the highest diversity compared to other around region with diversity value of PR = 9, SHDI = 1.89, SIDI = 0.84, SHEI = 0.86 and SIEI = 0.94.

ACKNOWLEDGMENT

Appreciation to Research Institutions and Community Service Universities Diponegoro for the RPP scheme funding on this research. We also grateful to PT. Waindo SpecTerra for the support of using ArcGIS ver 10.3, and ERDAS-ER Mapper softwares.

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