

Formulating marine sanctuary designation for sustainable management of blue swimming crab in Lancang Island, Kepulauan Seribu

Syamsul Bahri Agus*, Tarlan Subarno, Adriani Sunuddin

Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Indonesia

*e-mail: allanawani@gmail.com

Abstract. Lancang Island is the center of fisheries of blue swimming crab in Kepulauan Seribu, Jakarta. Most of the inhabitants in this island are fishermen, and blue swimming crab is the main target without considering the stocks. One of the management effort of blue swimming crab by the government is the restriction of catchment size. To support the government policy and to maintain the population stocks and the sustainability of blue swimming crab around Lancang Island, we need another effort such as proposing area of Marine Sanctuary. The analysis of possibility area of the marine sanctuary was performed with simulated annealing using Marxan. The datasets were used in analysis included geomorphic model of habitat (sea floor), coastal ecosystems, blue swimming crab catches (sample size, location, and fishing pressure). The results obtained three possibility locations of the marine sanctuary, which is around of Laki Island, Southern, and Southeastern of Lancang Island. From the possibility locations, we recommend the first location as the Marine Sanctuary with considering the more diverse of features represented.

1. Introduction

Kepulauan Seribu is a seascape that forming up a group of islands and consist of more than 100 islands. Geographically, Kepulauan Seribu is located in the north of Java Island and administratively included within DKI Jakarta Province. Some of the area in northern of Kepulauan Seribu is a conservation area, known as Taman Nasional Kepulauan Seribu (TNKpS) and managed by Ministry of Environment and Forestry. Most of the islands are uninhabited, and only 11 islands are occupied, one of which is the Lancang Island located in southern of Kepulauan Seribu.

Most of the islands outside of core zone of the conservation area in Kepulauan Seribu have become major tourist destinations. Sebira Island in the most north and Lancang Island in the southern of Kepulauan Seribu are the two inhabitant island that remains to be the fisheries center in Kepulauan Seribu besides as the tourist destination. Meanwhile, most of the other inhabitant islands have relied on tourism as the main economy drives. In Lancang Island, the catching of fishery commodity which is currently the mainstay is tiny fish, squid, and blue swimming crab.

The blue swimming crab (*Portunus pelagicus*) is one of the fishery resources with high economic value. High demand coupled with high price became one of the driving factors of exploitation intensively, especially around of Lancang Island. On the other hand, the government has issued regulations by restricting the conditions and captured sizes (PERMEN-KP/No.1/2015). Among the objectives of the regulation is to restrict population decline and to maintain the availability of blue swimming crab resources in nature. One of those regulated in the policy is the limitation of catchments sizes, where the allowed sizes of blue swimming crab are at least 10 cm.



The concept of sustainable of blue swimming crab fisheries management needs to be implemented in the Lancang Island. The management concept what is meant is the proposed the designation of a marine sanctuary in around of Lancang Island. Some others inhabitant islands in Kepulauan Seribu have established marine sanctuaries in 6 sites and managed by the local community. The marine sanctuaries were established to preserve the ecosystems especially coral reefs from the massive pressure of tourism in Kepulauan Seribu. Similar to the six existing marine sanctuaries in other inhabitant islands, in Lancang Island is necessary to propose and establish some of the environment area as the marine sanctuary to preserve the marine resources. One of important benefit if the marine sanctuary can be established, is expected to maintain the preservation of blue swimming crab fisheries, so that it can remain a major economic driver in Lancang Island. To determine the suitable location of the designation of the marine sanctuary, it is necessary to integrate geospatial aspects and systematic analysis. In this study, we integrate some geospatial information covering coastal ecosystems, geomorphological features of the seafloor, and geospatial aspects of blue swimming crabs.

The utilization of remote sensing technology to obtain information in coastal and marine is one way out to gather the required spatial information, including as one of the inputs in feasibility assessment of marine sanctuary. Spatial information on the distribution of mangrove, seagrass, and coral reefs can be derived from satellite imagery with several approaches [1, 5]. The characteristics of seafloor such as the geomorphological zones can be obtained from the modeling of the benthic habitat [6, 8]. The identifying of potential sites for a marine sanctuary, there is a well-known model or software and has been widely used, Marxan. Marxan is a tool that helps in decision making, one of its functions is to identify conservation sites, including marine conservation [9, 10].

2. Materials and Method

2.1. Study site

The research was conducted in the around of Lancang Island; there are three small islands are included in the study site, Lancang Island, Laki Island, and Bokor Island. Administratively the study location is included in District Administration of Kepulauan Seribu – Jakarta, and geographically located in the northern of Tangerang – Banten. The Lancang Island is one of the inhabited islands in Kepulauan Seribu, while the other two islands in this study site are uninhabited islands.

The total area of study site is about 154.88 Km² from western of Laki Island to the eastern of Bokor Island (figure 1). The study location was then divided into 4.84 km² of the spatial grid, and resulting 32 square grids (A1 – D8). The construction of this square grids was done to facilitate the collection of spatial information through participatory mapping and converting of non-spatial to spatial datasets.

2.2. Data collections

The datasets used in this study include primary and secondary data collected from several sources. The kinds of datasets used are presented in Table 1.

Table 1. The kinds and sources of datasets.

The kinds datasets	Data Sources
Fishing ground	Participatory mapping
Fishing pressure	Participatory mapping
The catchment size	Sample of catchment measurement
Water depth	Survey sounding
Bathymetric map	Indonesian Naval
Tidal	In-situ measurement (using moritide)
WorldView-2 imagery	Digital Globe
Distribution of coastal ecosystems (mangrove, seagrass, and reefs)	Imagery analysis

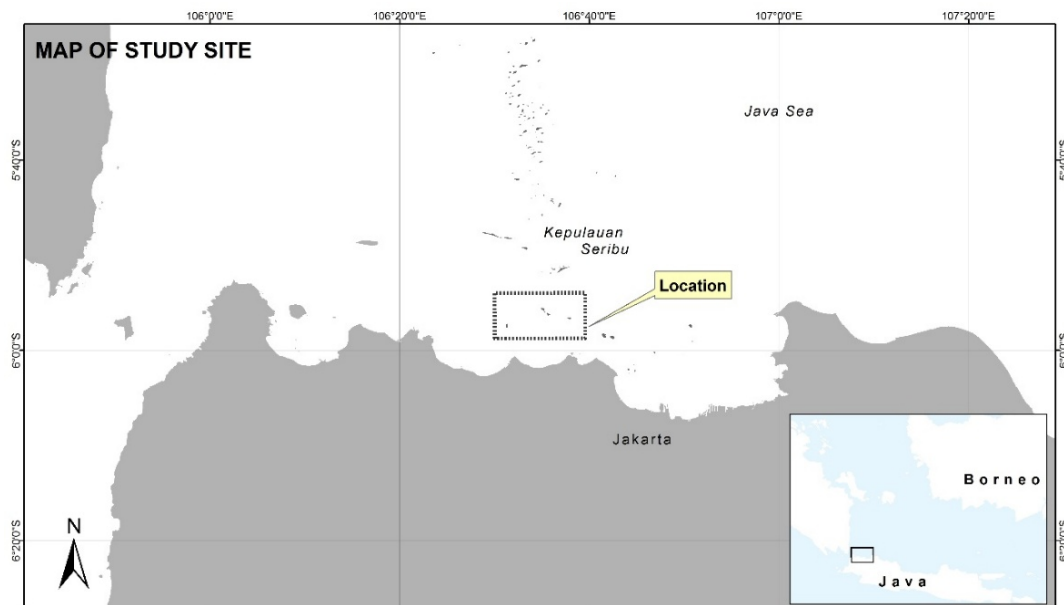


Figure 1. The study site located in southern of Kepulauan Seribu.

Data collection was conducted from 2015 to 2016, covering the entire fishing/monsoon season. Data collected are catchment and environmental data of fishing ground. The catchment data includes fishing ground, fishing intensity (fishing pressure), catchment sizes, catchment weight, and berried female. Identification of fishing ground was done through participatory mapping with fishermen when landing their catchment and conducted by ground check of the fishing ground using Global Position System (GPS). To facilitate the identification of fishing ground, the questionnaire was completed with a map of study site that has been divided into 32 grids with 4.84 km². The sampling of the catchments was done during the interview to measure the carapace, weigh of samples, and to identify the berried female.

Environmental data include water depth and coastal ecosystems. The depth data was obtained from a combination of the results from the survey and the secondary data of nautical chart from the Indonesian Navy Hydrographic. Tidal measurements for the depth correction of survey results were conducted using marine automatic tidal detection (Moritide).

2.3. Data analysis

Data analysis includes processing of satellite imagery, geomorphological modeling of benthic habitats, analysis of catchment data, and analysis the potential area of the marine sanctuary. Preparation and data processing in this research are illustrated as presented in figure 2.

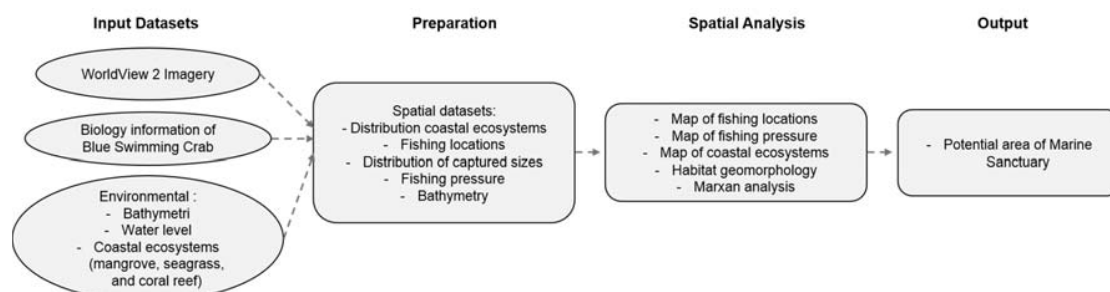


Figure 2. Workflow of preparation and data processing.

2.3.1. Spatial distribution of Blue Swimming Crab. Tabular data, i.e., catchment data then mapped using a quadratic grid, the characteristics of grid map have been described in the data collection section. Tabular data results then converted into spatial data and then obtained the spatial distribution of fishing ground of blue swimming crab for four monsoons. The location of fishing ground obtained within a year period, then grouped into four monsoons. The classification of the fishing season based on the terms by local fishermen, namely the southeast monsoon, alternate one monsoon, northwest monsoon, and alternate two monsoons. The nonspatial data obtained based on the measurements of the catchment samples was converted to attribute data to complement the fishing ground information of the identification resulted from participatory mapping and field checks. As such, from the map of the distribution of fishing ground then obtained information on the distribution of catchment sizes, distribution of the berried female, and the difference of fishing intensity in each grid.

2.3.2. Image processing. Image processing was conducted to derive spatial distribution of coastal ecosystems, including mangroves, seagrasses, and coral reefs on three small islands in the study site. The imagery used was WorldView-2, with the acquisition in June 2015. The classification method was supervised classification using maximum likelihood (MLC) algorithm. The MLC algorithm is one of the common algorithms used in remote sensing data processing [11]. The interpretation of imagery was done by referring to the information gathered from the field survey.

2.3.3. Modeling of benthic geomorphology. The seafloor around of Lancang Island was analyzed to obtain its geomorphological characteristics. Geomorphological characteristics were used as one of the inputs in determining the priority location as the marine sanctuary. The benthic geomorphological characteristics were then grouped into slope, depression, crest, and flat. The modeling of geomorphological characteristics was performed using Benthic Terrain Modeler (BTM) [6, 8, 12]. BTM analysis used bathymetry data as input in the analysis process, in this study the input analysis was the integration between the survey data and the data extracted from the nautical map.

2.3.4. Planning scenario to identify area for marine sanctuary. Marxan has been widely used as spatial analysis tools to identify potential sites for conservation areas, including marine protected area [10, 13, 14]. In this study, Marxan was used to identify potential sites as a marine sanctuary, to maintain the preservation of fishery resources around Lancang Island, especially blue swimming crab. The first step in analyzing to identify location was to divide the study area into planning unit (pu). The study area was divided into the hexagonal shape of pu with the size of each pu was 25980.76 m², the number of pu produced by that size was 6187 units. The size of the pu was adjusted to the study location and the representation of input parameters into each pu.

The analysis was done by simulating annealing with interactive improvement, as its marxan work, through 1000 repetitions [9, 15]. Target features and cost are factors that greatly affect the results of the marxan analysis. The target features used were ecosystems distribution (mangrove, seagrass, and coral reefs), a map of fishing ground (size and condition of berried females), and habitat geomorphology. One of the purposes of using Marxan analysis is to minimize the possibility of conflict occurring from the use of marine space. For that purpose, it was developed scenario analysis to represent the use of existing marine spaces used as cost. Scenario cost used were the fishing intensity, distance from the mainland, and the fishing boat traffics.

3. Results

3.1. Coastal ecosystems and benthic habitat

Spatial distribution of coastal ecosystems in three islands obtained from the results of analysis of Worldview-2 imagery. The spatial information of this coastal ecosystems based on the result of image processing using field data as a reference. Based on imagery analysis and validated by field observation, it is known that mangroves exist only on Lancang Island and Laki Island, and are not found on Bokor Island. The Lancang island consists of Lancang Kecil and Lancang Besar islands, and there are mangroves in both of them. Seagrass and coral reefs were found in shallow waters on three islands.

Figure 3 shows the distribution of coastal ecosystems on the islands of Lancang, Laki, and Bokor. Generally, Lancang Island dominates shallow water areas, as well as the distribution of coastal ecosystems.

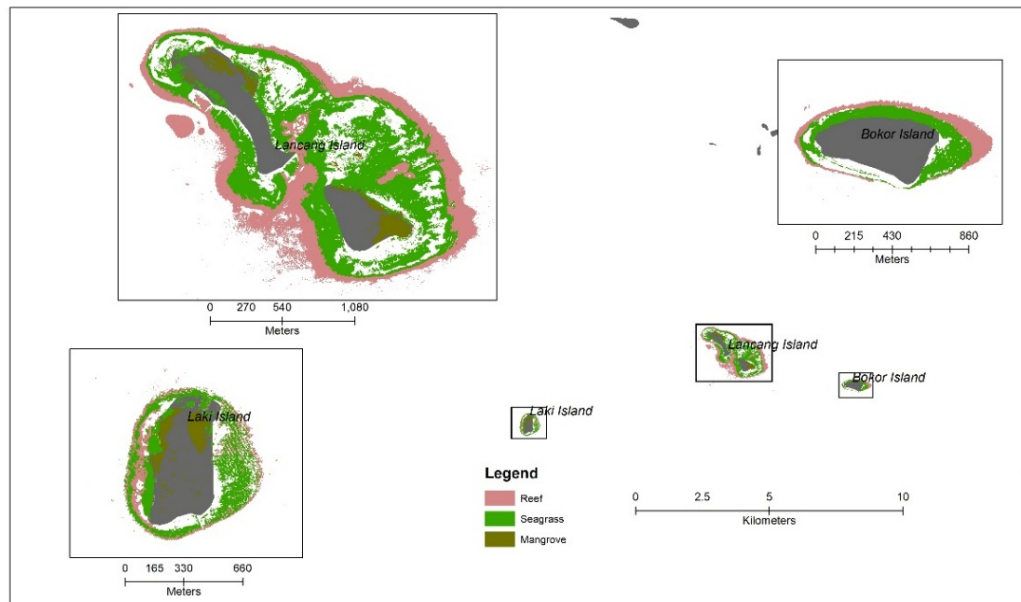


Figure 3. The distribution of coastal ecosystems in the study area.

Table 2 shows the area of coastal ecosystems of mangroves, seagrasses and coral reefs derived from satellite imagery. Each coastal ecosystem with the largest area found on the Lancang Island. Based on the area of both land and shallow waters, Lancang Island is bigger than the other two islands (figure 3, so that the area of the coastal ecosystem is wider on Lancang Island. The smallest area of seagrass and coral reefs were found in Laki Island. Based on field observations, in the shallow waters of that location, there are many rubbles that cover some of the benthic areas of the island.

Table 2. The area of each coastal ecosystems derived from imagery.

Islands Ekosystem	Lancang Island (ha)	Bokor Island (ha)	Laki Island (ha)
Mangrove	9.38	-	3.93
Seagrass	105.34	10.29	15.27
Reefs	72.19	6.62	6.87

Geomorphological characteristics of benthic habitat obtained from modeling using BTM were grouped by geomorphological zone. There were four classes of geomorphological zone used in the classification of benthic habitats, i.e. Crest, Slope, Depression and Flat [8, 16]. The results of the analysis indicate that the benthic geomorphology in the study sites tends to be flat, the crest zone is found in the area close to the mainland, and some of the crests are found in areas close to Laki Island. Generally, the results of the analysis indicate that the geomorphological characteristics around of the Laki Island are more complex than others.

3.2. Spatial distribution of fishing ground

The location of the crab fishing by the Lancang Island fishermen has varied distribution based on the spatial grid. At each fishing season, the distribution of fishing ground was generally concentrated in the

South and West of Lancang Island. As can be seen in figure 4 on the southern Lancang Island be fishing every monsoon, which means that the area is almost a center for the fishing ground of blue swimming crab throughout the years. Certain locations are only be fishing in some seasons, for example on grid A4 and B2 are only fishing in the northwest monsoon, at other locations, ie, on grid A8 and D2 only fishing during alternate two monsoons.

The information obtained from fishermen that among their considerations in selecting fishing sites is a high chance of catching in certain areas. When they get a catch at a location, it is likely they will revisit the same location. As can be seen in figure 4, several grids location have fished in 3 - 4 seasons, i.e., in grids A5 and C5 while in other locations it is only in 1 - 2 fishing seasons, i.e., A8 and B8.

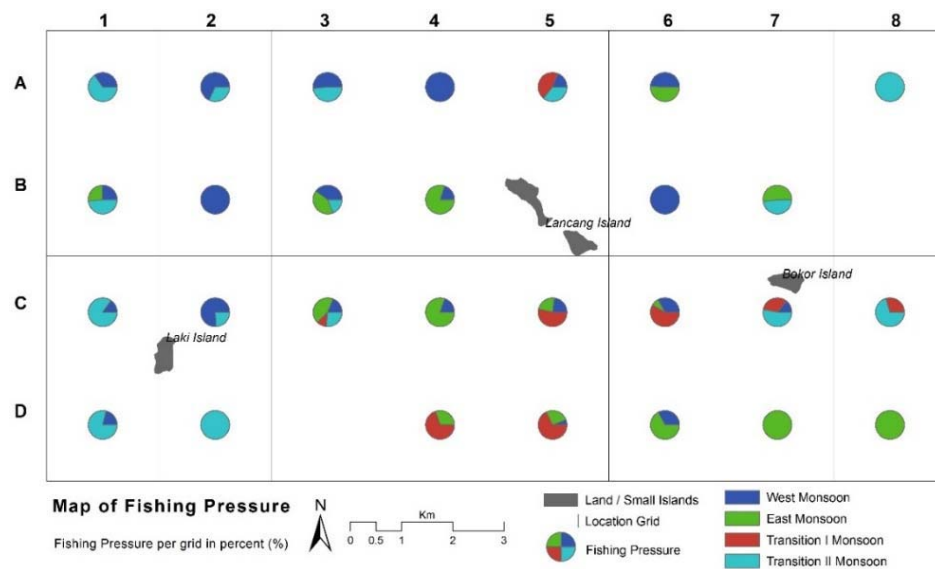


Figure 4. The distribution fishing intensity based-on seasonal fishing monsoon.

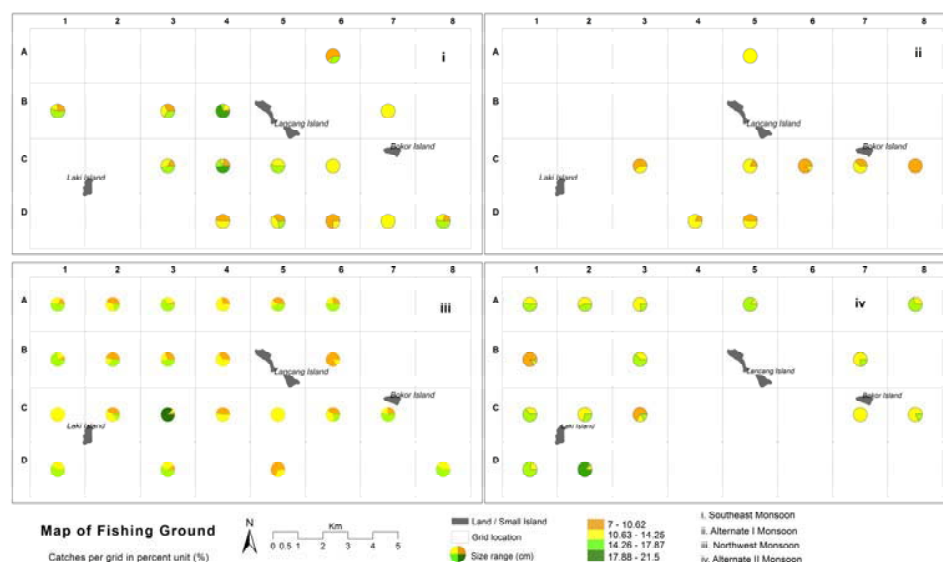


Figure 5. Map of distribution of fishing ground in every monsoon.

The blue swimming crab caught by fishermen have a size range of 7 - 21.5 cm distributed varying in each grid. Based on fishermen information, their fishing sites are located at 10-26m of water depth. In Lampung waters, Zairion, et al. [17] obtained crab sampling catch with a size of 5.1 cm at the area with depth less than 5m. To facilitate the analysis process, the range of sizes were grouped into 4 classes: C1 (7 - 10.62 cm), C2 (10.63 - 14.25 cm), C3 (14.26 - 17.87 cm), and C4 (17.68 - 21.5 cm). Based on the fishing season, the C1 and C2 classes almost dominate in the alternate two monsoons, while in the other three seasons vary with the highest catchment variation in the northwest monsoon (figure 5). In the northwest seasons, besides the variations in different size classes, it also appears to be the fishing season with the highest intensity than other seasons.

3.3. Marxan results

The analysis for determining potential sites using Marxan was done by applying several scenarios. Scenarios in the analysis were more emphasized on the representation of conservation features at each potential location. There were three scenarios values of the proportion of conservation features applied, i.e. 30%, 40%, and 50%. After applying some experimental parameter values in the analysis, the final selected parameters are the proportion of 30% (0.3), boundary length modifier (BLM) 2, species penalty factor (SPF) 1, and 1000 repetitions.

Potential areas identified from spatial analysis results, obtained in three locations (figure 6). The first location is around of Laki Island, which is concentrated in the East to the North of Laki Island. The second location is South of Lancang Island, and the third location is in the Southeast of Lancang Kecil Island, especially between Lancang Kecil Island and Bokor Island. From the three potential sites, based on the researchers' judgment, such as the ease of monitoring and possible conflicts of marine spatial use, the proposed sites for marine sanctuary are in the potential site 1 (around of Laki Island). In this area represents the distribution of coastal ecosystems as well as the uniqueness of geomorphological characteristics of the benthic habitat. In this region, a significant number of crabs with less than 10 cm of sizes, besides that this area is not a main of fishing area of blue swimming crab by local fishermen.

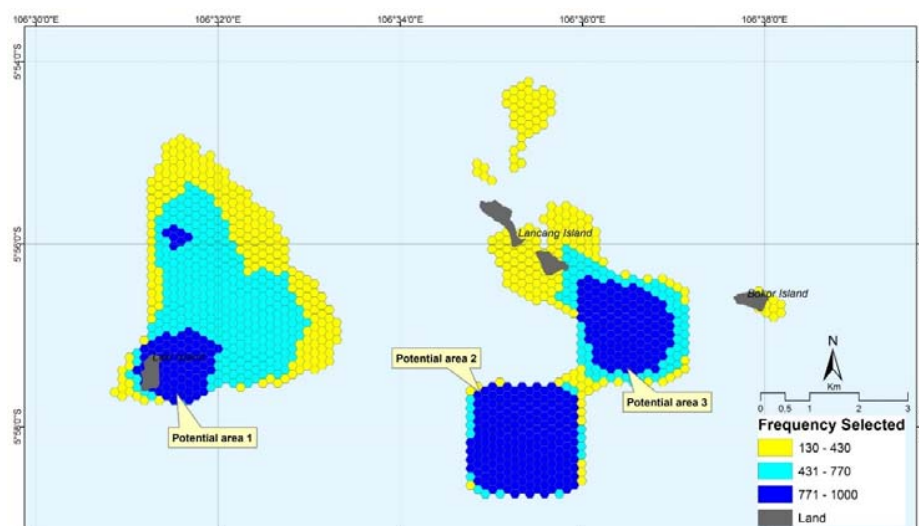


Figure 6. Potential locations for a marine sanctuary.

4. Discussion

Marxan was able to find potential sites for proposing as marine sanctuary around Lancang Island. Considering coastal ecosystems, habitat geomorphological characteristics, and spatial distribution of blue swimming crab, especially the captured sizes. The cost parameters represented by the intensity of fishing ground and the vessel traffic are considered to avoid conflicts in the utilization of marine spaces. In this case marxan is quite reliable in determining the planning decisions to minimize the possibility of

marine space utilization conflicts [9, 10]. Marxan has been widely known and widely used as a tool in designing conservation areas, including marine protected areas. Even other studies use Marxan to design a watershed as a development area of economic centers as marine aquaculture areas [15].

Most of the analysis conducted in designing the marine conservation has not considered the complex parameters. This study tries to include one of the parameters in the analysis process that unnoticed, namely the habitat complexity of the study location. The habitat complexity describes the complexity of seafloor, in this case, is the variety of benthic features present in the study site. The habitat complexity can be measured through several approaches, the approach taken in this research was based on geomorphological characteristics of the seafloor. In shallow waters where electromagnetic waves can penetrate to the bottom of the water column, geomorphological characteristics can be derived from satellite images [18,21]. In deeper waters, the benthic geomorphological characteristics of can be analyzed by using bathymetric information obtained from several sources [6,22].

Most of the region in northern of Kepulauan Seribu are included as conservation area known as Taman Nasional Kepulaun Seribu (TNKpS). For the areas that do not include in TNKpS, i.e. some inhabited islands, some of the waters have been designated as a marine sanctuary (Daerah Perlindungan Laut-DPL) and managed by local communities. Marine sanctuaries on the other islands, i.e. as many as six sites in Kepulauan Seribu, the threat to some of these areas comes from the ever-increasing marine tourism activities. Lancang Island or Laki Island is proposed as a marine sanctuary to minimize exploitation and pressure of fisheries resources, especially blue swimming crab that does not pay attention to the sustainable stock in marine environment.

Lancang Island is currently the only one fisheries center in the South of Kepulauan Seribu, so it needs a sustainable fisheries management model. One of the management models is to set part of the marine area as the marine protection, that is conservation of marine in small scale. The expected benefits to be achieved if the marine sanctuary around the Lancang Island established, among them is the protected of shallow water ecosystem (seagrass and coral reefs) so that it retained its function as a supplier of ecological processes in the marine environment. By applying some locations as a marine sanctuary, it is also expected to realize the utilization of fishery resources, especially the wiser in exploitation of blue swimming crab to achieve sustainable fisheries.

5. Conclusion

From this research can be made some conclusions, first by integrating some aspects geospatially, marxan able to identify the potential locations for designation of the marine sanctuary. Second, there are three potential locations found for marine sanctuary in the study site, and the recommended location is around of Lancang Island. We hope the results of this study can be considered by decision-makers to determine some areas in the around of the Lancang Island to designate as a marine sanctuary.

Acknowledgement

Special thanks to Ministry of Research, Technology and Higher Education who has funded this research through BOPTN in 2015 – 2016. And the community of Lancang Island for the cooperation when conducting this research.

References

- [1] Traganos D and Reinartz P 2017 Mapping Mediterranean seagrasses with Sentinel-2 imagery *Mar. Pollut Bul.* Jul 01
- [2] Pu R and Bell S 2017 Mapping seagrass coverage and spatial patterns with high spatial resolution IKONOS imagery *International Journal of Applied Earth Observation and Geoinformation* **54** 145-158
- [3] Heumann B W 2011 An object-based classification of mangroves using a hybrid decision tree-support vector machine approach *Remote Sensing* **3** 2440-2460
- [4] Roelfsema C, Phinn S, Jupiter S, Comley J, and Albert S 2013 Mapping coral reefs at reef to reef-system scales, 10s–1000s km², using object-based image analysis *International Journal of Remote Sensing* **34** 6367-6388

- [5] Haya L O M Y and Fujii M 2017 Mapping the change of coral reefs using remote sensing and in-situ measurements: a case study in Pangkajene and Kepulauan Regency, Spermonde Archipelago, Indonesia *Journal of Oceanography* **2017**
- [6] Lundblad E R, Wright D J, Miller J, Larkin E M, Rinehart R, Naar D F, *et al.* 2006 A Benthic Terrain Classification Scheme for American Samoa *Marine Geodesy* **29** 89-111
- [7] Wedding L M, Friedlander A M, McGranaghan M, Yost R S and Monaco M E 2008 Using bathymetric lidar to define nearshore benthic habitat complexity: Implications for management of reef fish assemblages in Hawaii *Remote Sensing of Environment* **112** 4159-65
- [8] Subarno T, Siregar V P, Agus S B, and Sunuddin A 2016 Modelling complex terrain of reef geomorphological structures in Harapan-Kelapa Island, Kepulauan Seribu *Procedia Environmental Sciences* **33** 478-486
- [9] Ball I R, Possingham H P and Watts M 2009 Marxan and relatives: software for spatial conservation prioritization *Spatial conservation prioritization: quantitative methods and computational tools Oxford University Press Oxford* pp 185-195
- [10] Ardron J A, Possingham H P, and Klein C J 2010 *Marxan Good Practices Handbook*
- [11] Otukei J R and Blaschke T 2010 Land cover change assessment using decision trees, support vector machines and maximum likelihood classification algorithms *International Journal of Applied Earth Observation and Geoinformation* **12** S27-S31
- [12] Wright D J, Lundblad E R, Larkin E M, Rinehart R W, Murphy J, Cary-Kothera L, *et al.* 2005 ArcGIS Benthic Terrain Modeler
- [13] Pasnin O, Attwood C and Klaus R 2016 Marine systematic conservation planning for Rodrigues Island, western Indian Ocean *Ocean and Coastal Management* **130** 213-220
- [14] Watts M E, Ball I R, Stewart R S, Klein C J, Wilson K, Steinback C, *et al.* 2009 Marxan with Zones: Software for optimal conservation based land- and sea-use zoning *Environmental Modelling and Software* **24** 1513-1521
- [15] Henriques N S, Monteiro P, Bentes L, Oliveira F, Afonso C M L and Gonçalves J M S 2017 Marxan as a zoning tool for development and economic purposed areas - Aquaculture Management Areas (AMAs) *Ocean and Coastal Management* **141** 90-97
- [16] Erdey-Heydorn M D 2008 An ArcGIS Seabed Characterization Toolbox Developed for Investigating Benthic Habitats *Marine Geodesy* **31** 318-358
- [17] Zairion Z, Boer M, Wardiatno Y and Fahrudin A 2016 Composition and size of the blue swimming crab (*Portunus pelagicus*) caught at several bathymetric stratifications in East Lampung Waters *Jurnal Penelitian Perikanan Indonesia* **20** 199-206
- [18] Phinn S R, Roelfsema C M and Mumby P J 2012 Multi-scale, object-based image analysis for mapping geomorphic and ecological zones on coral reefs *International Journal of Remote Sensing* **33** 3768-3797
- [19] Hamilton S M and Spencer T 2011 Geomorphological modeling of tropical marine landscapes: Optical remote sensing, patches and spatial statistics *Continental Shelf Research* **31** S151-S161
- [20] Anggoro A, Siregar V P, and Agus S B Geomorphic zones mapping of coral reef ecosystem with OBIA method, case study in Pari Island *Jurnal Penginderaan Jauh* vol **12** pp 1-12 2015
- [21] Selamat M B, Jaya I, Siregar V P and Hestirianoto T 2012 Geomorphology zonation and column correction for bottom substrate mapping using Quickbird Image *Jurnal Teknologi Perikanan dan Kelautan* **3**
- [22] Wright D J and Heyman W D 2008 Introduction to the special issue: marine and coastal GIS for geomorphology, habitat mapping, and marine reserves *Marine Geodesy* **31** 223-230