

Marine Environmental Suitability Mapping for Lobster Sea-cage Culture in East Lombok Using Remote Sensing Data and GIS Approaches

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Abstract

Zealandia Sarah N.F., Anggia Rivani, Bety Puspitasari, Firdian I., Fonna M., Ridho Dwi D., Sufiyana Eka P., and Wirastuti Widyatmanti. 2016. Marine Environmental Suitability Mapping for Lobster Sea-cage Culture in East Lombok Using Remote Sensing Data and GIS Approaches. *Aquacultura Indonesiana*. 17 (2): 60-68. Lobster, one of the high values sea-cage culture commodities in Indonesia, has some specific requirements of life environment. However, there haven't been any studies that specifically identify these potential sites. Until today it is only 3.50 ha out of 526.86 ha of these that have been utilized. This study aims to map the marine suitability environment for lobster cultivation in Ekas Bay, using remote sensing and GIS approaches. The requirement parameters maps for lobster marine suitability, includes oxygen levels (DO), nutrition, salinity, temperature, depthness, pH, and water clearance which were extracted from Landsat 8 imagery. Using GIS, a model was developed to integrate those maps with marine environment secondary maps, water laboratory analysis, and other information from interview result with the local farmers. The result showed that lobsters live in the temperature environment between 20⁰ and 25⁰C while the water depth 100 m. Laboratory analysis resulted pH value of above 7 in average, DO from 5-8 mg/L, and salinity level from 28 to 35 ppt. In summary, the integration of remote sensing and GIS approaches were able to identify the common parameter that support the environment suitability for lobsters which can be formulated as a standard of marine environment suitability mapping.

Keywords: Lobster; Marine suitability environment; Remote sensing and GIS

Introduction

East Lombok Regency has marine environment covering 1,074.33 km² area and its approximately 220 km coastlines (MMAF-CTF, 2014). This marine environment is famed with abundant natural resources that had enough potential to support the welfare of East Lombok society. One of the leading fishery commodities in this area is lobster which is a highly prized crustacean, following the increasing demand from both local and international market (Hart, 2009). The potential area for the lobster cultivation reaching 526.86 ha based on the productivity and wild capture activity report, but it was only about 3.50 ha that has been utilized for traditional sea-cage culture (CTF, 2006). However, in 2014, lobster cultivations in East Lombok in-shore marine environment have been vastly growing and becoming a trend in society (MMAF, 2015). There are approximately 2,000 units of floating net and the longline net to capture the lobster seeds. In addition, there are another approximately 1,000 units of floating net which are used to rise the lobsters in waters south of the island of Lombok. This vast growing of

lobster cultivation, however, are only located in some specific and limited cluster only. The lack of information related to distribution of marine territorial areas and of potential environment for lobster habitat become the main reason of that limited lobster cultivation areas.

Lobsters inhabitant a specific water environment. Previous studies revealed that several habitat parameters can be identify through its physical characteristics, i.e., the coral coastal waters, salinity, pH, depth, chlorophyll-a, current, wave, and temperature (MMAF, 2015; Priyambodo, 2013). Most of those data were collected using detail field survey covering small scope area. In fact, to develop a coastal management planning it is important to recognise the sea water quality of the in-shore marine environment through spatializing theses information through mapping. Nevertheless, the conventional data generation needs immense coast, energy and time, before it becomes a guidance or fact foundation for decision maker. Therefore, a valid but rapid and effective methods to map the water quality data that covers large area are urgently needed.

Remote sensing data together with Geographic Information System (GIS) are well known as the solution to significantly decrease the cost, time and energy consumption in terrestrial survey (Sutanto, 1999). Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 2000). In the fields of marine, satellite imagery is commonly used to monitor and analyze the condition of the water. The parameters that can be detected by satellite sensors include sea surface temperature, chlorophyll-a and suspended solid (Hellweger *et al.*, 2004). As remote sensing and GIS also can be applied to extract the coastal and marine parameters that related to the characteristics of lobster habitat, with cautious investigation and identification on the type of data, approach and algorithm, it is possible to consider them as the water quality rapid assessment solution. Several water quality algorithms for remote sensing data extraction that related to the lobster habitat characteristics are the temperature of the sea water, turbidity, salinity of sea water, and the concentration of chlorophyll-a.

The integration of remote sensing data and GIS develop a model to generate the in-shore marine environment suitability for lobster. The management and analysis of spatial data research results carried out using GIS. This applications can be used in the management of territorial waters using decision support system to choose the suitable location for marine aquaculture, such as site selection for lobster marine environment (modelling) (Prahasta and eddy, 2002). Therefore, this study aims to map the in-shore marine suitable environment for lobster cultivation in Ekas Bay, East Lombok using (and identifying) the most appropriate remote sensing and Geographic Information System (GIS) approaches.

Method

Study area

The study area was located in Ekas Bay, Eastern Lombok, West Nusa Tenggara (Figure 1). This study processed the Landsat 8 which were recorded on May 19, 2016. Landsat imagery were processed using ENVI and ArcGIS software to obtain the parameters in determining the suitability of the marine environment for lobster (Ramdan and Arifin, 2013). Extracted Data from

the satellite imagery were sea surface temperature, chlorophyll-a, and NDSSI. Other parameters such as TSS, DO, chlorophyll-a, salinity, and pH, were obtained from water laboratory analysis (Sidik, 2014). These parameters were determined the samples number and location by generating new marine environment unit using superimposed method. Post-field survey were also conducted to check the validity, and the regression of the field data (Sugiyono, 1999).

Sampling was conducted between 9 to 10 am in accordance with the recording time of Landsat 8, covering the sites of floating cages and non floating cages. The results of random sampling method obtained 6 samples for laboratory analysis spreading in the Ekas Bay, but almost every mapping unit were being field sampling/measured. The parameter values taken in the field are the water temperature and the water turbidity while the value of Total Suspended Sediment (TSS), chlorophyll-a, pH, salinity, and dissolved water (DO) were analysed in the laboratory.

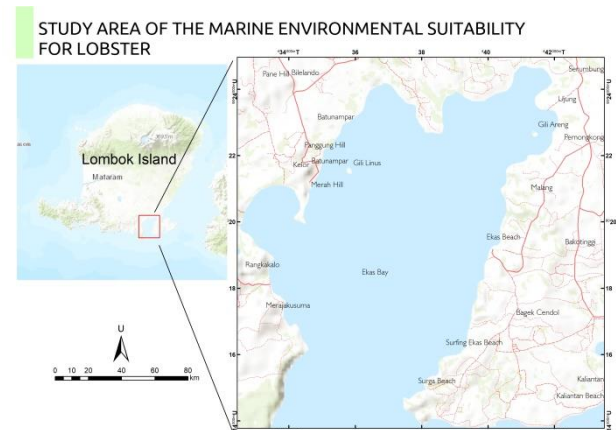
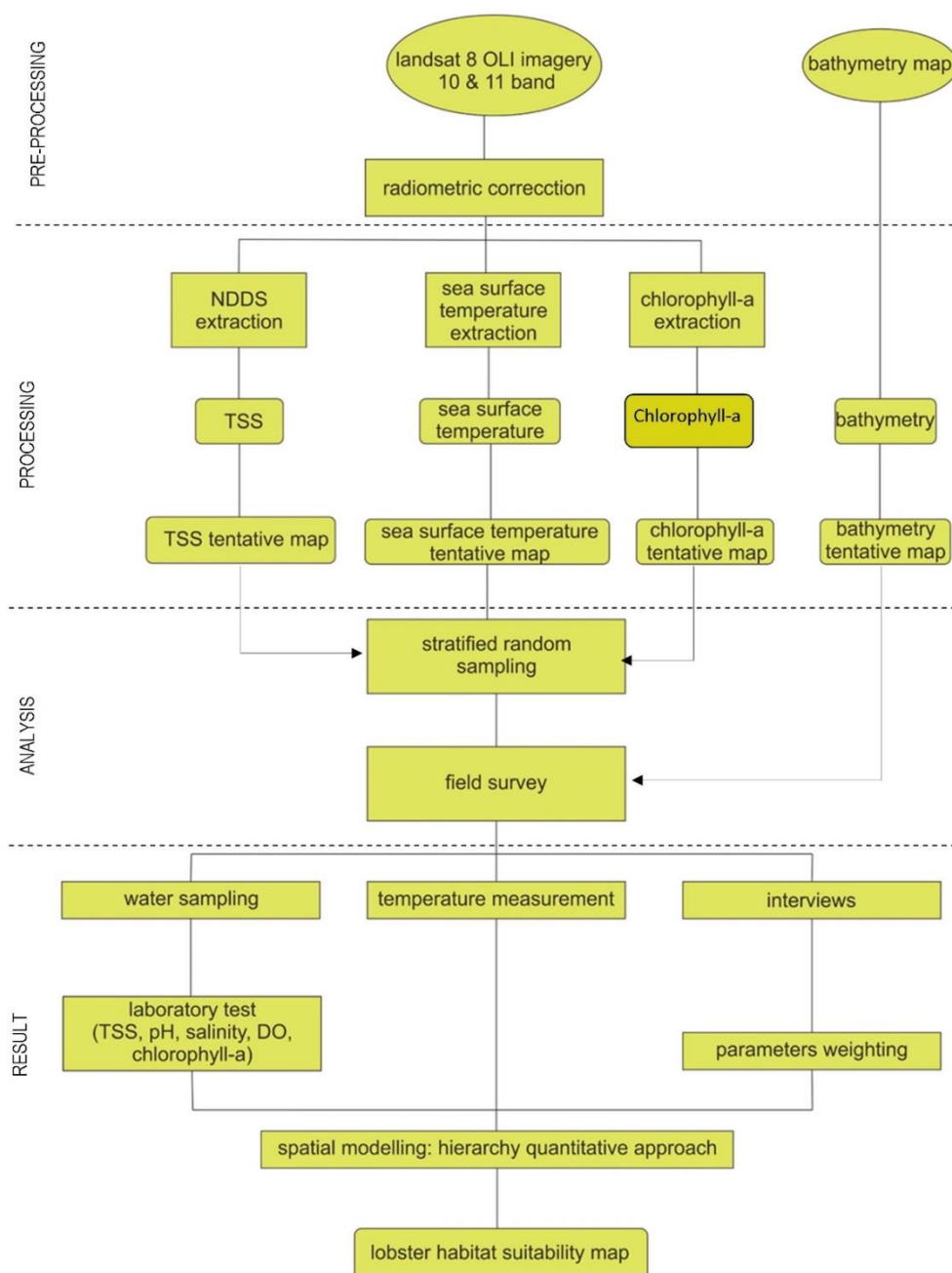


Figure 1. The study area, Ekas Bay, Eastern Lombok Province.

Image processing methods

The Landsat 8 image processing stage involved several algorithms to obtain the map of NDSS, SST and Chlorophyll-a values. These maps, combined with the available bathymetry map, were superimposed to get the mapping unit to determine the location of water sample collection. The sampling points were taken to represent each mapping unit using stratified random sampling method. The maps from the Landsat 8 extraction then being validated based on the water laboratory analysis result using regression statistical analysis. From this result a model was develop using hierarchy quantitative approach, based on the marine environment suitability criteria generated from the field survey and interview results.



The research flow diagram

Landsat 8

Landsat 8 has two sensors which are onboard Operational Land Imagery (OLI) and Thermal InfraRed Sensor (TIRS). This satellite consists of 9 channels (band 1-9) in the OLI sensor and of 2 channels (bands 10 and 11) on TIRS. Landsat 8 has a spatial resolution of 30 m for visible and infrared channels (TIRS resampled from 100 m to 30 m), and 15 m for the panchromatic channel, which is appropriate for

mapping shallow water environment. The new band 1 (ultra-blue) is useful for coastal and aerosol studies. This study utilized the Landsat 8 to gain the information of sea surface temperature, total suspended solid and sediment from NDSSI, and Chlorophyll-a. Whereas, other parameters were obtained from direct measurement on the field which was coinciding to the Landsat 8 time range of acquisition in Indonesian territory.

Sea Surface Temperature

Sea surface temperature from Landsat 8 can be extracted from the value of the spectral radiant (T_R). This radiance temperature is then being converted into kinetic temperature (T_K)

$$T_R = \frac{K_2}{\left(\ln \left(\frac{K_1}{L_\lambda + 1} \right) \right)}$$

T_R : Radiance temperature ($^{\circ}K$)
 K_1 : Constant calibration 1 ($774.89^{\circ}K$)
 K_2 : Constant calibration 2 ($1321.08^{\circ}K$)
 L_λ : TOA spectral radiance

This T_K formula produces a kinetic temperature value corresponding to the value of the object temperature on Earth with equations from Robinson (1985).

$$T_K = \frac{T_R}{\varepsilon^{1/4}}$$

T_K : surface temperature
 ε : sea water emissivity (0.98)

Water depth

Water depth is closely linked to productivity, vertical temperature, light penetration, density, oxygen, and nutrients that affects the biota were cultivated (Hutabarat and Evans, 2006). It is also related to the pressure received in the water, because it is increasing within the depth (Nybakken, 1992). In this study, water depth information was obtained from the interview with local farmers. Water depth was derived from national sea environmental map.

Normalize Difference Suspended Sediment Index (NDSSI)

Normalize Difference Suspended Sediment Index (NDSSI) is an index used to develop models that are associated with dissolved sediments in water (Azad *et al.*, 2012). NDSSI utilizes the values of blue and near infrared bands. NDSSI produce the index with vulnerable level of -1 to + 1. A lower value means more turbid water conditions and higher means brighter.

$$NDSSI = \frac{p_{blue} - p_{nir}}{p_{blue} + p_{nir}}$$

Total Suspended Solid (TSS)

The analysis of Total Suspended Solid (TSS) is a method to determine the number and distribution of material suspended in a water environment. The higher concentration of Total Suspended Solid (TSS), the higher sedimentation is, especially on the mouth of the river and along the coast (Siswanto, 2010). The good suspended solids concentration for marine cultivation is 5 to 25 mg/L (KLH, 1988). TSS was got by taking the sea water before brought to the laboratory to be tested.

Chlorophyll-a

Chlorophyll is a group of photosynthetic pigments on vegetation. It absorbs red, blue, and purple light and reflects the green light so it can reveal their vegetal characteristics. Chlorophyll-a is one source of foods for small fish such as pelagic fish. Thus the higher content of chlorophyll-a means a marine area is more fecund and have a lot of fish. The availability of fish in the waters as a food source is associated with lobster marine suitability environment. It was measured by taking the sea water, then brought to laboratory to be tested.

The algorithm used in the extraction of chlorophyll is an algorithm from Nuriya *et al.* (2010), with some modification from Landsat 7 ETM⁺ to Landsat 8 OLI on their band ratio. The band used in the extraction of chlorophyll below are band 6, 5, and 4.

$$C = 0.2818x \left(\frac{B5+B6}{B4} \right)^{3.497}$$

Explanation

C : Concentration of chlorophyll-a (mg/m3)
 B4 : Reflectance Value Landsat channel 4
 B5 : Reflectance Value 5 Landsat 8 channels
 B6 : Reflectance Value channel 6 Landsat 8

Salinity

Salinity is dissolved salts in one kilogram of sea water and is expressed in units of part per thousand or ppt (Nybakken, 1992). The sea water of dissolved salts especially assorted NaCl,

otherwise, there are salts of magnesium, potassium, etc. (Nontji, 1993). Salinity was measured by laboratory testing at Balai Perikanan Budidaya Laut (BPBL) in Lombok.

Dissolved Oxygen (DO)

Soluble oxygen is the oxygen that are dissolved in the water, which is a main component for the metabolism water organism which are used for growth, reproduction, and fertility algae (Arrigo, 2005). Factors that reduce levels of oxygen in the sea water is the rises of water temperature, respiration (especially at night), the oil layer above the sea level and the entry of organic waste which is easily disassemble into the sea environment (Khasanah, 2013). DO was known by the laboratory testing at Balai Perikanan Budidaya Laut (BPBL) in Lombok.

pH

The degree of acidity (pH) is a measure of the amount of hydrogen ion concentration and indicate whether the water is acidic or wet in reaction (Wardoyo, 1975). The degree of acidity (pH) has an enormous influence on waters organisms so it is used as a hint to state the water quality level. It was measured by taking the sea water before tested by universal indicator to know the acidity level of the sea water.

Interview process

Interview were conducted to identify other information that related to the marine suitability environment for lobster which couldn't be obtained from the existing or post-processing data. According to Sarjono and Budi (1996), the general morphology of a lobster are the symmetrical body that consists of feet on segment, and of principals (cephalothorax), body (abdomen), and tail. The regional dissemination of lobster can be divided into three, among others:

1. Types of lobster off the coast (oceanic species) that lobsters that live in deep ocean waters,
2. Types of lobster water coral (coral species) is living in the coral waters of the inshore and off the coast rather inside
3. Type of lobster shallow waters of the beach reefs (*continental species*)

From the interview results, it is concluded that lobster is one type of shrimp that live in rockery sea waters or in the area that has a coral reef. Other species of lobsters also lives on sandy or muddy shallow seafloor. Lobster has a high economic value because they contain high nutrient sought by local and global people. Adult lobsters are going towards deep water to release larvae or eggs that have been fertilized. But the larvae live in shallow water with a depth of 2-5 m, near the beach or mangrove, to be juveniles. Young lobster will live in waters with a depth of 10-15 m and the adulthood in a depth of 20-30 m, and are commonly on the corals hole and caves. Lobster is a shrimp species that will actively foraging in shallow water at night (Nocturnal) so it will settle into a hole or coral cave at noon. Lobster also make the change of skin process (molting). The type of lobster food is mollusc (conch, shellfish) and echinoderms as well as fresh fish.

Some types of lobster that can be found in this bay are the pearl lobster (*Panulirus Ornatus*), green lobster (*Panulirus homarus*), flowers lobster (*Panulirus longipes*), jaka lobster (*Panulirus penicilatus*), barong lobster (*Panulirus vercicalor*), and orchids lobster (*Panulirus laevicanda*). Out of these six species, the green sand lobster (*Panulirus homarus*) is the most abundant caught and cultivated species.

The criteria for water suitability environment

The quality of water for sea lobsters not been obtained specifically. However, the results based on the interview and the standard of good water quality for general marine cultivation (MMAF, 2015) are the criteria for lobster marine environment suitability covering:

- pH above 7;
- dissolved oxygen ranges from 5-8 mg/L;
- depth of 15-25 m
- salinity of 28-32 ppt and;
- temperatures, from 25 to 29°C;
- For species of bamboo lobster, batik lobster, lobster and rock lobster color the salinity ranges from 26-30 ppt salinit, whereas for sand and pearl lobster, the ranges are from 32 to 35 ppt.

Result and Discussion

The interview result

The fishermen, breeders and collectors who are looking for lobsters in the Ekas Bay are mostly local people living around Ekas Bay. They mostly catch *Panulirus homarus* and *P. ornatus* because of their money wise. The fisherman use simple nets to catch the lobster to reduce costs and environmental damage. The best fishing season is during the dry season because of its calm waves and its warm sea water temperature. While, the best time to catch lobster is at sunset until sunrise because lobster is sensitive to the presence of light.

Lobster live at ocean depths between 0 to 100 m. The age of caught lobsters are varied, ranging from a few days (seed lobster) up to 12 months. Lobster seedling weights are less than 100 grams, while the lobster aged between 6-12 months had a weight of about 100-300 g. The location where lobsters are commonly found about 200 m from the coastline, thus many fishermen catch the lobster along the shoreline of the bay. Diseases commonly found in the Ekas Bay is yellow head disease. If the disease is severe, the infection spot may appear on the body of the lobster. A little lobster disease is characterized by the appearance of a milky white spots on the underside of the body of the lobster and a broken leg.

Lobster can be found on the sea with coral reefs, but fishermen also often find lobster on the sea surface when the sea is under a calm current condition. The farmers takes the lobsters seeds directly from the sea. They feed these lobsters with Ruca fish as well as pellets. All farmers do not use any kind of chemicals food to breed lobsters. Most farmers know that the temperatures required by lobsters in captivity is between 20-25 degrees Celsius. Farmers found and caught lobster at a depth of 0-100 m on the clear rocky sea water.

Sample points

Sampling results indicate that the water temperature in the Ekas Bay of 6 samples was taken between 30°C and 30.5°C. Laboratory tests result in TSS values ranging from 0:17 to 0:12 mg/L. This value shows the level of clarity of the water in the sample sites included into clear categories. Chlorophyll a in the Ekas Bay ranged from 0.0118 mg/m³ up to 0.0771 mg/m³. According to Salmin (2000), the criteria of

chlorophyll-a on the bays and estuaries is considered as good if the values is under 15 mg/m³, as medium for 15-30 mg/m³ category, and as poor for below 30 mg/m³. Th chlorophyll-a content in the Ekas Bay is categorized into good category.

The level of acidity or pH was around 8, while the salinity were more various ranging from 23 to 28 ppt, this value indicates that the salinity in the Ekas Bay was categorized as moderate to high. Dissolve Oxygen was ranged from 6 to 8 mg/L. Standard dissolved oxygen for aquatic organisms in coldwater fisheries is minimum 7 mg/L and 5 mL/g for protected warm water fisheries, but no more than 12 mg/L (ANZECC, 2000). Thus, the results showed that the content of DO in the Ekas Bay was suitable for marine organisms habitat including lobster.

The comparison between each parameter of water quality on sea-cage and non sea-cage shows that there was no significant different. It means that there was no modification needed when applying sea-cage for lobster in natural conditions.

The regression analysis on NDSSI, chlorophyll-a and SST

NDSSI is an index of water clarity obtained from satellite imagery. Tabel 1 shows that changing of values of NDSSI and TSS are not proportional so when the TSS is higher, the value NDSSI is not always consistently higher. Therefore, the *r* value produced from the regression analysis is 0.0836, indicating the absence of a relationship between NDSSI with TSS so the regression results should not be used for further modelling. This low value of *r* between these two variables could be caused by a different date of sampling collection to the one of image acquisition, even though the time of samples collection is the same with the one of imagery acquisition (the image was recorded on May 19, 2016 and samples were taken on 23rd and 24th May 2016. Therefore, there is probably already a changing in water conditions that are not represented by the collected water samples. Another possibility that causing this low *r* value is that the pixel values of the image represent only 30 m x 30 m area, so more detail sampling representing that several pixels in one mapping unit is definitely needed for future studies.

Chlorophyll-a value can be estimated through the process of extraction from remote sensing imagery. Chlorophyll-a regression value

of imagery aims to determine the equation of the relationship between the pixel values of the image with the samples taken in the field (Tabel 1). However, in this study the comparison between the image processing and laboratory tests of chlorophyll-a results are not alike, resulting another low r value on regression analysis. Similar reasons to NDSSI situation are identified as the main factors of this absence of relationship on Chlorophyll-a parameters.

Regression analysis was also carried out for the temperature parameter to correct the pixel values of the image using the field data samples. As on the previous two variables, the temperature

also has a low r value (lower than 0.1). The causes of the low r value of determination the regression analysis experience similar issues as occurred on two previous parameters. However, on this temperature variable, other important factor was the inappropriate temperature instrument which only have lower accuracy of 0.5 so compared to three decimal number from imagery algorithm processing result. Nonetheless, this study is able to provide the parameters maps based on the mapping units generating from the imagery processing but the database was develop using field and laboratory measurements (Figure 2).

Tabel 1. The parameters average values measured from some sample points based on image processing and field survey/laboratory analysis

No.	Suspended Solid		Chlorophyll-a		Sea surface temperature	
	NDSSI	TSS	based on imagery	field survey	based on imagery	field survey
1	0.62	0.14	0.0237	0.33	24.02	30.00
2	0.61	0.12	0.0118	0.29	23.93	30.00
3	0.68	0.17	0.0296	0.13	24.06	30.00
4	0.71	0.16	0.0534	0.06	24.05	30.50
5	0.48	0.16	0.0771	0.78	24.22	30.50

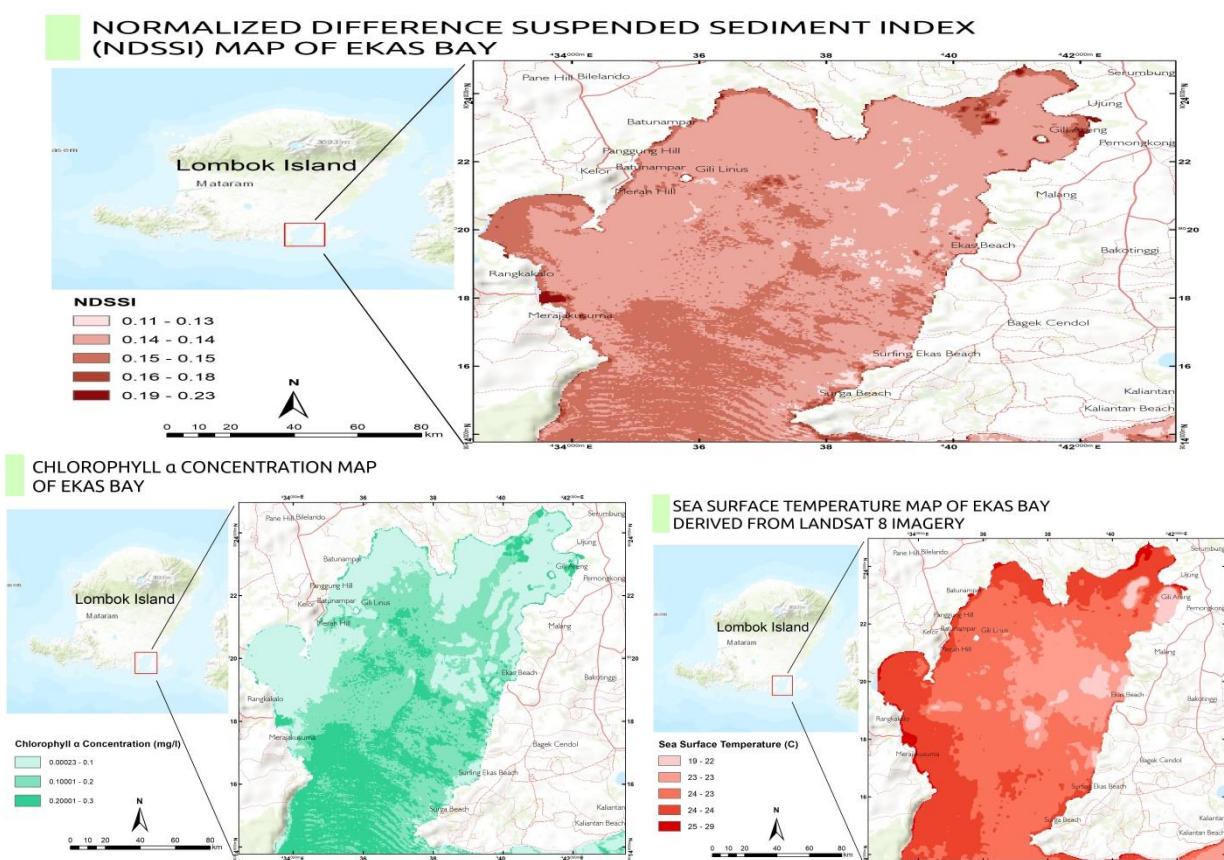


Figure 2. The maps of parameter image processing results showing the distribution values of NDSSI, Chlorophyll-a and SST based on image processing.

The Modelling's Results

The sea environmental suitability modelling for lobsters was obtained from overlaying the parameters map using hierarchy quantitative approach, by comparing the mapping units of each parameters maps and the interview result. From that method it was found that the order to put those parameters together in generating suitability map are salinity, temperature, food sources (from the chlorophyll-a), turbidity, and depth.

The result of the modelling shows that the lobster marine environment suitability level at this area are mostly high, especially nearby the in-shore marine (Figure 3). This suitable marine environment meet the criteria concluded from this study modelling processes. The salinity and temperature become the main factors that influence the suitability level, as lobster life is vulnerable by these parameters changing. The unstable environment weaken the lobster and lead to different kind of diseases. For the marine environment of medium and low suitability level, they were validated by the interview result and observation that the fisherman rarely sail farther out of the coast or bay when they catch the lobsters. Indeed, the boundary of mapping units are not definite, as other factors such as wind, current movement influence the water column quality parameters seasonally. Nonetheless, the preliminary study presents the possibility to spatially map the marine suitability environment for lobster or other in-shore marine cultivation using remote sensing and GIS.

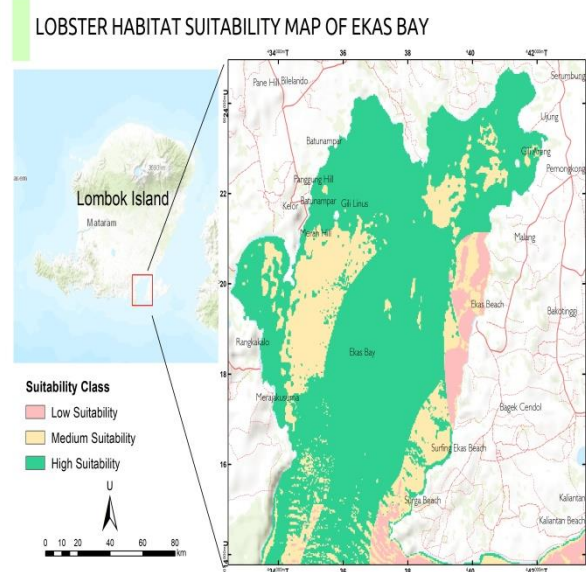


Figure 3. Map of marine environmental suitability level for lobster.

Conclusion

The results of this study can be concluded that the parameters that have high to low influence on the environment suitability lobster is salinity, temperature, food sources, and depth. Based on field surveys, Ekas Bay which is the location in this study had a marine environment that is suitable for the cultivation of lobster.

Values lower regression showed that the necessary studies with more samples and details. Selection algorithm used for modeling in sub-tropical locations need to be careful because it is not always suitable to be applied in a tropical location. Utilization of remote sensing in the future is expected to determine the most appropriate algorithm or can develop new algorithms for a tropical country so the results more accurate.

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