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The potential study of marine aquaculture location in Eastern Bintan Island

R Pramana[1*], R D Putra[2], B Y Suprapto[3] and Z Nawawi[3]

[1]Department of Electrical Engineering, Faculty of Engineering, Maritime Raja Ali Haji University, Kampus UMRAH Senggarang 29111, Tanjungppinang, Indonesia
[2]Department of Naval Architecture, Faculty of Engineering, Maritime Raja Ali Haji University, Kampus UMRAH Senggarang 29111, Tanjungppinang, Indonesia
[3]Department of Electrical Engineering, Faculty of Engineering, Universitas Sriwijaya, Jl. Raya Palembang Prabumulih, KM.32, Indralaya, Indonesia

*E-mail: risandi@umrah.ac.id

Abstract. Bintan is one of Indonesia's islands, consisting of nearly 2408 small islands and directly adjacent to Singapore and Malaysia. The strategic geographic location and many small islands and supported by 95% of the sea area give Bintan Island an advantage in developing the marine aquaculture sector. This study aims to apply remote sensing analysis to collect comprehensive information on the strategic Marine Aquaculture Zone (MAZ) in the eastern part of Bintan Island. The data used in this study were the concentration of *chlorophyll-a* (Chl-a) and Sea Surface Temperature (SST) from MODIS level-3 with a resolution of 4 km from January to December 2019. The pre-processing data analysis on SST and Chl-a concentrations was used SeaDas software to ensure the results of the data projections in the form of the World Geodetic System 84 (WGS84) format. The data processing stage uses ER Mapper software to project the SST distribution and Chl-a concentration into a contour. Post-processing data analysis was used ArcGIS software to determine the results of crossing the SST contour and Chl-a combination to obtain the optimal potential location for the Marine Aquaculture Zone (MAZ). Image data processing shows the lowest potential marine aquaculture location was in Bintan Island in West Season with 202 MAZ. The highest potential location for marine aquaculture on Bintan Island in North Season with 584 MAZ. The results showed the potential location for marine aquaculture locations in Bintan Island was widely distributed, and most of the locations far from the coastline of eastern Bintan Island. This study indicates that the east part of Bintan Island has the potential to be implemented for marine aquaculture areas to develop sustainable marine aquaculture production.

1. Introduction

In recent years, continued growth has dramatically increased the demand for public consumption of animal protein and seafood[1–3]. Global demand for seafood increases steadily, driven by rising per capita consumption[4,5] in line with the current increase in food demand [4,6,7]due to population increases. In the future, aquaculture must supply two-thirds of edible production by 2030 [8] due to predictions of drastic increases in demand for food consumption and reduced marine fishing production. In recent decades also shown, seafood has contributed enormously to and has helped alleviate food crises in many developing countries [9].

On the other hand, the increased consumption of seafood and the need for marine aquaculture is caused by overexploitation of fish stocks and increased marine pollution, which gradually erodes marine resources and encourages us to consider aquaculture as a source of fish and seafood products in the future [10–16]. Aquaculture methods also produce more efficient marine resources than livestock production [17], consisting of various compositions including fish, seaweed, sea cucumber, and mollusk crustaceans, and other marine invertebrates' resources [18].

Many researchers have shown that seafood has nutritional characteristics that maintain and promote health [9,19]. In general, seafood is a high-quality protein source with provides health benefits for growing children, adolescents, and the elderly by giving a high protein content, amino acids, fiber, vitamins, and minerals needed by the body system[9]. Another essential role shows that seafood is associated with a lower environmental impact than other animal protein sources, especially beef [20]. This causes the need for seafood protein to increase and a global appetite also increasing[21].

Aquaculture is expanding into deeper offshore environments in response to increased consumer demand for seafood [22]. The offshore aquaculture industry has enormous growth potential and has been seen as a mechanism to meet the increasing demand for protein from seafood consumption [23] The expansion of the offshore aquaculture industry in the coming years seems inevitable. The increasing global demand for seafood and the offshore aquaculture industry promises an efficient and space-saving method for producing a large enough seafood [3]. Technological improvements and limitations in conventional fishing activities have made the offshore marine aquaculture industry a new economic development in the seafood industry [22]. In some large industrialized countries such as China, more than half of total marine product output comes from offshore aquaculture as an open system[24,25]. Not only China had grown in demand, and offshore aquaculture is increasing significantly. Several other countries have shown that the proportion of seafood products produced and traded internationally is very high and increasing, primarily due to globalization with geographical differences between aquaculture production in Asia and the demand for seafood is dominated by Europe and North America[17].

Bintan is an area that mostly consists of oceans and potentially develops quite extensive sustainable marine aquaculture. Bintan also consists of 2,408 Small Islands, and each small island can also support the potential for marine aquaculture development. Monitoring research conducted by LIPI on monitoring coral reef ecosystems, the potential for reef fish composition, and several benthic species compositions shows that Bintan's marine fishery production is very volatile and tends to decline. Several phenomena such as coral bleaching [26], an increase in the East Bintan tourist areas, a very congested shipping route in North Bintan, and mining production[27] have resulted in limited fishery production in the Bintan. In addition, the increase in the population of Bintan Island and the increase in the number of immigrants also have caused the need for marine products to increase significantly.

Aquaculture is one of the solutions for the provision of protein commodities for marine products in Bintan Island with the support of a large marine area. Bintan island is one of the outer islands in Indonesia bordering Singapore and Malaysia and provide Bintan more effective for trading and exporting aquaculture products if the Bintan can take a role in the development of marine aquaculture. The sustainable use of marine aquaculture on Bintan Island can increase Bintan Island's income and economic contribution to the export of marine products to Singapore and Malaysia in the future. Therefore, this study aims to determine the potential for marine aquaculture location in Bintan Island by using remote sensing methods to determine suitable habitat conditions by observing changes in Sea Surface Temperature (SST) fluctuations in marine organisms and the primary food sources available at sea with Chlorophyll-a (Chl-a) variable.

2. Research Methodology

2.1 Research location

Bintan Island is one of the islands in the Riau Archipelago Province with two local governments. Tanjungpinang City is the Riau Islands Province and Bintan Regency capital with the Bintan Lagoy Exclusive Tourism area (ETA). Bintan Island is the largest island in the Riau Archipelago, consisting of nearly 2,408 large and small islands reaching from Singapore to Johor Baru, Malaysia. The island spreads from Malacca to the South China Sea. The morphological conditions of the coastal on Bintan Island are sandy composition, but several islands have different morphology characteristics. In general, coastal morphology can be divided into three types; sandy shores, rocky shores, and mangrove areas. Bintan Island marine ecosystem is an ecosystem that has high biological value, such as mangrove forest ecosystems, coral reef ecosystems, and seagrass beds. Bintan Island is also known for its marine products from coral reef fisheries, which have potential high economic value, especially snapper and grouper fish. The implementation of the development and management of coastal natural resources require integrated management practice. The increasing development of tourism and mining areas [27] on Bintan Island impacts environmental damage. Previously, South Bintan and East Bintan coastal areas were strategic areas as transportation routes for mining products and the target areas for sea sand dredging/mining. The efforts to control the risk of pollution in this area are essential, considering that coastal areas have biodiversity that is vulnerable to pollution and can affect marine products in Bintan Island, especially capture fisheries commodities.

2.2 Data collected

The data used in this study are primary data from the extraction of Sea Surface Temperature (SST) and chlorophyll-a (Chl-a) using remote sensing technology information obtained from records processed and provided by NASA using MODIS satellite sensors. MODIS satellite image results from remote sensing observations with an image technology product that can estimate SST and chlorophyll-a values[28–30]. In practice, the SST and Chl-a values can be obtained through remote sensing or direct measurement, but the remote sensing method more superiority than direct measurement, especially for estimate the SST and Chl-a value [31,32]. Remote sensing provides the data for larger areas and offers faster, effective, efficient, and more accurate data analysis than direct measurements requiring more cost and effort with its coverage area relatively small[33]. The selection of SST and chlorophyll-a variables are important oceanographic factors for aquatic organisms and are very useful for zoning the marine aquaculture area.

The remote sensing image data downloaded from NASA's Ocean Color Web is supported by the Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center http://oceancolor.gsfc.nasa.gov. The image data used from the extraction of chlorophyll-a and SSTconducted from January 2019 to December 2019 at level 3 with a resolution of 1 km [34]. MODIS product image data for marine includes three characteristics: seawater color, SST, and primary seawater production through chlorophyll content detection [30]. MODIS level 3 imagery is product data processed with an image quality that corrects the atmosphere, eliminating the very high scattering of light caused by atmospheric components. The corrected components were Rayleigh scattering and aerosol scattering. In addition, MODIS level 3 imagery is used for climatological data and ozone data, which are environmental data to improve image output[35]. The advantages of Aqua MODIS imagery are its spectral wavelength (radiometric resolution), more precise land cover (spatial resolution), and more frequent observations (temporal resolution) [36]. Aqua MODIS satellite data provides better results in defining in-situ seawater conditions for determining marine aquaculture areas in Bintan Island. It is also apparent from previous research using satellite image data for SST has high accuracy with in-situ data.

2.3. Data analysis

The data that has been downloaded is then processed first in the SeaDas application. The file format changes from the World Geodetic System (WGS) 84 are then stored in the form of GeoTiff for further processing in the ER Mapper [37]. Data with the GeoTiff format were entered into the ER Mapper for image cropping. The variable values for sea surface temperature and chlorophyll-a were changed [38] by changing the threshold value for SST with variable 1 to 25 and variable 2 to 35, while for

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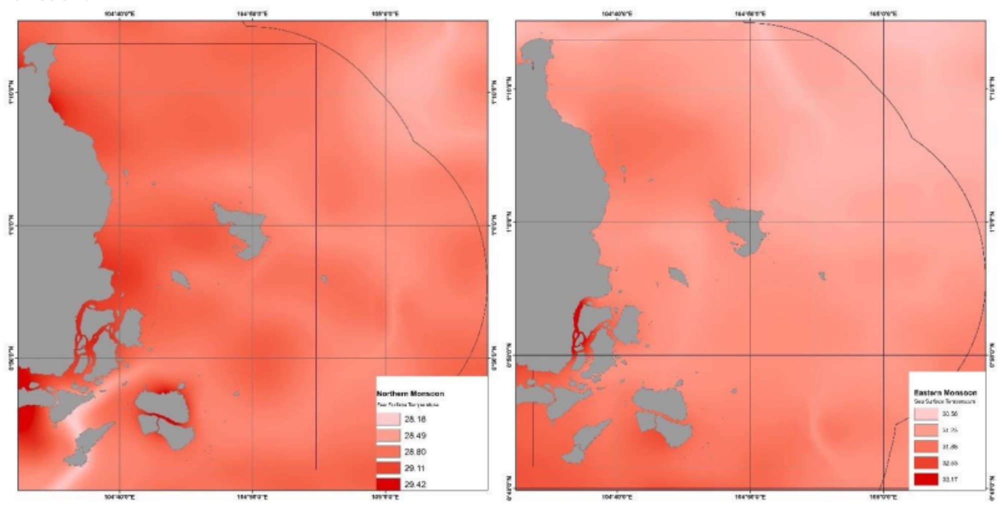
chlorophyll-a, the threshold value for variable 1 was adjusted to 0.1, and variable two became 0.5[26,39].

After changing the threshold value of SPL and chlorophyll-a so that the variable function can be projected into a contour of sea surface temperature distribution and chlorophyll, the data is saved in raster (.ers) format post-processing of contour processing in ArcGIS software [40]. The primary data used as contour projections are sea surface temperature and chlorophyll-a with a contour projection value of sea surface temperature and chlorophyll with interval values of 0.5 and 0.1, respectively [38]. The contours of sea surface temperature and chlorophyll were analyzed by identification at the intersection of temperature and chlorophyll-a variable contours. The area presumed as the marine aquaculture zone location is a location close to the optimal temperature and has a high chlorophyll-a content, which meets the contours of sea surface temperature and chlorophyll-a.

3. Result and Discussion

3.1. Sea surface temperature analysis in Eastern Bintan Island

The Sea surface temperature (SST) conditions in the northern monsoon range between 28.18 - 29.42 ºC around East Bintan's seawaters, where the temperature in the north monsoon lower than the other monsoon.



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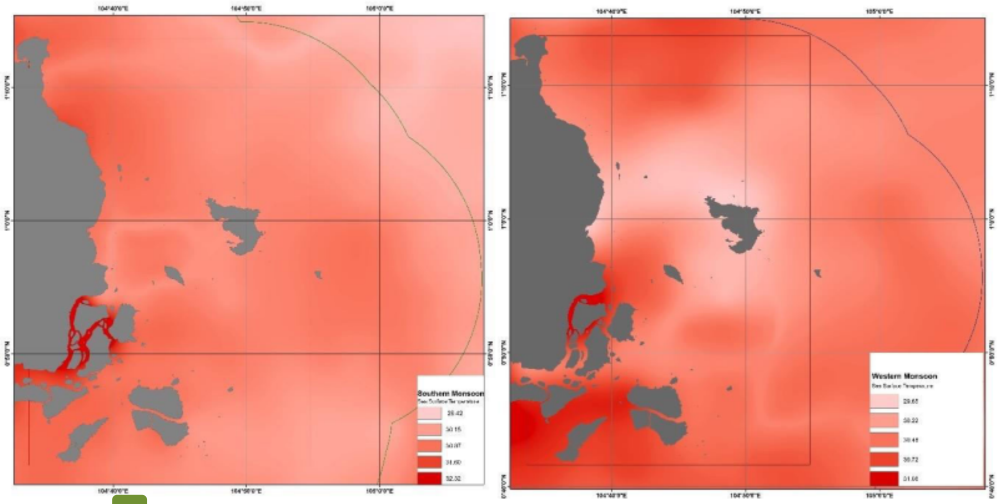


Figure 1. Distribution of Sea Surface Temperature (SST) in Easter Bintan Island in each different monsoon (Northern, Eastern, Southern, Western).

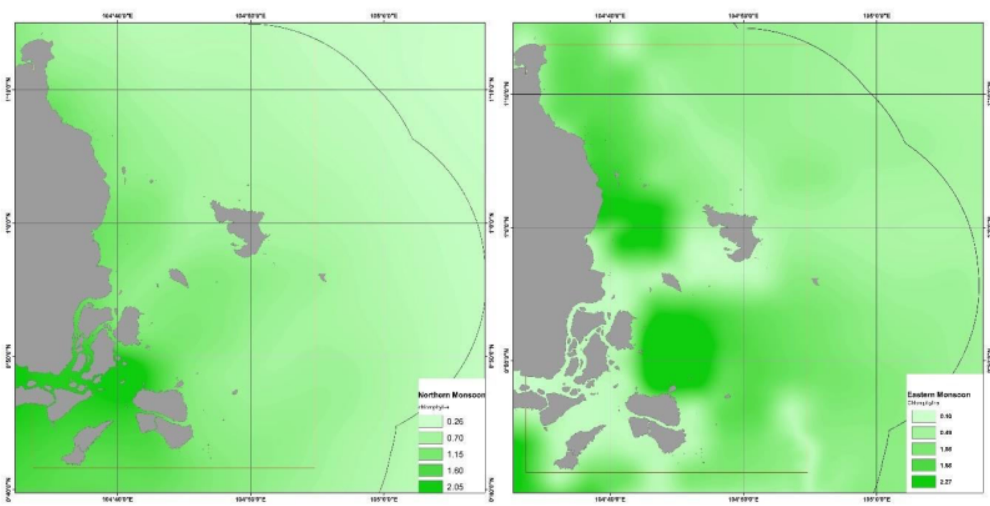
Currents and high rainfall movement cause Sea Surface Temperature (SST) conditions to lower in the northern season (figure 1). The direction of the wind during this monsoon also significantly affects the lower sea surface temperatures. The wind moved to the seawaters of the eastern coast of Bintan Island during the northern monsoon, blows from the north with a lot of water vapor. East monsoon tends to be dry and warm and influences sea surface temperature conditions in East Bintan seawaters. This monsoon is a dry season, and the Sea Surface Temperature (SST) in Bintan Island reaches its maximum temperature and tends to be higher than in another monsoon. The eastern monsoon also indicates low rainfall and wind movements that tend to be faster, causing the seawater to remain warmer this monsoon. The temperature range was at 30.56 ^{o}C for the lowest temperature and had the highest temperature reaching 33.17 ^{o}C.

The Sea Surface Temperature conditions in the southern monsoon indicate that the East Bintan seawaters are still warm, with the temperature range in this monsoon ranges from 29.42 - 32.32 ^{o}C (Figure 1). The condition of SST in this monsoon is always influenced by the east monsoon, which tends to be warmer. In terms of distribution patterns in this southern monsoon, the sea surface temperature has decreased and tends to be more evenly distributed in most of East Bintan's seawaters. However, there are still many seawater areas in eastern Bintan that tend to be warmer. The sea surface temperature in the west monsoon ranges from 29.65 - 31.08 ^{o}C. This month's temperature increases, due to which this month the intensity of the rain slightly decreases. The pattern of temperature distribution during this season tends to be warmer and uneven distributed. The Currents and more sunlight intensity also influence warm waters, but this season, because it is a transitional month, is still affected by conditions in the previous season, causing some seawater areas lower or decreasing temperatures.

Temperature is an essential factor for organisms in the sea, affecting metabolic activity and reproduction [41,42]. From the results of our research, it was found that the distribution of sea surface temperature in East Bintan ranged from 28.18 ˚C to 33.17 ˚C, which indicates the ideal temperature for the marine aquaculture from several economically important fishes. Our results also show that for each monsoon difference in the East Bintan seawaters, the seas surface temperature had no change exceedingly more than 10 ^{o}C. In general, organisms that cannot regulate their body temperature have a metabolic process that increases two-fold for every 10 ^{o}C temperature rise. Furthermore, it is said that even though water temperature fluctuations are less varied, it is still a limiting factor because aquatic organisms have a narrow temperature tolerance range (stenotherm). The differences in each monsoon that occur in East Bintan seawaters still allow the development of sustainable marine aquaculture where the sea surface temperature can also be used as seawater fertility to the growth of several economically important marine fishes [43,44].

3.2. Chlorophyll-a (Chl-a) analysis in Eastern Bintan Island

The analysis results of chlorophyll-a at north monsoon in Bintan Island were in the range of 0.26 - 2.05 mg/m^3(Figure 2). The chlorophyll-a concentration in north monsoon is distributed centrally in the smalls island cluster located in the Southeast area of East Bintan Island location. In general, chlorophyll-a distribution in north monsoon show the areas close to the coastal area in eastern Bintan Island had more chlorophyll concentration in seawaters received additional nutrients from the land. The change in the value of chlorophyll-a concentration in East Bintan is shown in the east monsoon with the chlorophyll-a distribution pattern that begins to move away from the coastline area. In the east monsoon, the value of chlorophyll-a concentration in the seawaters of East Bintan showed that the average distribution value of chlorophyll-a was higher than the distribution of chlorophyll-a at the north monsoon with chlorophyll concentration values ranging from 0.10 - 2.27 mg/m^3. Figure 2 shows that the seawater area near the coast shows the lowest concentration, with the concentration pattern starting to distribute move centrally towards the open sea during the east monsoon.



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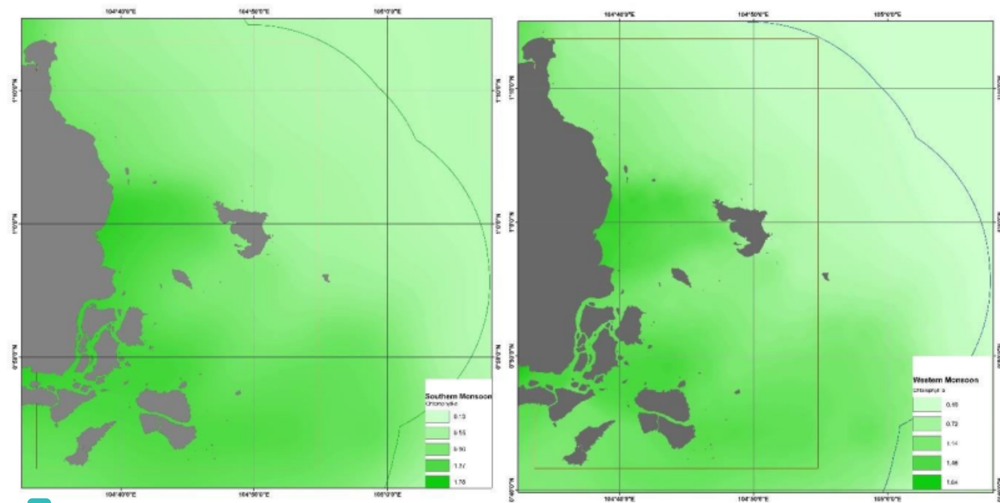

Figure 2. Distribution of Chlorophyll-a (Chl-a) in Easter Bintan Island in each different monsoon (Northern, Eastern, Southern, Western).

The chlorophyll analysis results in the southern monsoon can be seen in Figure 2, where the concentration of chlorophyll-a conditions in this monsoon tends to decrease in the range of 0.13 - 1.78 mg/m^3(figure 2). The distribution pattern of chlorophyll-a in the southern monsoon repeatedly forms a spreading pattern with a north monsoon with a lower concentration level. The decline in chlorophyll-a concentration in this monsoon due to lack of nutritional intake. The temperature condition in this monsoon was not suitable for chlorophyll-a and also influenced chlorophyll-a to grow. The most massive intake of nutrients comes from the land. The chlorophyll-a concentration in the seawater near the island has a higher concentration than other areas because it is farther from the island, the chlorophyll concentration tends to decrease. The West monsoon's chlorophyll-a concentrations showed that the lowest levels ranged from 0.1 - 1.64 mg/m^3. In this monsoon, chlorophyll-a distribution tends to follow the eastern monsoon pattern with a more even distribution. The condition is due to chlorophyll-a movement by faster currents and carrying chlorophyll to the high seas. Besides that, the tendency of decreasing chlorophyll-a concentration and uneven distribution compared to the previous season was caused by the factor of less rainfall, which limited the development of plankton to photosynthesis. Even though there is plenty of sunlight, chlorophyll-a requires sufficient nutrition to be able to grow. The nutrient intake from the mainland is reduced due to the lack of rain intensity this monsoon.

The distribution of chlorophyll-a in the ocean varies geographically and is based on water depth [43]. This variation is caused by differences in sunlight intensity and nutrient concentrations in seawater [45]. Based on the research results, the eastern part of Bintan has a low chlorophyll concentration value. This was also following the statement from (Zhang, et al, 2019) [46] shown tropical waters generally have low chlorophyll-a concentrations due to limited nutrients and the strong stratification of the water column due to water surface heating that occurs almost throughout the year. Based on the seasonal and spatial distribution patterns of chlorophyll-a, in some parts of the seawater, it was found that chlorophyll-a concentrations were higher, especially in eastern monsoon due to nutrient enrichment in the surface layer of the waters through a water mass dynamic process [40]. Our research results show that most of the chlorophyll concentrations in East Bintan were scattered in the coastal area. Chlorophyll-a concentrations in the ocean are higher in the coastal area and lower in the offshore area[47]. Many nutrients cause the distribution of high chlorophyll-a concentrations in coastal and coastal waters through runoff from land.

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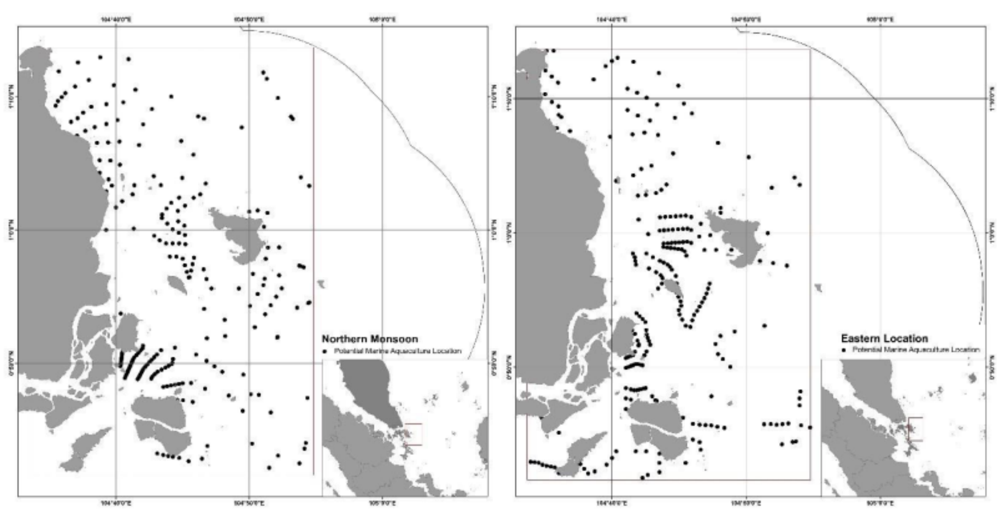
In contrast, the low concentration of chlorophyll-a in offshore waters is due to the absence of direct nutrient supply from the land. However, in certain areas in offshore waters, chlorophyll-a concentrations were found to be relatively high. This situation is caused by the high concentration of nutrients produced through the physical process of water mass, where the mass of water in water lifts nutrients from the inner layer to the surface layer [48].

3.3. The potential marine aquaculture location in Eastern Bintan Island

Image data processing found 394 potential points of marine aquaculture location, mostly in the northern part of East Bintan. The potential for marine aquaculture was closer to the main island, especially along the northern part of the eastern Bintan coastline. On the other hand, most of the potentials marine aquaculture was found along the southeast coast of East Bintan, located in a row along the waters of small islands located in Southeast of Bintan Island. The potential for aquaculture activities in East Bintan seawaters may be quite immense in the northern monsoon. A supply of suitable seawater locations is proper for several economically important fish for growth. In the east monsoon, there were 220 potential points for marine aquaculture location. This monsoon condition caused the potential number of marine aquaculture locations has decreased significantly compared to the northern monsoon. Several factors reduce the potential point of marine aquaculture location, including oceanographic factors with the temperature and chlorophyll-a, were less able to support several economically important fish to grow. The warmer Sea Surface Temperatures (SST) do not provide enough capacity for potential marine aquaculture locations during this monsoon. The distribution pattern of potential marine aquaculture locations at this monsoon also tends to lead to the coastal area and is mostly concentrated in East Bintan's internal waters. Another factor that causes a decrease in potential points for marine aquaculture location, including only a small amount of chlorophyll-a found, provides potential marine aquaculture location. The Seasonal factors can also influence this condition because there was a change in current patterns that affect the number of potential points for marine aquaculture location.



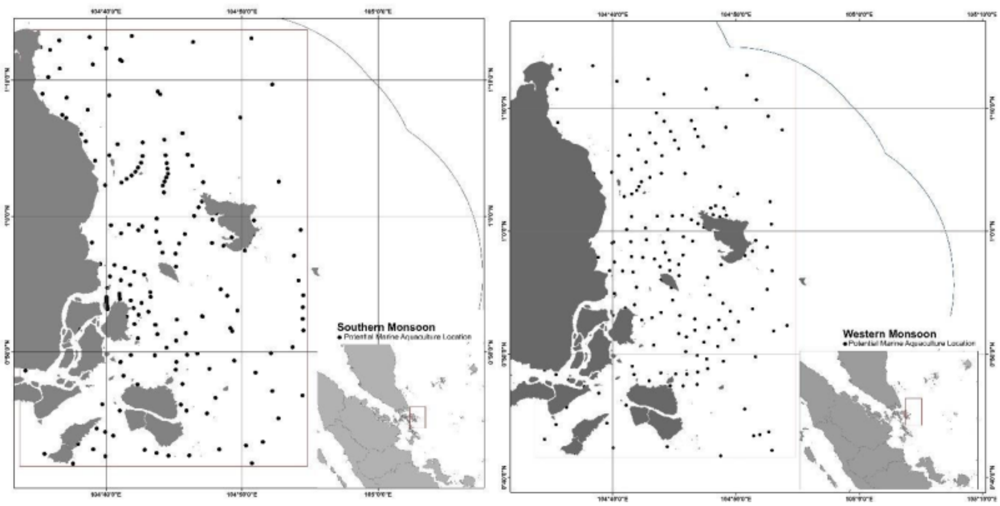


Figure 3. Distribution of Potential Marine Aquaculture zone in Easter Bintan Island in each different monsoon (Northern, Eastern, Southern, Western)

The number of potential points for marine aquaculture in the southern monsoon increases to 335 potential points. The increased rainfall causes nutrients from land to flow into the seawaters, and increased rainfall intensity reduces warm sea surface temperatures creating the suitable for fish growth and aquaculture development. Marine aquaculture's potential points begin to spread to the north and south region in the southern monsoon (figure 3). In contrast, in the eastern part, it begins to decrease because warm temperatures still influence the eastern monsoon's effect (dry season) in the previous season. The analysis results in the west monsoon found 202 potential points for marine aquaculture location. This monsoon decreased the number of potential points for marine aquaculture due to the increased intensity of rain; consequently, the sea surface temperature becomes lower and resulting in a less suitable temperature for fish. Figure 4 shown, the distribution of potential points of marine aquaculture was increasingly evenly distributed but in less in number. the seawaters of East Bintan cool down more slowly due to was still influenced by the previous season on the high seas, which are provided by currents and winds at the time of changing seasons.

4. Conclusion

The East Bintan has the potential for applying marine aquaculture development. The highest potential marine aquaculture location is in East Bintan during the northern monsoon with 394 potential marine aquaculture locations and the lowest potential marine aquaculture location in East Bintan with 202 potential marine aquaculture locations.

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