ANALYSIS OF POTENTIAL FISHING ZONES IN COASTAL WATERS: A CASE STUDY OF NIAS ISLAND WATERS

Anang Dwi Purwanto[1]*, Teguh Prayogo, Sartono Marpaung, and Argo Galih Suhada
[1]Remote Sensing Applications Center,
National Institute of Aeronautics and Space
*e-mail: anang.dwi@lapan.go.id

Abstract. The need for information on potential fishing zones based on remote sensing satellite data (ZPPI) in coastal waters is increasing. This study aims to create an information model of such zones in coastal waters (coastal ZPPI). The image data used include GHRSST, SNPP-VIIRS and MODIS-Aqua images acquired from September 1st-30th, 2018 and September 1st-30th, 2019, together with other supporting data. The coastal ZPPI information is based on the results of thermal front SST detection and overlaying this with chlorophyll-a. The method of determining the thermal front sea surface temperature (SST) used Single Image Edge Detection (SIED). The chlorophyll-a range used was in the mesotropic area (0.2-0.5 mg/m³). Coastal ZPPI coordinates were determined using the polygon centre of mass, while the coastal ZPPI information generated was only for coastal areas with a radius of between 4-12 nautical miles and was divided into two criteria, namely High Potential (HP) and Low Potential (LP). The results show that the coastal ZPPI models were suitable to determine fishing locations around Nias Island. The percentage of coastal ZPPI information generated was around 90% information monthly. In September 2018, 27 days of information were produced, consisting of 11 HP sets of coastal ZPPI information and 16 sets of LP information, while in September 2019 it was possible to produce 29 days of such information, comprising 11 sets of HP coastal ZPPI information and 18 LP sets. The use of SST parameters of GHRSST images and the addition of chlorophyll-a parameters to MODIS-Aqua images are very effective and efficient ways of supporting the provision of coastal ZPPI information in the waters of Nias Island and its surroundings.

Keywords: *Potential Fishing Zones, Coastal ZPPI, GHRSST, Single Image Edge Detection (SIED), Nias Island*

1   INTRODUCTION

Indonesia is a country that has a larger water area than land area. The International Convention of the Law of the Sea 1982 states that the total area of Indonesian waters is 5.9 million km² consisting of 3.2 million km² of territorial waters and 2.7 million km² of Exclusive Economic Zone (EEZ) waters (Lasabuda, 2013). The total area of these waters shows that 2/3 of Indonesian territory is water, with the remainder being land. The waters of Indonesia have a very high potential for fish resources. Based on data from the annual report of the Ministry of Maritime Affairs and Fisheries (KKP) of 2017, Indonesian fisheries production amounted to 6.99 million tons in 2017. In order to support the increase in the level of fishing, the National Institute of Aeronautics and Space (LAPAN) remains committed to provide fishing area information based on remote sensing satellite imagery data, known as potential fishing zones (ZPPI) (Hasyim, 2015). The ZPPI information produced by LAPAN is currently used by most fishermen in Indonesia.

Distribution of the ZPPI information is made using an android application, a website and e-mail to both central and local government users, the private sector, state-owned enterprises and other stakeholders.

The current ZPPI information does not include waters under 12 nautical miles from the coastline due to various considerations, including the avoidance of the fishing activities of large vessels (loading capacity above 30 GT) fishing in coastal waters (under 12 nautical miles from the coastline) and to provide flexibility for small/traditional fishermen with small vessels (loading capacity below 30 GT) in fishing activities in coastal areas. In addition, if fishermen with small boats fish in the open sea (above 12 miles), this will greatly endanger their safety. Based on data of the Ministry of Maritime Affairs and Fisheries (2008), cited in Retnowati (2011), the number of Indonesian fishermen in in 2009 was 2,752,490, with a total number of boats of 596,230; 90% of the fishermen were small-scale. Therefore, it is necessary to develop ZPPI information related to waters within 12 nautical miles of the coastline which is specifically intended for small or traditional fishermen.

Along with the rapid development of science and technology, remote sensing technology can be optimised for the detection of oceanographic parameters, including the determination of potential fishing zones. Oceanographic conditions can be used as an indicator of the presence of fish, as a cold water mass rich in nutrients is suitable for the presence of fish (Balaguru, Ramakrishnan, Vidhya & Thanabalan, 2014). Purwanto et al. (2012) conducted a study of sea surface temperatures in the Western Java Sea using NOAA and MODIS satellite imagery. In addition, Marpaung et al. (2018) conducted research related to information on potential fishing zones based on SNPP-VIIRS and Himawari 8 imagery. Sea surface temperature and chlorophyll concentration can be measured to determine fishing ground prediction models using MODIS data (Suwargana et al., 2004). Hamzah et al. (2016) used the polygon mass centre method to determine the coordinates of potential fishing zones.
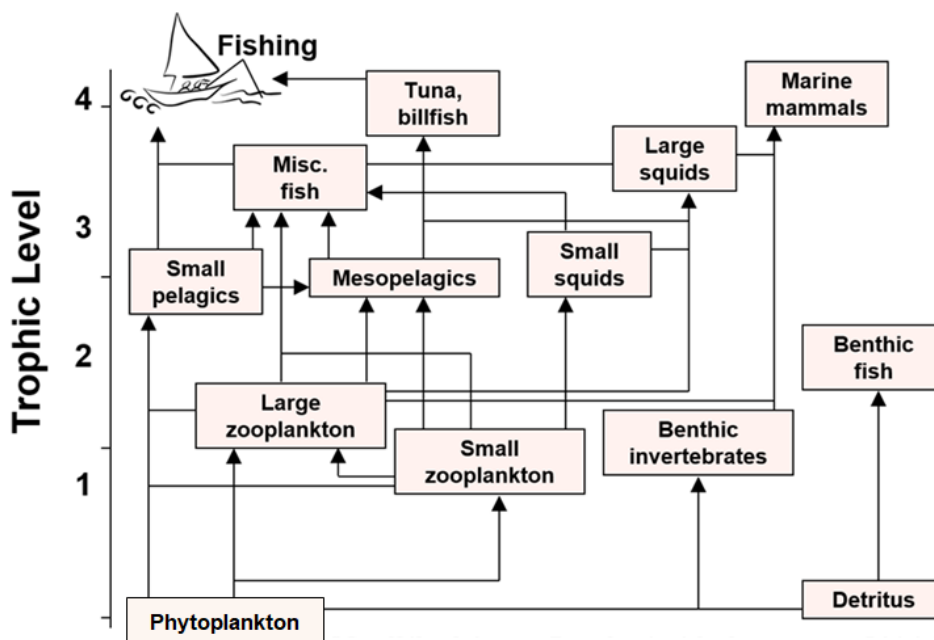

Figure 1-1: Food chain in the sea (Pauly & Christensen, 1993)

Figure 1-1 shows the food chain process in waters where the chlorophyll-a parameter plays an important role. Using satellite imagery, Zainuddin et al. (2006) found that there was a relationship between albacore tuna fish catches and the concentration of chlorophyll-a, with its value in the highest catchment area in the northwestern North Pacific being in the range of 0.2-0.4 mg/m³. Another study conducted by Zainuddin (2011) showed the highest number of skipjack tuna catches in Bone Bay was in areas with chlorophyll concentrations of between 0.1-0.4 mg/m³. In addition, the results of a study conducted by Nurdin et al. (2017) also showed that the highest concentration of rastrelliger kanagurta catches in Spermonde Islands waters was at a concentration of chlorophyll-a of between 0.2-05 mg/m³.

The results of the evaluation of socialisation activities and focus group discussions with the local government, private sector and the fishing community show that the requirements for potential fishing zones in coastal areas is increasing, one of these being for fishermen in Nias Island waters. The large sea area and diverse types of fish with a sufficiently high market value indicate that the Nias region has great potential for marine fisheries (Zebua et al., 2014). Based on data from the North Nias Regency Fisheries Office, catches by fishermen in the area in the period 2000-2018 were dominated by tuna and cakalang. In addition, the fishing boats in the area were dominated by small vessels with a loading capacity of 0.5-1 GT, with fishing operations carried out over a relatively short period of time, commonly known as one day fishing activity. This type of fishing operation takes place within a range fairly close to the coast and is usually done on a daily

basis; that is, leaving in the morning and returning in the afternoon, or leaving in the afternoon and returning in the morning.

The aim of this study is to create a model of potential fishing zones in the coastal waters of Nias Island (coastal ZPPI) based on remote sensing satellite imagery. It is hoped that the availability of such information will help and facilitate fishing activities, especially for traditional or small fishermen, and support the increase in the volume of fish catches, thus improving the welfare of fishermen in the area.

2   MATERIALS AND METHODOLOGY
2.1   Location and Data

This research was located in the western waters of Indonesia, specifically around Nias Island, with the coordinates 3 °N-0.9 °S and 95.8-99.2 °E. This area was chosen chosen to represent open sea waters directly facing the Indian Ocean, but also with closed waters on the eastern side. The research location is bordered by the Indian Ocean to the west, north and south, while to the east it is bordered by Sumatra Island. The waters have steep coastal depths. Figure 2-1 shows the location.
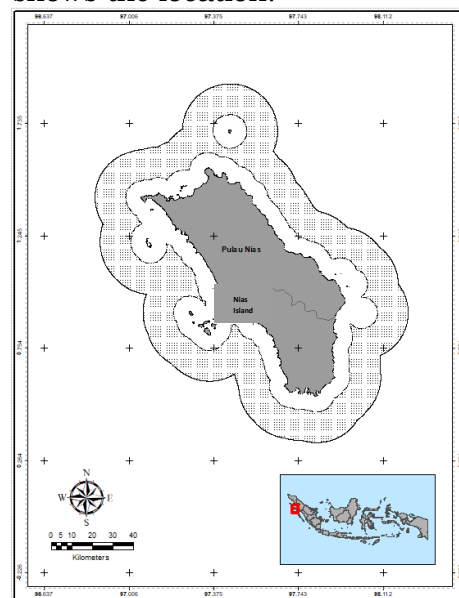

Figure 2-1: Map of the research area

The image data used were low resolution satellite imagery, including Visible/Infrared Imager Radiometer Suite (SNPP-VIIRS) Level 2 with a spatial resolution of 750 meters and Group for High Resolution Sea Surface Temperature (GHRSST) Level 4, with a spatial resolution of 1 kilometer, which was used to extract daily sea surface temperatures. SNPP-VIIRS images were obtained from the LAPAN Pustekdata catalog website (modis-catalog.lapan.go.id), while the GHRSST image data were obtained from the NASA website (http://podaac.jpl.nasa.gov/). Paena et al. (2015) explain that GHRSST images are the result of interpolation from several data sensors, namely microwave (Advanced Microwave Scanning Radiometer-AMSR and Tropical Rainfall Measuring Mission Microwave Imager-TMI) and infrared (Moderate Resolution Imaging Spectroradiometer-MODIS). The use of the GHRSST images is expected to be able to cover the lack of current potential fishing zone information, which has been one of the obstacles to the operationalisation of ZPPI in LAPAN. Other image data used were MODIS Aqua imagery Level 2, with a spatial resolution of 1 kilometer, used to extract daily and eight daily chlorophyll-a, which was obtained from NASA's Ocean Color website (https://oceancolor.gsfc.nasa.gov).

The three types of image data used were acquired in September 2018 and September 2019. The time of image selection was adjusted to the time of field data retrieval, which was conducted twice, namely in September 2018 and September 2019. Two types of field measurement data were employed: oceanographic measurement data and interviews with coastal fishermen in North Nias and Gunungsitoli about fishing operations (fishing locations, fish catches, fishing time, number of personnel, fishing gear, etc). Other supporting data used were Nias Island administrative boundaries, Gebco water depth data, grid vector data size of 1 nautical mile, and buffer area data of 4 and 12 nautical miles.

2.2 Methods

Sea surface temperature and chlorophyll-a data were used as the main parameters in the determination of coastal ZPPI information. These were downloaded in netcdf (.nc) format, so it was necessary to convert them into geotiff format using Seadas 7.5.1 software to make further processing easier using other image processing software. Generally, the stages of determining coastal ZPPI information include determining the thermal front of sea surface temperature using the Single Image Edge Detection (SIED) method; determining the value of chlorophyll-a in the mesotropic area (0.2-0.5 mg/m^3); an overlay process between the thermal front and chlorophyll-a (mesotropic area); grouping the overlay results into grid sizes of 1 nautical mile; and determining coastal ZPPI coordinates using the polygon mass centre method.

The thermal front parameters were obtained from daily SST data from GHRSST and SNPP-VIIRS satellite imagery. Thermal front detection was conducted in several stages, including selection of SST channels (specifically SNPP-VIIRS); geometric and atmospheric corrections; data selection based on recording time; cropping image data based on area of interest (AOI); and thermal front detection using the SIED algorithm (Cayula & Cornillon, 1992). Jatisworo and Murdianto (2013), Hamzah et al. (2014) and Hanintyo et al. (2015) have also employed the SIED algorithm in Indonesian waters using a threshold parameter of 0.5 ^{0}C.
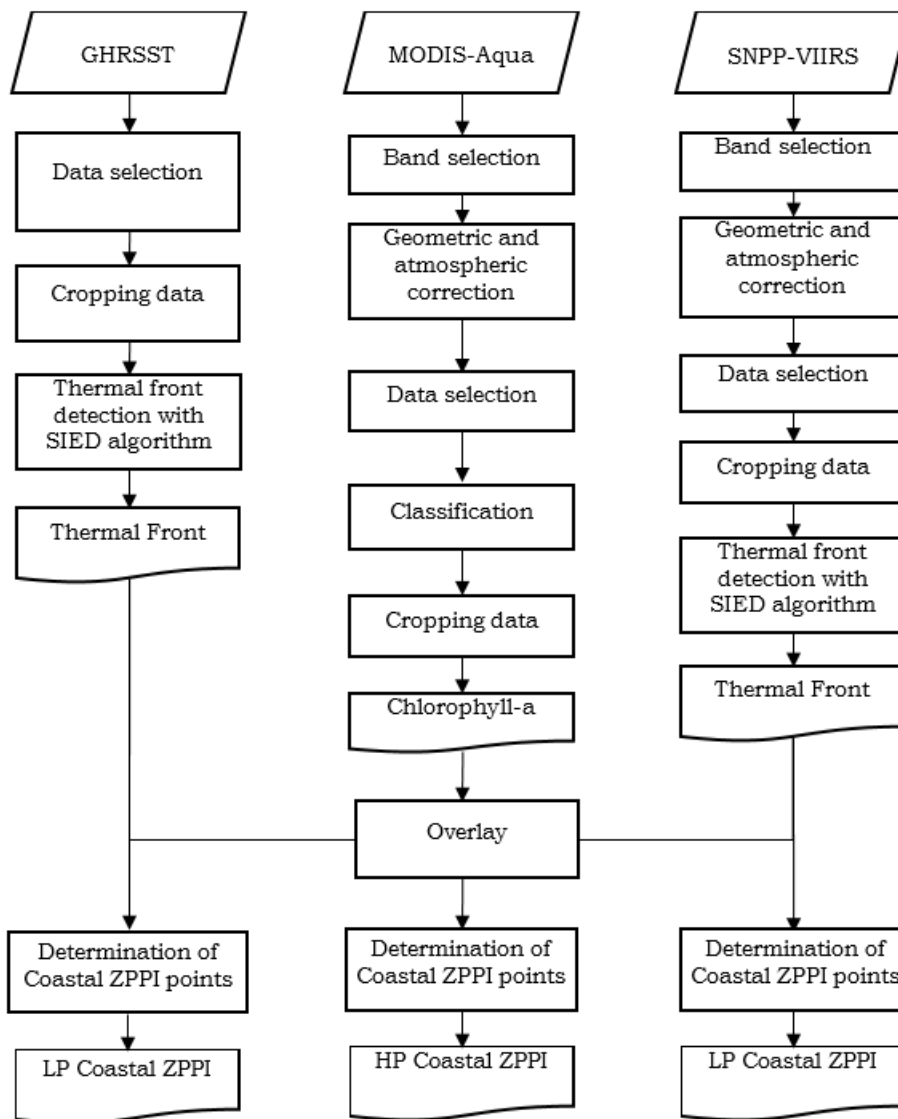
Figure 2-2: Detection Flow Chart of Thermal Front and Chlorophyll-a

Chlorophyll-a information was obtained from MODIS Aqua images, with stages including chlorophyll-a channel selection, geometric and atmospheric corrections, data selection based on recording time and concentrations in the range of 0.2-0.5 mg/m^3, and cropping image data based on AOI. A range of chlorophyll values of 0.2-0.5 mg/m^3 was used, in line with Nurdin et al. (2017), who explain that pelagic fishing is dominated by chlorophyll concentration. Reclassification was performed to separate chlorophyll-a from the existing day unit, with a class length of 0.05 mg/m^3. The flow diagram of this study is shown in Figure 2-2, relating to the detection of thermal front parameters and chlorophyll-a, while Figure 2-3 shows the stages of determining coastal ZPPI points.Determination of the coordinates of coastal ZPPI starts with the conversion of raster data to polygons, removal of small polygons, polygon smoothing, determination of areas containing a fishnet grid size of 1 nautical miles, determination of the midpoint of each polygon, and extraction of the midpoint coordinate values of each polygon.
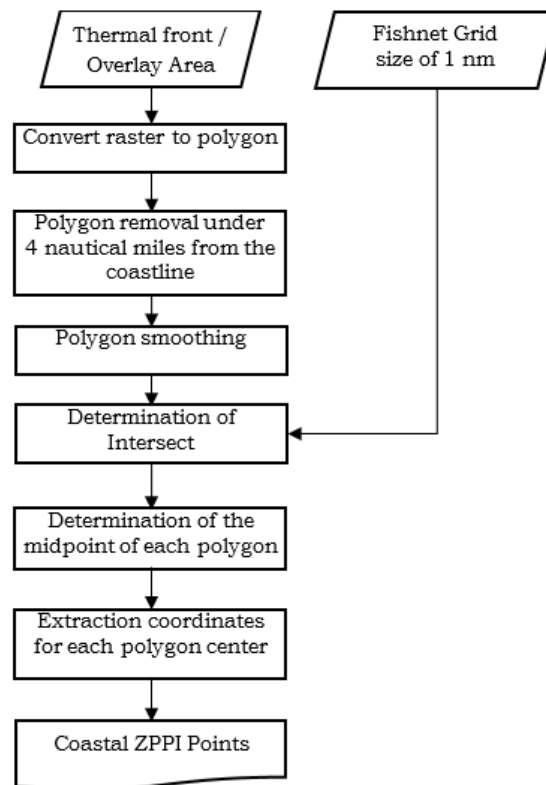
Figure 2-3: Determination Flow Chart of Coastal ZPPI Point

The resulting coastal ZPPI information is divided into two criteria, high potential (HP) and low potential (LP), as shown in Table 2-1. A coastal ZPPI with HP criteria is obtained from the overlay between sea surface temperature parameters and chlorophyll-a, while coastal ZPPI with LP criteria are obtained from only one of the parameters of sea surface temperature or chlorophyll-a. HP coastal ZPPI information has tended to be of higher potential than that in the LP category because it is strengthened by the presence of two main parameters, namely the thermal front and chlorophyll-a. Angraeni et al. (2014) explain that there is a tendency for a relationship between thermal fronts and large pelagic fish catches. A thermal front is defined as a meeting area of two water masses that have different temperature characteristics (Hanintyo et al., 2015) and can be used as an indicator of potential fishing areas (Simbolon et al., 2013). In addition,

Simbolon et al. (2009) also explain that the chlorophyll-a parameter plays a role as a primary producer in marine ecosystems and can also be used in estimating fishing grounds.

Table 2-1: Coastal ZPPI Criteria

Parameter		Coastal ZPPI Criteria
Thermal Front	Chlorophyll -a	
✓	✓	High Potential (HP)
✓		Low Potential (LP)
	✓	Low Potential (LP)

To establish the quality of the resulting spatial model, it is necessary to compare it with the actual conditions in the field related to fishing areas, especially in the coastal waters of Nias Island. In this study, a qualitative suitability test was conducted. The resulting coastal ZPPI model was

matched with data on fishing locations around the island. Fishing location data were obtained from interviews with several fishermen in North Nias District and Gunung Sitoli City.

3   RESULTS AND DISCUSSION

3.1 Extraction of Sea Surface Temperature and Chlorophyll-a

The main imagery data used for the extraction of sea surface temperature information were GHRSST images, while extraction of chlorophyll-a information was from MODIS Aqua imagery. Sea surface temperature information from the SNPP VIIRS imagery was used to provide data which was lacking and complete the SST thermal front information from the GHRSST satellite imagery. The use of such imagery is very effective in supporting the provision of sea surface temperature information in the waters around Nias Island. Almost all of SST information is produced completely in September 2018 and September 2019. In September 2018, the thermal front information generated included 21 days from the GHRSST images and 4 days from the SNPP-VIIRS images, while the chlorophyll-a (mesotropic area) information produced covered 15 days. In September 2019, thermal front information was generated for 29 days from the GHRSST imagery and 6 days from the SNPP-VIIRS imagery, while the chlorophyll-a (mesotropic area) information produced covered 11 days. Figures 3-1 and 3-2 show an example of the results of the extraction of SST information from GHRSST images and chlorophyll-a information from MODIS-Aqua images for daily periods in waters around Nias Island.
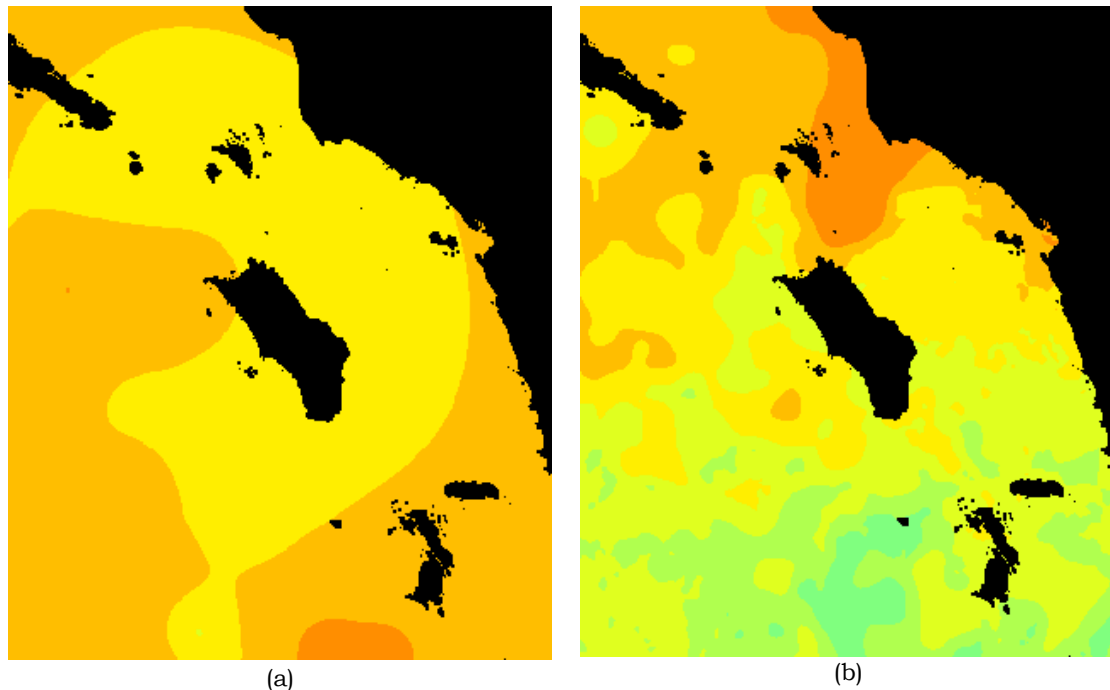

(a)   (b)

Figure 3-1: SST Extraction Results of GHRSST Images (a) September 22th, 2018, and (b) September 22th, 2019
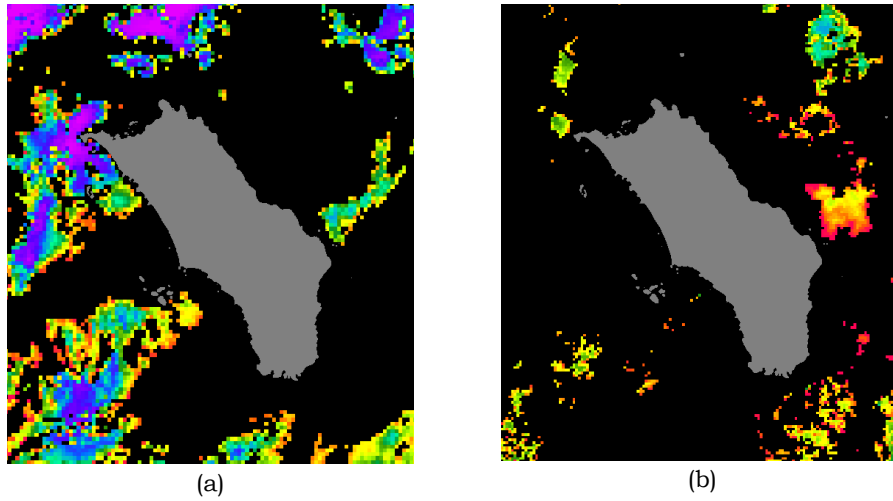
(a)

(b)

Figure 3-2: Chlorophyll-a Extraction Results (a) September 22th, 2018, and (b) September 18th, 2019

3.2. Determination Results of Coastal ZPPI

Overlay analysis was performed on polygons that intersect the thermal front and chlorophyll-a parameters. This intersection area is assumed to have a better correlation with the presence of pelagic fish because each parameter can be used as an indication of habitat from the presence of a shoal of fish. Examples of the intersect results of several parameters used to produce coastal ZPPI information are shown in Figure 3-3.
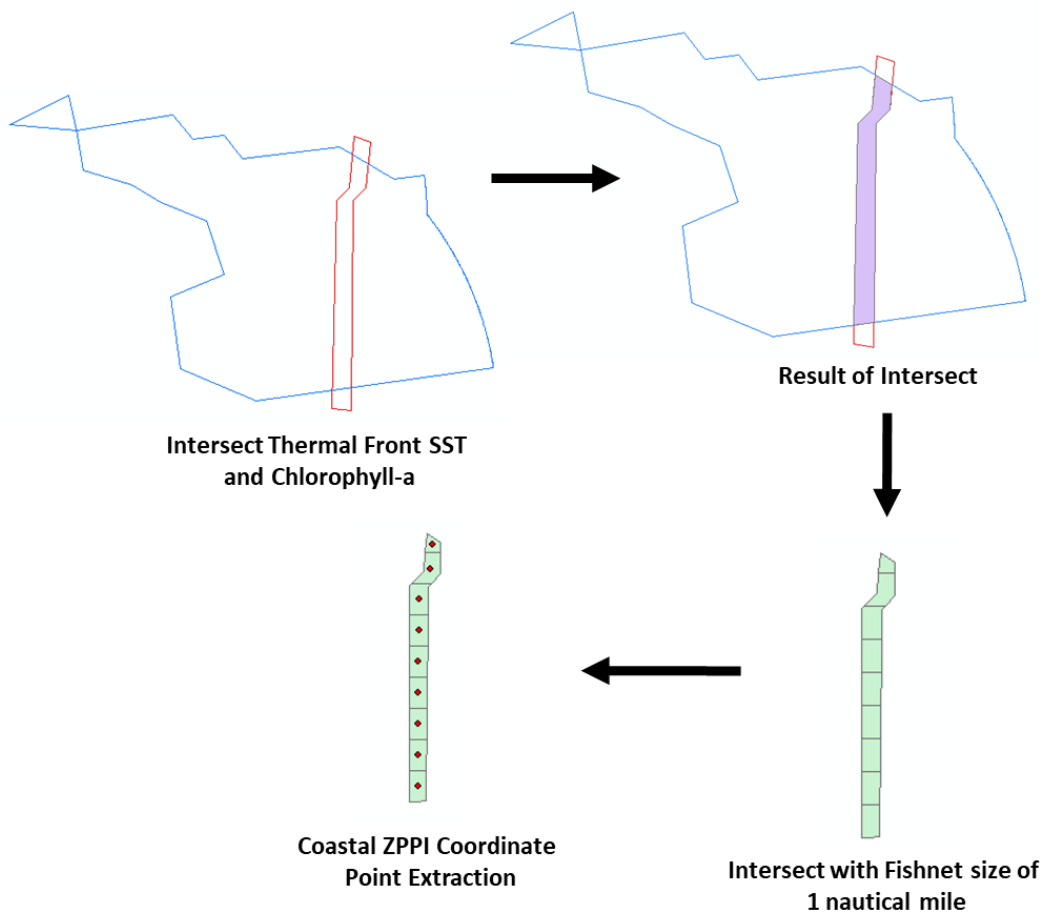

Intersect Thermal Front SST
and Chlorophyll-a

Result of Intersect

Coastal ZPPI Coordinate
Point Extraction

Intersect with Fishnet size of
1 nautical mile

Figure 3-3: Intersection Results of several coastal ZPPI parameters

Table 3-1: Recapitulation of the results of coastal ZPPI determination

Date	Sept 2018			Coastal ZPPI	Sept 2019			Coastal ZPPI
	Front-GHRSST	Front-VIIRS	Chl-a		Front-GHRSST	Front-VIIRS	Chl-a	
1	✓		✓	HP	✓			LP
2	✓		✓	HP	✓			LP
3	✓		✓	HP	✓			LP
4	✓		✓	HP	✓			LP
5	✓		✓	HP	✓			LP
6	✓		✓	HP	✓	✓		LP
7	✓		✓	HP	✓			LP
8	✓		✓	HP	✓			LP
9	✓			LP	✓		✓	HP
10		✓		LP	✓		✓	HP
11	■	■	■	■	✓	✓	✓	HP
12			✓	LP	✓	✓		LP
13			✓	LP	✓		✓	HP
14	■	■	■	■	✓			LP
15	✓		✓	HP	✓			LP
16	✓			LP	✓			LP
17	✓			LP	✓	✓	✓	HP
18	■	■	■	■	✓		✓	HP
19			✓	LP	✓			LP
20			✓	LP	✓		✓	HP
21		✓		LP	✓		✓	HP
22	✓		✓	HP	✓	✓	✓	HP
23	✓			LP	✓	✓	✓	HP
24	✓			LP	✓		✓	HP
25	✓	✓		LP	✓			LP
26	✓	✓		LP	✓			LP
27	✓		✓	HP	✓			LP
28	✓			LP	✓			LP
29	✓			LP	■	■	■	■
30	✓			LP	✓			LP

The use of satellite imagery to extract the two main parameters of coastal ZPPI, namely sea surface temperature and chlorophyll-a is able to increase the number coastal ZPPI information. From the overall data used, 27 days of ZPPI coastal information was generated in September 2018, and 29 days in September 2019. A recapitulation of the results of the determination can be seen in Table 3-1.

The results of the coastal ZPPI recapitulation in Table 3-1 show that within a period of one month the percentage of related information generated was around 90%. In September 2018, coastal ZPPI information was generated over 27 days, consisting of 11 sets of information with high potential (HP) criteria and 16 with Low Potential (LP) criteria, whereas in September 2019 coastal ZPPI information was generated for 29 days, with 11 sets of HP criteria and 18 of LP criteria. From the calculation details, it can be seen that the developed model is able to support the provision of coastal ZPPI information to small-scale fishermen, especially in the waters around Nias Island. Figure 3-4 shows a comparison between HP and LP coastal ZPPI information.
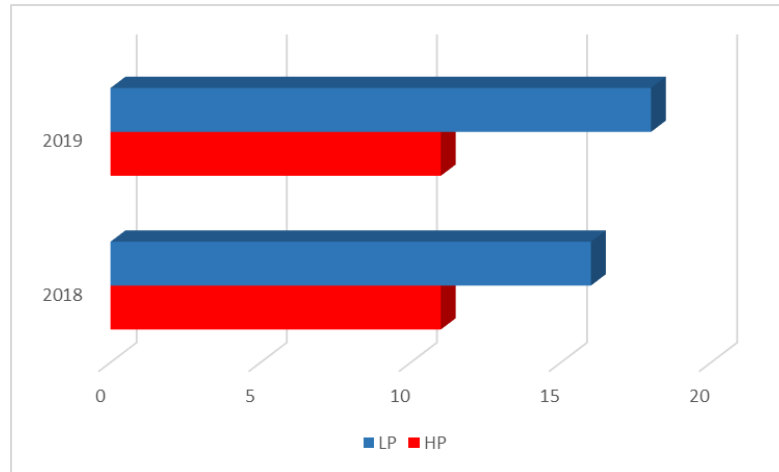
Figure 3-4: Comparison of Coastal ZPPI information based on High Potential (HP) and Low Potential (LP) criteria

Information on potential fishing zones in coastal areas (coastal ZPPI) is needed by small-scale fishermen who have small vessels with a loading capacity of under 5 GT. Such information is produced by two methods, namely the overlay of thermal front SST and chlorophyll-a parameters, as well as the results of determining thermal front SST. HP coastal ZPPI indicates there is a high potential for fish shoals because they are supported by a suitable environment and high nutrient conditions. LP coastal ZPPI indicates there is low potential for fish shoals because they are only supported by

appropriate environmental factors, but not by the level of water nutrients.

Coastal ZPPI information was only generated for coastal areas with a radius of between 4-12 nautical miles. The lowest limit of 4 nautical miles was obtained based on the interviews with fishermen on Nias Island on 24-20 September 2019, while the highest limit of 12 nautical miles was based on the lowest limit of the exclusive economic zone of Indonesian waters. The results of determining coastal ZPPI information for Nias Island waters are shown in Figure 3-5.
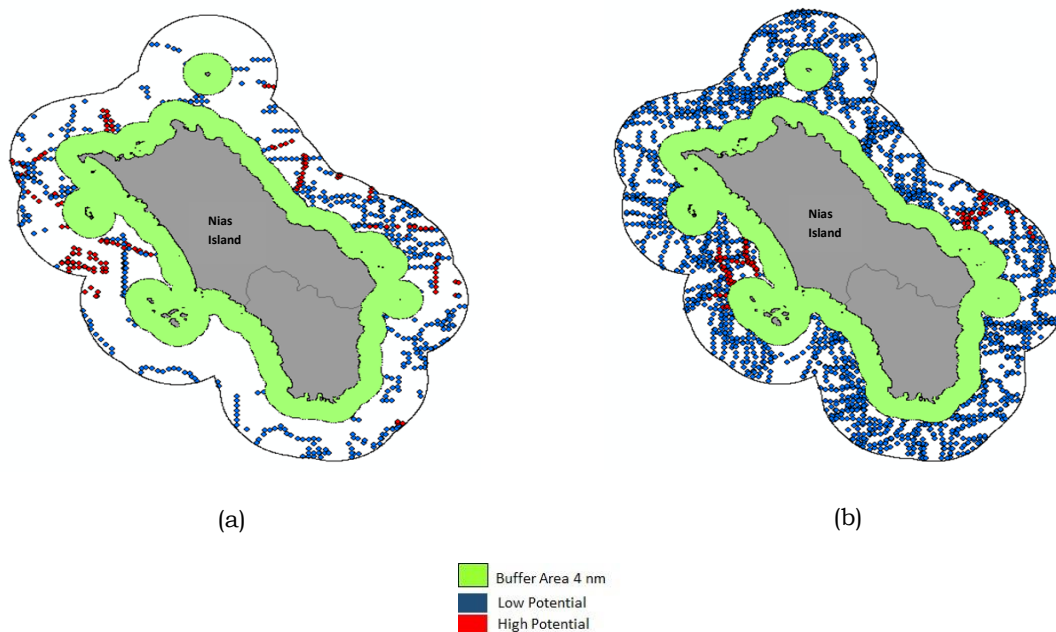

Figure 3-5: Coastal ZPPI Information for Nias Island Waters: (a) September 2018, (b) September 2019

The distribution of coastal ZPPI information in 2019, both HP and LP, was higher than that of 2018. The recapitulation data in Table 3-1 show that in September 2018 there was an information vacuum fof 3 days, namely on the 11th, 14th and 18th. This was due to several factors, including the lack of thermal front events on these dates from both GHRSST and SNPP VIIRS images, the value of chlorophyll-a concentrations being outside the limits of the mesotrophic area, as well as the fact that there was cloud cover around the research location. In September 2019, there was only one day of information vacuum, on the 29th. Even though the chlorophyll-a information was lower than in September 2018, the SST information from the GHRSST images was higher, meaning that the coastal ZPPI information generated in September 2019 was higher than in September 2018.

HP coastal ZPPI distribution was found in the west and east of the study site. The distribution of HP coastal ZPPI on the western part of Nias Island was adjacent to the location of the reef (or locally 'gosong') which is often used as a fishing ground. Based on information from the local fishermen, coral reefs are located at a depth of around 15-20 meters. Purwanto et al. (2020) mapped the distribution of 'gosong karang' around the waters of North Nias using Sentinel 2A images, with the location of the reef distribution is in accordance with the fishing locations of fishermen in North Nias Regency (Winardi et al., 2007, cited in Telaumbana, 2009). Distribution of the HP coastal ZPPI in the eastern part of Nias Island was in the water depth transition area, as shown in Figure 3-6. This area indicates the mixing of water masses, so it can be assumed that underwater masses rise to the surface carrying a high level of nutrients that will be used as food by the fish. This natural event is often known as the upwelling process.
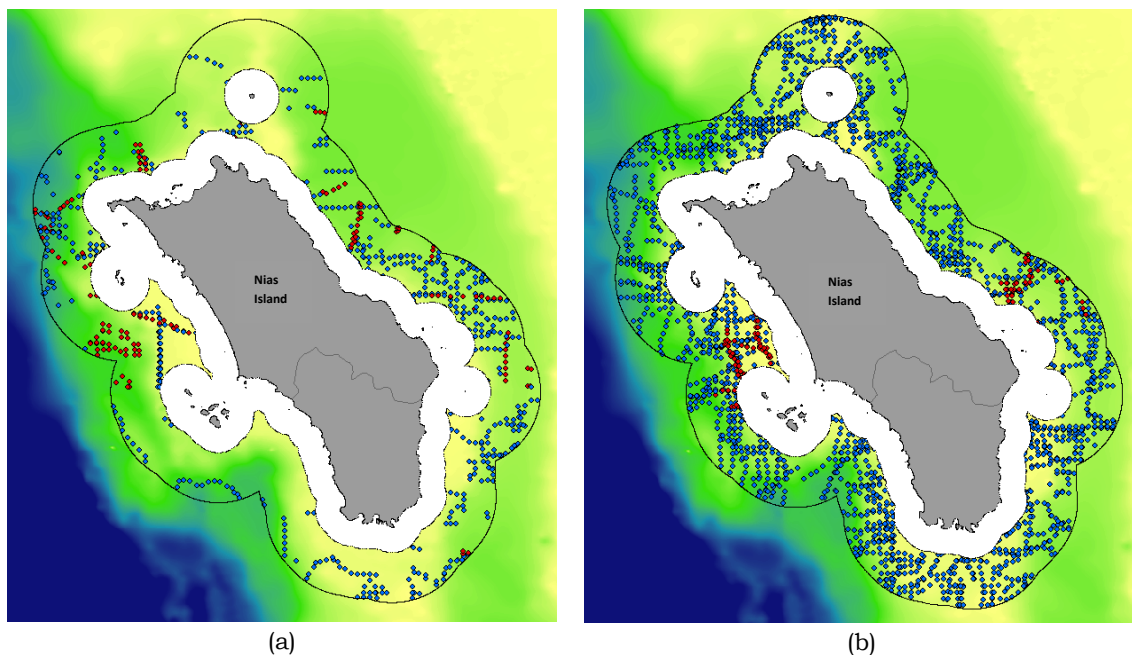

(a)   (b)

Figure 3-6: Overlay of Water Depth Map and Coastal ZPPI Information: (a) September 2018, (b) September 2019 (Source: Gebco Data 2014)

3.3 Effectiveness of the Use of GHRSST Imagery for Determining Coastal ZPPI

One obstacle to producing current ZPPI information (using SNPP-VIIRS imagery) is cloud cover, which is very high on certain days, so ZPPI information cannot be generated. GHRSST imagery can be optimised to solve some the weaknesses of the use of certain previous satellite imagery. Figure 3-7 shows the suitability of coastal ZPPI information from thermal front GHRSST images and SNPP VIIRS images on September 25th and September 26th, 2018. The figure shows the suitability of the two locations circled to the east and west of the sland, with the two images

used (GHRSST and SNPP-VIIRS) producing the coastal ZPPI information at that location.

A suitability test was also peformed on the results of the determination of coastal ZPPI based on thermal fronts from the GHRSST and SNPP VIIRS images on adjacent dates, i.e. September 6th, 11th, 17th and 22th, 2019, as shown in Figure 3-8. On September 6th and 11th, suitable coastal ZPPI points from the GHRSST and SNPP VIIRS images were found in the western and southern parts of the study site, while suitable coastal ZPPI distribution on September 17th and 22th from both images was also found in the northern and eastern parts of the study location.
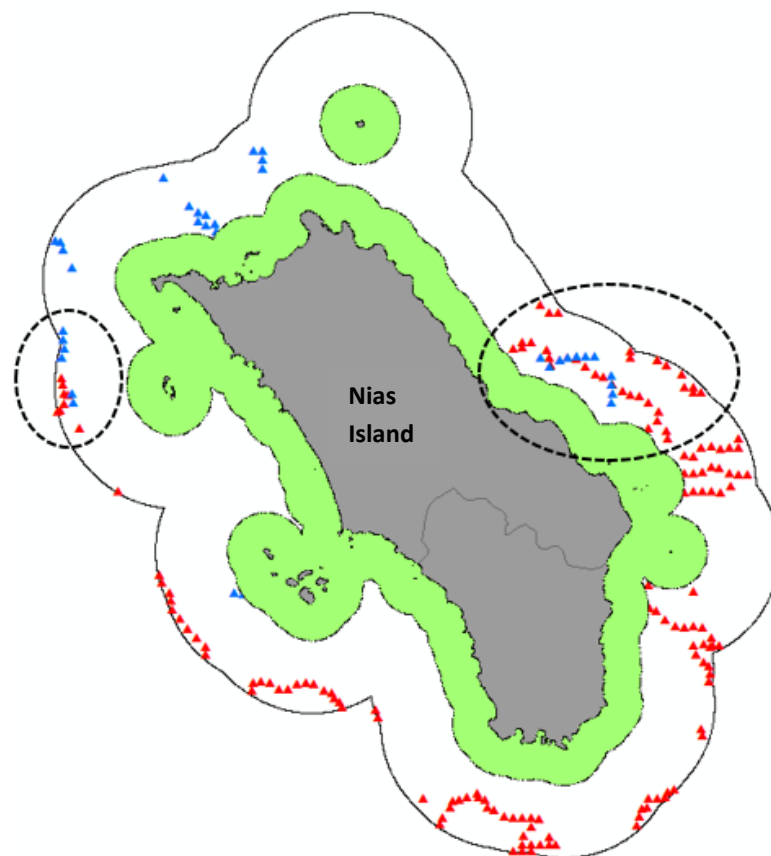

Figure 3-7: Suitability of Coastal ZPPI information from GHRSST (blue) and SNPP VIIRS (red) on September 25th and 26th, 2018
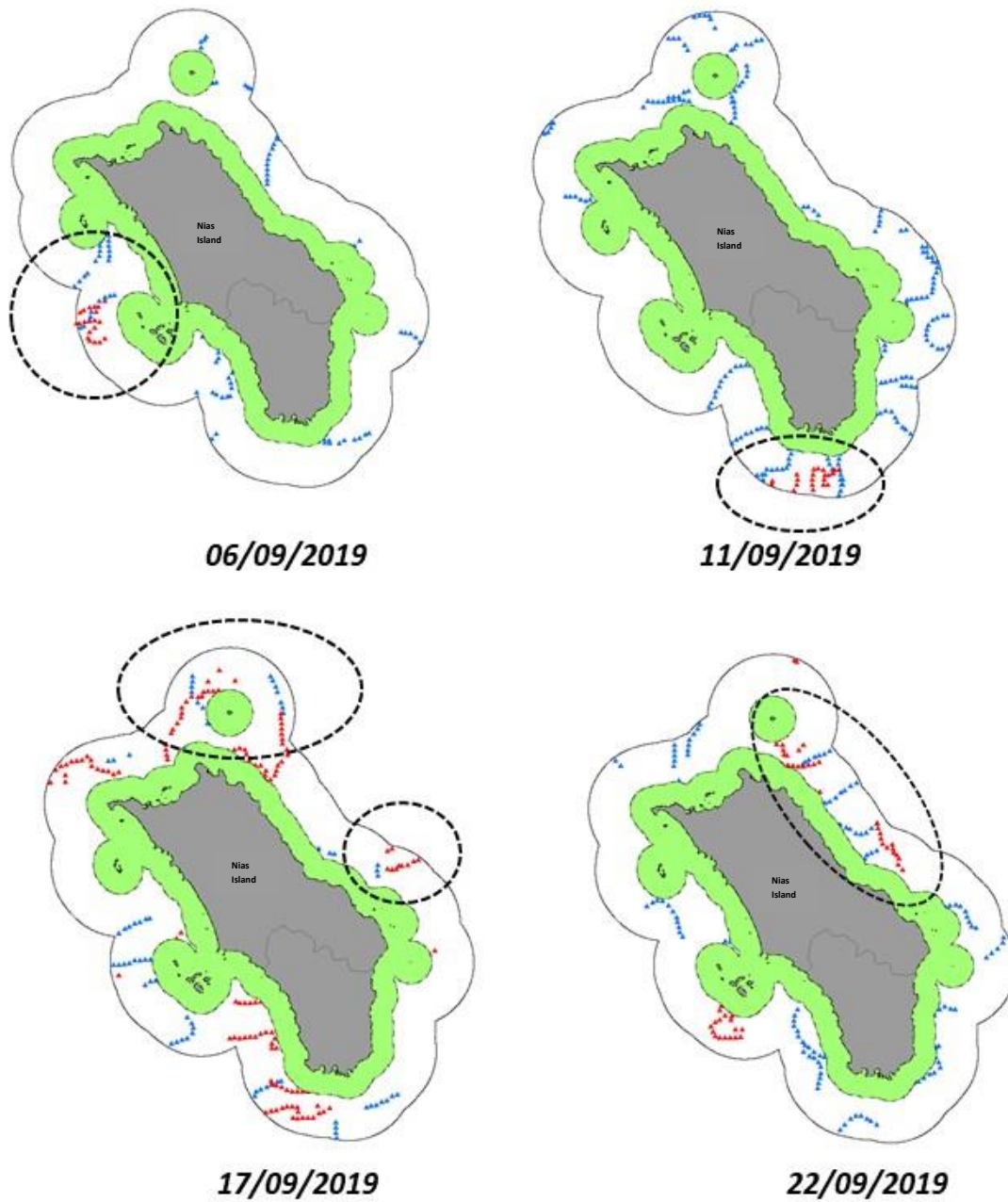
Figure 3-8: Suitability of Coastal ZPPI information from GHRSST (blue) and SNPP-VIIRS (red) on September 6th and 11th, and 17th and 22th, 2019
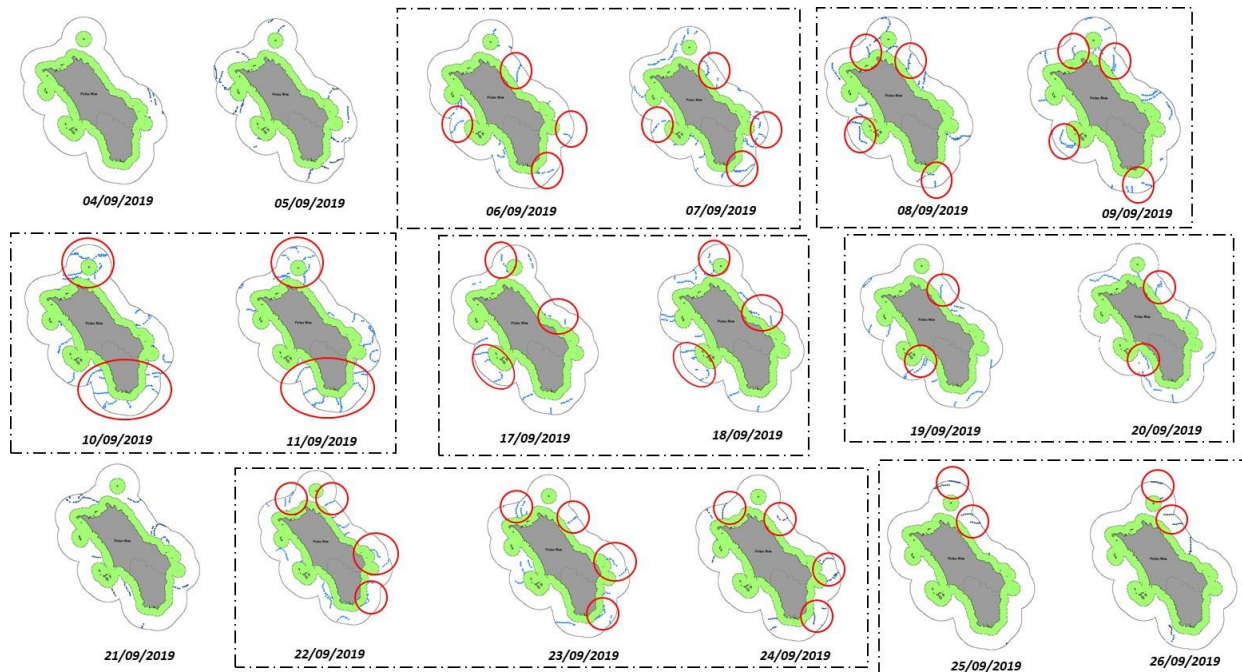
Figure 3-9: Coastal ZPPI Distribution Pattern based on Thermal Fronts from GHRSST Images on September 6th-22th and 17th-22th, 2019

Figure 3-9 shows the distribution pattern of the coastal ZPPI in September 2019 based on thermal front GHRSST images. In general, the thermal front has almost the same pattern over a two day period, while a difference in thermal front patterns over a 2-3 day period is seen in some parts of Nias Island. Thermal fronts occur in the western and southern parts of the island because the oceanographic conditions in these waters are more dynamic than in other parts, while the fronts that occur in the eastern and northern parts of the island tend to be in water depth transition areas.

4   CONCLUSION

The use of SST parameters from GHRSST images and the addition of chlorophyll-a parameters from MODIS Aqua images are very effective and efficient in supporting the provision of coastal ZPPI information in the waters of Nias Island and its surroundings. The use of GHRSST image data is able to complete the lack of daily ZPPI information due to weaknesses in the SNPP-VIIRS imagery. The results of determining the information on coastal ZPPI in Nias Island waters can be divided into two categories, namely high potential (HP) and low potential (LP) coastal ZPPI.

The resulting coastal ZPPI model is suitable for fishing locations around Nias Island. About 90 percent of ZPPI Coastal information is generated monthly. In September 2018, 27 days of coastal ZPPI information were produced, consisting of 11 sets of HP information and 16 of LP information, while in September 2019 there were 29 coastal ZPPI information days, consisting of 11 HP sets of information and 18 LP sets. The limit of the coastal ZPPI information was at a distance of 4-12 nautial miles from the coastline. The model that have been developed should also be tested in other water locations in Indonesia because the character of marine waters, especially in coastal areas, differs greatly.

AUTHOR CONTRIBUTIONS

Analysis of Potential Fishing Zones In Coastal Waters: A Case Study Of Nias Island Waters. Lead Author: Anang Dwi Purwanto, Co-Author: Teguh Prayogo, Sartono Marpaung, and Argo Galih Suhada.

REFERENCES

Angraeni, Rezkyanti, N.I., Safruddin, & Zainuddin, M. (2014). Spatial and Temporal Analysis of Skipjack Tuna (Katsuwonus pelamis) Catch and Thermal Front during the Transition Season in the Bone Bay. *Jurnal IPTEKS PSP, 1*(1), 20 – 27.

Balaguru, B., Ramakrishnan, S.S., Vidhya, R., & Thanabalan, P. (2014). A Comparative Study on Utilization Of Multi-Sensor Satellite Data To Detect Potential Fishing Zone (PFZ). *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-8*, 2014. ISPRS Technical Commission VIII Symposium, 09 - 12 December 2014, Hyderabad, India.

Departemen Kelautan dan Perikanan. (2008). Implementation Guidelines for Fisheries Port Management, Jakarta.

Hamzah, R., Prayogo, T., & Marpaung, S. (2016). Method Of Determination Points Coordinate for Potential Fishing Zone Based on Detection of Thermal Front Sea Surface Temperature. *Jurnal Penginderaan Jauh, 13*(2), 97–108.

Hasyim, B. (2015). Indonesian Institute of Aviation and Space Develop the Potential Fishing Zones. https://berita2bahasa.com/berita/1/15 591610-lapan-kembangkan-zppi-bantu-nelayan-identifikasi-zona-ikan. Accessed 20 Jan 2020.

Hanintyo, R., Hadianti, S., Mahardhika, R.M.P., Aldino, & Islamy, F. (2015). Seasonal Distribution of Thermal Front Events Based on Aqua-MODIS Imagery in WPP-RI 714, 715, WPP-RI 716. Prosiding Seminar Nasional Penginderaan Jauh Nasional 2015.

Lasabuda, R. (2013). Regional Development in Coastal and Ocean in Archipelago Perspective of The Republic of Indonesia. *Jurnal Ilmiah Platax, I*-2, 92-101.

Marpaung, S., Prayogo, T., Parwati, E., Setiawan, K.T & Roswintiarti, O. (2018). Study On Potential Fishing Zones (PFZ) Information Based On S-Npp Viirs and Himawari-8 Satellites Data. *International Journal of Remote Sensing and EarthSciences, 15*(1), 51–62.

Nurdin, S., Mustapha, M., Lihan, T., & Zainuddin, M. (2017). Applicability of remote sensing oceanographic data in the detection of potential fishing grounds of Rastrelliger kanagurta in the archipelagic waters of Spermonde, Indonesia. *Fisheries Research, 196,* 1-12.

Paena, M., Suhaimi, R.A., & Undu, M.C. (2015). Analysis of Dissolved Oxygen Concentration (DO), pH, Salinity and Temperature in the rainy season on the decline in water quality in the Punduh Waters Pesawaran Regency Lampung Province. Seminar Nasional Kelautan X, Sinergitas Teknologi dan Sumber Daya Kelautan untuk Mewujudkan Indonesia sebagai Poros Maritim Dunia. Fakultas Teknik dan Ilmu Kelautan Universitas Hang Tuah, Surabaya 21 Mei 2015.

Pauly, D., & Christensen, V. (1993). Stratified Models of Large Marine Ecosystem: A General Approach and an Application to the South China Sea. In: K. Sherman,

L.M Alexander and B.D Gold (Eds.), *Large Marine Ecosystems: Stress, mitigation and Sustainability*. Washington, D.C: AAAS Press:3-14.

Purwanto, A.D & Harsanugraha, W.K. (2012). Analysis of Sea Surface Temperature (SST) in the Western Java Sea Based on NOAA-AVHRR and MODIS Data. Prosiding PIT MAPIN XIX. Makassar.

Purwanto, A.D., Prayogo, T., & Marpaung, S. (2020). Identification of Coral Reef Using Sentinel 2A Satellite Imagery (Case Study: Coastal Waters of Northern Nias). *Jurnal Teknologi Lingkungan, 21*(1), , 095-108.

Retnowati, E. (2011). Indonesian fishermen in the vortex of structural poverty (social, economic and legal perspectives)*Jurnal Perspektif, XVI*(3), 149-159.

Simbolon, D. & Girsang, H.S. (2009). Relationship between chlorophyl-a concentration and frigate mackerel catches in fishing ground of Pelabuhanratu waters. *Jurnal Penelitian Perikanan Indonesia, 15*(4), 297-305.

Simbolon, D., Silvia, S & Wahyuningrum, P.I. (2013). The Prediction of Thermal Front and Upwelling as Indicator of Potential Fishing Grounds in Mentawai Water. *Marine Fisheries, 4*(1), 85-95.

Suwargana, N., & Ariel, M., (2004). Determination of Sea Surface Temperature and Chlorophyll Concentration for Developing of Predictional / Fishing Ground Models using MODIS Data. *Jurnal Penginderaan Jauh dan Pengolahan Data Citra Digital, 1*(1), 1-13.

Telaumbanua, S.B. (2009). *A Study of Capture Fisheries Development in Nias Regency*. Tesis. Sekolah Pascasarjana Institut Pertanian Bogor: Bogor.

Winardi, & Manuputy, A.E.W. (2007). Nias Ecology Baseline. Jakarta: COREMAP II–LIPI.

Zainuddin, M., Kiyofuji, H., Saitoh, K., & Saitoh, S. (2006). Using multi-sensor satellite remote sensing and catch data to detect ocean hot spots for albacore (Thunnus alalunga) in the northwestern North Pacific. *Deep-Sea Research II 53*(3-4) 419–431.

Zainuddin, M. (2011). Skipjack Tuna In Relation To Sea Surface Temperature And Chlorophyll-A Concentration Of Bone Bay Using Remotely Sensed Satellite Data. *Jurnal Ilmu dan Teknologi Kelautan Tropis, 3*(1), 82-90.

Zebua, N.D. & Ramli. (2014). Analyze the effect of the number of fleets, the number of fisherman, GDP, and investment to the production of fisheries in the region of Nias (Panel Data Analysis).. *Jurnal Ekonomi dan Keuangan, 2*(8), 463-474.