Siklus Daerah Potensial Penangkapan Ikan di WPP-NRI 711 Tahun 2011-2020
Cycle of Potential Fishing Area of WPP-NRI 711 Year 2011-2020

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Abstract
This study discussed the cycle of potential fishing areas in WPP-NRI 711 based on the distribution of Sea Surface Temperature (SST) and distribution of chlorophyll-a concentration using MODIS Aqua satellite imagery. The distribution of Potential Fishing Areas (PFA) was determined based on the distribution of the thermal front which was processed using MGET (Marine Geospatial Ecology Tools) and chlorophyll-a. Determination of fluctuations and the emergence period of PFA for 10 years (2011-2020) is carried out using wavelets. The results showed that the average SST in WPP-NRI 711 was 29 °C. The highest average SST is 31 °C in May of the Transitional I Season, and the lowest average temperature is 27.9 °C in February of the West Monsoon Season. The average chlorophyll-a concentration was 0.6 mg/m², the highest average chlorophyll-a concentration was 0.76 mg/m² in December West Monsoon Season, and the lowest average was 0.53 mg/m² in October Transitional II Season. The average PFA distribution area is 1.111 km², the highest average area is 1.324 km² in the West Monsoon Season, then the lowest area is 924 km² in the Transitional II Season. Based on global spectrum and wavelet analysis, it is known that the period of the appearance of PFA is 3-6 months or Seasonal. then in the Northern Region segment of WPP-NRI 711, covering the Natuna Sea, the appearance of PFA is strongly influenced by Seasonal current movements. Meanwhile in the southern part, including the Karimata Strait, the emergence of PFA is strongly influenced by river runoff and changing Seasons.

Keywords: North Natuna Sea, Potential Fishing Area, WPP-NRI 711, Aqua-MODIS

Abstrak
Penelitian ini membahas pola siklus daerah potensi penangkapan ikan di WPP-NRI 711 berdasarkan data sebaran Suhu Permukaan Laut (SST) dan sebaran konsentrasi klorofil-a menggunakan citra MODIS Aqua. Sebaran Daerah Potensi Penangkapan Ikan (PFA) ditentukan berdasarkan sebaran thermal front yang diolah menggunakan MGET (Marine Geospatial Ecology Tools) dan data klorofil-a. Penentuan fluktuasi dan periode kemunculan PFA selama 10 tahun (2011-2020) dilakukan menggunakan wavelet. Hasil penelitian menunjukkan bahwa rata-rata SST di WPP-NRI 711 yaitu 29 °C. SST rata-rata tertinggi yaitu 31 °C di bulan Mei musim Peralihan I, dan suhu rata-rata terendah yaitu 27,9 °C di bulan Februari musim Barat. Konsentrasi klorofil-a rata-rata adalah 0,6 mg/m², rata-rata konsentrasi klorofil-a tertinggi adalah 0,76 mg/m² di bulan Desember musim Barat, rata-rata terendah 0,53 mg/m² di bulan Oktober musim Peralihan II. Rata-rata luas sebaran PFA adalah 1,111 km², rata-rata tertinggi dengan luas 1,324 km² di musim Barat, kemudian luas terendah 924 km² di musim Peralihan II. Berdasarkan analisis spectrum global dan wavelet diketahui bahwa periode dari kemunculan PFA adalah 3-6 bulan atau musiman. kemudian pada segmen Wilayah Utara WPP-NRI 711, mencakup Laut Natuna, kemunculan PFA sangat dipengaruhi oleh pergerakan arus musiman. Sementara di bagian Selatan, mencakup Selat Karimata, kemunculan PFA sangat dipengaruhi oleh limpasan sungai dan pergantian musim.

Kata kunci: Laut Natuna Utara, Daerah Potensial Penangkapan Ikan, WPP-NRI 711, Aqua-MODIS
1. Introductions

The State Fisheries Management Area of the Republic of Indonesia 711 (WPP-NRI 711) is one of eleven fisheries management areas with capture fishery production of 805,233 tons according to the Ministry of Maritime Affairs and Fisheries in 2014, which includes groups of small pelagic fish, large pelagic fish, demersal fish, reef fish, mollusks and crustaceans. The abundant marine commodity in WPP-NRI 711 is also a national strategic water bordering the sea directly with neighboring countries such as Singapore, Malaysia, the Philippines, Thailand, and Vietnam (Nikijuluw, 2008).

Studies on PFA (Potential Fishing Areas) in WPP-NRI 711 have been carried out previously but are still limited. Permana et al., (2019) had done Seasonal PFA detection of WPP-NRI 711 using remote sensing based on thermal front detected by SIED (Single Image Edge Detection) method and concentration of chlorophyll-a to determine the frequency of PFA occurrence points with 3 years of data, where the results of the distribution of PFA in the waters of West Kalimantan, North Natuna Sea, Bangka Island, and Belitung Island with the highest distribution of PFA in the Transitional I Season, while the lowest distribution during the East Monsoon Season. According to the previous study of Nababan and Simamora (2012), the variability of chlorophyll-a concentration in Natuna Sea ranges from 0.11-4.92 mg/m³ with an average of 0.56 mg/m³ and in the East Monsoon Season ranges from 0.09-2.93 mg/m³ with an average of 0.66 mg/m³. The distribution of chlorophyll-a concentrations is generally lower in the middle of the Natuna Sea and increases towards the coastal waters. The abundance of fishing grounds can be found during Transitional Season II (September-November) in the continental shelf boundary area, which is approximately 2-150 nautical miles from the coast line. It is characterized by high fishing activity in this season (Fadilah et al., 2020).

A study that discusses the characteristics of PFA in WPP-NRI 711 needs to be carried out to determine the period of PFA emergence and PFA fluctuations for 10 years from 2011-2020, and this study will discuss the condition of sea surface temperature, chlorophyll-a and the distribution of monthly PFA for 10 years (2011-2020) in WPP-NRI 711, then PFA data will be used to determine the PFA cycle using the wavelet to find out the characteristics of PFA in WPP-NRI 711 more deeply, in order to increase more study of WPP-NRI 711, as well as maximizing the potential of WPP-NRI 711 as a fishery commodity for the Republic of Indonesia.

2. Methods

2.1. Time and Place

The study area in this research is located in WPP-NRI 711, with geographical coordinates of WPP-NRI 711 and its position lies between 102°59'32" East Longitude (BT) to 110°38'50" East Longitude and 3°2’ 17’’ to 1°31’ 26’’ North Latitude (BD) to 2°49’ 19” North Latitude (BD).
South Latitude (LS) to 7°44'34" N Latitude. Data processing activities are carried out in September 2021–May 2022. The location for data processing is the Modeling and Mapping Laboratory of the Marine Sciences Department, Faculty of Mathematics and Natural Sciences, Tanjungpura University, Pontianak.

2.2. Data Collection

Data collection includes secondary data obtained by downloading from sites that provide chlorophyll a and sea surface temperature obtained from Aqua MODIS (Moderate Resolution Imaging Spectroradiometer) images, accessed using browser 3 from NASA which can be accessed through the https://oceancolor.gsfc.nasa.gov/, then it will be processed using a laptop.

2.3. Image Processing

Stages of data processing using GIS start from cropping and layout of chlorophyll a and SST data into SHP WPP-NRI 711, then entering the optimal criteria for determining PFA (0.2 - 1 mg/m³) on chlorophyll a and 24 °C - 31 °C at sea surface temperature), and then determine the average value of the image for 10 years for each month.

2.4. Chlorophyll and SST

Chlorophyll a data used is in the form of level 3 SMI (Standard Mapped Image) data with the OCI algorithm, which has gone through the sensor calibration process, atmospheric correction, application of the bio-optical algorithm at level 2, and at level 3 has been equipped with radiance normalization and optical aerosol thickness.

The equations of the CI and OCI algorithms are as follows:

\[
CI = R_i(\lambda_{blue}) - R_i(\lambda_{red}) + (R_i(\lambda_{red} - \lambda_{blue})/R_i(\lambda_{red} - \lambda_{green}))/R_i(\lambda_{green} - \lambda_{blue})
\]  

(1)

\[
\log_{10}(\text{chlor}_a) = a_0 + \sum_{i=1}^{N} a_i \left( \log_{10}\left( \frac{R_i(\lambda_{blue})}{R_i(\lambda_{green})} \right) \right)
\]  

(2)

Description:

\(\lambda_{blue} = 443\) nm

\(\lambda_{green} = 553\) nm

\(\lambda_{red} = 670\) nm

The SST data uses a nonlinear algorithm from Walton et al. (1998) which has been modified and uses empirical coefficients from in situ data regression and satellite measurements (NASA, 2018).

The equations of the sea surface temperature algorithm are as follows:

\[
SST = a_{i1} + a_{i2}BT_{11\mu m} + a_{i3}(BT_{11\mu m} - BT_{12\mu m}) + a_{i4}(\sec(\theta - 1)(BT_{11\mu m} - BT_{12\mu m}) + a_{i5}(\text{mirror}) + a_{i6}(\theta^2)
\]  

(2.3)

Description:

\(BT_{11\mu m} = \) Brightness temperature in 11µm channel.

\(BT_{12\mu m} = \) Brightness temperature in 12µm channel.

\(T_{sfc} = \) SST reference

\(\theta = \) Sensor peak angle

\(\theta^* = \) Sensor peak angle in negative

\(\text{mirror} = \) Mirror side number (0 or 1)

coefficient \(a_{ij} = \) Algorithm coefficient set for month of year, and latitude.

2.5. Thermal Front Area Detection

Detection of thermal front are using the Cornilon algorithm (1992) in Marine Geospatial Ecology Tools (MGET) additional module version 0.8a in GIS program that can be downloaded on the website (http http://mgel2011kvm.env.duke.edu/mget/download/).

The temperature threshold and the histogram window used are 0.3 °C and 32x32, which are the optimal parameters that can be implemented in Indonesian waters (Hamzah et al., 2014).

The equations of the SIED algorithm of Cayula and Cornillon (1992) are as follows:

\[ C = \{ (X_p, Y_p) p \in [1, N] \} \]  

(2.4)

Description

\(C\) = Isoline

\(N\) = Length of isolines (pixels)

\(X_p, Y_p\) = Pixel location coordinates

\(S_q = \{ (X_p, Y_p) p \in [q, q + \lambda - 1] \cap [1, N] \} \]  

(2.5)

Description

\(S_q\) = Image segment

\(\lambda\) = Length of gradient

\(X_p, Y_p\) = Pixel location coordinates
2.6. PFA Cycle Determination

Determination of the PFA cycle is using wavelet analysis of PFA distribution data of 10 years which is first separated into North and South segments, then proceed to calculate the fluctuation of PFA and the period of PFA emergence from these two segments for 10 years of data. Transformation wavelet refers to Torrence and Compo (1998), where a morlet wavelet which the first step will determine the value of the wavelet transformation, then it will be converted into a wavelet, then the wavelet power spectrum will be averaged to a certain scale that describes the series. Time variance, and in the global wavelet spectrum power will be averaged wavelet over the local wavelet along the time axis (Hajrul et al., 2019). The equations of the wavelet will be described sequentially as follows:

\[ W^2(S) = \frac{1}{N} \sum_{n=0}^{N-1} |W_n(S)|^2 \]  

\[ \sigma^2 = \frac{\hat{\delta}^2}{C_\delta N} \sum_{j=0}^{J} \frac{|W_n(s_j)|^2}{s_j} \]  

\[ SD = \left| W_n(S) \right|^2 \]  

\[ W_n(s) = \sum_{k=0}^{N-1} x_k \psi(s) e^{i\omega_k} \]  

Description:

\( \hat{\delta} \) = Time interval  
\( s \) = Dilated parameter  
\( n \) = Translation parameter  
\( x_k \) = Time series  
\( \sigma \) = Time series variance  
\( k \) = Frequency index  
\( \omega_k \) = Angular frequency  
\( C_\delta \) = Reconstruction factor  
\( \hat{\delta} \) = Average scale factor

3. Results and Discussion

3.1. Distribution of Sea Surface Temperature in WPP-NRI 711 for 10 Years

![Figure 2. Distribution of Sea Surface Temperature in WPP-NRI 711 for 10 Years](image)
The average SST (Sea Surface Temperature) of WPP-NRI 711 is 29 °C with the highest average in May, which is 31 °C and the lowest average temperature is in May-February with a temperature of 27.9 °C, Figure 4.1. In the West Monsoon Season (December-February) the North Natuna Sea has an average temperature of 27 °C. In this Season there is advection of cold ocean currents originating from the Northeastern part of the North Natuna Sea. This current is driven by the Northwest Monsoon winds that pass along the coast of the eastern peninsula of Malaysia and towards the Karimata Strait (Daryabor et al. 2016; Kok et al., 2021). In the coastal areas of the islands of Kalimantan and Sumatra, the sea surface temperature ranges from 30-31 °C, then in the Karimata Strait, the SST ranges from 29-30 °C.

During the East Monsoon Season (June-August) the average temperature reaches 30.1 °C, SST in the coastal waters of the islands of Kalimantan and Sumatra ranges from 30-32 °C, in the Natuna Sea the SST ranges from 29-31 °C, and in the Karimata Strait ranges from 28.5-30 °C. In this Season the wind pressure reverses from the Northwest to the Southeast, bringing the mass of water from the Java Sea that moves through the Karimata Strait. This mass movement of seawater brings cold temperatures from the Java Sea making the temperature of the coastal areas decrease.

During the Transitional I Season (March-May) the average sea surface temperature was 30.2 °C, in March it is shown in Figure 4.1, SST in the coastal areas of the island of Kalimantan reaches 36 °C, then on the coast of the island of Sumatra it is 31 °C. SST which is higher than the high seas can be caused by the hotter land effect (Nababan & Simamora, 2014). SST in the Natuna Sea is 27 °C, then in the Karimata Strait, the SST ranges from 29-31 °C.

During the Transitional II Season (September-November) the average sea surface temperature is 30 °C, then in the coastal areas of Kalimantan and Sumatra, the SST ranges from 30-32 °C. In the Natuna Sea, the SST ranges from 28.5-30 °C, and in the Karimata Strait, the SST ranges from 28.5-30.5 °C. In this Season the wind pressure decreases and will change direction from Southeast to Northwest causing SST to rise again because the current supply from the Java Sea decreases, in Figure 4.1 in November it can be seen that low SST began to emerge from the North Natuna Sea (Apriansyah & Atmadipoera, 2020).

3.2. Distribution of Chlorophyll a Concentration in WPP-NRI 711 for 10 Years

![Figure 3. Distribution of Chlorophyll a Concentration in WPP-NRI 711 for 10 Years](image-url)
Results of chlorophyll-a data processing of WPP-NRI 711 for 10 years (2011-2020) is the average concentration of chlorophyll-a in WPP-NRI 711 is 0.6 mg/m³, in Figure 4.2 the highest average chlorophyll-a concentration is 0.76 mg/m³ in the West Monsoon Season in December, then the lowest average is 0.53 mg/m³ in October’s Transitional II Season.

Table 1. Classification of chlorophyll-a concentration according to Arsjad et al. (2004).

<table>
<thead>
<tr>
<th>Class</th>
<th>Concentration mg/m³</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt;0.3</td>
<td>Low Concentration/ clear water</td>
</tr>
<tr>
<td>II</td>
<td>0.3-0.5</td>
<td>Medium Concentration/ medium rich phytoplankton</td>
</tr>
<tr>
<td>III</td>
<td>0.5-1.0</td>
<td>High Concentration/ rich phytoplankton</td>
</tr>
<tr>
<td>IV</td>
<td>1.0-2</td>
<td>Chlorophyll-a &amp; high suspended content/ slightly turbid water</td>
</tr>
<tr>
<td>V</td>
<td>&gt;2</td>
<td>High suspended content/ high turbidity</td>
</tr>
</tbody>
</table>

According to the table, the concentration of chlorophyll-a (Table 4.1), chlorophyll-a concentration in the waters of WPP-NRI 711 belong to class III (0.5-1.0 mg/m³) or high concentration/rich phytoplankton for the North Natuna sea area and the Karimata Strait area, then in the coastal areas of Kalimantan and Sumatra the concentration of chlorophyll-a fall under class V (> 2 mg/m³) or high suspended content/high turbidity. High concentration of chlorophyll-a are the results of image processing, especially in coastal areas, are thought to be due to contamination with chlorophyll-a values on satellite sensors by suspended sediment (Wirasatriya et al., 2021).

During the West Monsoon Season (December-February), the average concentration of chlorophyll-a reached 0.7 mg/m³. In this Season there is a distribution of chlorophyll-a concentration ranging from 0.5-1 mg/m³ in the North Natuna Sea and evenly distributed in the Karimata Strait. The high concentration of chlorophyll-a in the West Monsoon Season is influenced by the advection of cold currents from the North Natuna Sea and high rainfall which results from river runoff from Kalimantan and Sumatra bringing nutrients to the sea and then increasing chlorophyll-a levels in coastal areas (Xu et al., 2021; Kok et al., 2021). This is in accordance with the research of Daryabor et al. (2016) where the concentration of chlorophyll-a in the Karimata Strait is higher in the West Monsoon compared to the East Monsoon because influence by the river runoff which is higher in the West Monsoon Season.

In the Transitional Season I (March-May), the average concentration of chlorophyll-a decreased to 0.62 mg/m³, the concentration of chlorophyll-a only scattered in the coastal areas of the Karimata Strait, this is due to the decrease in wind pressure due to the transition of the Monsoon from Northwest to Southeast. In the East Monsoon Season (June-August) the concentration of chlorophyll-a increased to 0.65 mg/m³, the concentration of chlorophyll-a is evenly distributed in the Karimata Strait and slightly distributed in the North Natuna Sea area this Season. In this Season the distribution of chlorophyll-a is influenced by the current from the Java Sea which moves north along the Karimata Strait.

In the Transitional II Season (September-November), the concentration of chlorophyll-a decreased to 0.57 mg/m³ which is the lowest of the four Seasons, this is due to the decrease in wind pressure by the transition of the Monsoon from Southeast to Northwest (Apriansyah & Atmadipoera, 2020). Same as in the Transitional Season I, there is a distribution of chlorophyll-a in the coastal area, but in this Season the distribution on the coast has more area than the Transitional Season I, and in the North Natuna Sea there is a small distribution of chlorophyll-a.
3.3. Distribution of Potential Fishing Areas in WPP-NRI 711 for 10 Years

The results of PFA data processing of WPP-NRI 711 obtained that the average PFA distribution is 1,111 km², then the highest average was in the West Monsoon Season (December-February) with an area of 1,324 km², then decreased in the Transitional Season I with an average area an average of 989 km², then in the East Monsoon Season (June-August) with an average area of 1,208 km² and in the Transitional Season II with the lowest area of 924 km² as shown in Figure 4.3. In the West Monsoon Season (December-February) the average PFA area reaches 1,324 km². The wide distribution of the PFA is influenced by the advection of cold ocean currents in the North Natuna Sea which forms an eddy around the Natuna Islands and which support the offshore biological activity (Kok et al., 2021). In Figure 4.2 PFA in the West Monsoon Season (December-February) is spread from the Natuna Sea to the Karimata Strait.

In the first transitional Season, the average PFA distribution decreased to 989 km². According to Zhou et al., (2015) this is due to low wind pressure and current transport in Transitional Season which results in the mixing process of water masses not forming optimally. In this Season there is a small distribution in the Natuna Sea and a large distribution in the Karimata Strait.

In the East Monsoon Season (June-August) the distribution of PFA increases with an average area of 1,208 km². In this Season there is a current that moves northward from the Karimata Strait towards the coast of Thailand, which forms an eddy in the North Natuna Sea. This eddy rotates to south on the northeast coast of the Natuna islands, then turns south towards the northern coast of West Kalimantan,
and rotates to form a weaker eddy in the East Monsoon Season (June-August). There are PFA around the Natuna Islands and the northern part of West Kalimantan (Daryabor et al., 2016; Kok et al., 2021). In this Season, a small area of PFA is found in the Natuna Sea and a large area in the Karimata Strait.

In the Transitional II Season (September-November), the average distribution of PFA again decreased to 924 km². This is caused by decreased wind pressure due to the transition of the Monsoon from Southeast to Northwest (Zhou et al., 2015). In this Season, PFA has a small distribution in the Natuna Sea and a large distribution in the Karimata Strait.

3.4. PFA Fluctuations in WPP-NRI 711 for 10 Years

The wide fluctuation of PFA in WPP-NRI 711 for 10 years using the wavelet transform method, which is divided into two segments (North and South segments) first, then the result is that PFA in WPP-NRI 711 waters has a period of 0.25-0.5 years (3-6 months) as shown in Figure 4.6, for both segments are marked in orange - red color which means they have a high PFA.

Figure 4.6. PFA Fluctuations in WPP-NRI 711 for 10 Years

In the waters of WPP-NRI 711, the PFA period of 3-6 months has a strong influence from the Monsoon system, where the Southeast Monsoon peaks in June to late August (Eastern Monsoon Season) which will bring dry air from Australia resulting in a dry Season in Indonesia. After that, in Indonesia was replaced by the Northwest Monsoon which peaked in December-February (West Monsoon Season) bringing high rainfall to Indonesia (Wirasatriya et al., 2021).

According to Apriansyah and Atmadipoera (2020), the cycle of currents passing through the Karimata Strait has similarities to the Natuna Sea. There is a high sea level slope between the Natuna Sea and the Java Sea in the West Monsoon, which forms a horizontal pressure gradient that is very influential on the Sunda Strait Cross Current, where the ocean current will flow to the south after passing through the Natuna Sea and Karimata Strait, then it will turn towards East as it enters the Java Sea.

This 6-month or semiannual tends to occur on equatorial waters except for the equatorial Indian Ocean region. This semiannual cycle is also found in the Java Sea and Makassar Strait, then the annual cycle is found in the Banda Sea and the Seram Sea (Syarifah et al., 2020).
In Figure 6 in the temporal variation section between the two segments, it can be seen that the fluctuations in the PFA for the Southern segment which includes the Karimata Strait are higher than the North segment which includes the North Natuna Sea, which indicates that PFA occurrences are more common in the Southern segment, but the highest PFA area is in the northern segment which reached 5,000 km² in January 2019.

The temporal variation with high fluctuations in the southern segment of the PFA is caused by the high amount of water runoff from river mouths due to rain that brings nutrients to the sea. The concentration of chlorophyll-a in the Karimata Strait does not experience significant fluctuations every season due to the low annual variability of rainfall, which means that rainfall experiences low variability, therefore the distribution of PFA in the Karimata Strait area is strongly influenced by river runoff (Aditya, 2021; Koropitan and Ikeda, 2016).

In the northern segment which includes the North Natuna Sea, PFA in this area is influenced by current movements along the eastern region of Peninsular Malaysia which form eddy cyclones in the West Monsoon and anticyclones in the East Monsoon in the waters around the Natuna Islands and Anambas Islands due to the emergence of baroclinic instability, then this current also results in the emergence of a thermal front in the northern region of West Kalimantan in the West Monsoon (Daryabor et al., 2016; Kok et al., 2021).

4. Conclusions

1. The average temperature in WPP-NRI 711 for 10 years is 29 °C, the highest average sea surface temperature is 31 °C in May of the Transitional Season I, and the lowest average sea surface temperature is 27.9 °C in February West Monsoon Season.

2. The average concentration of chlorophyll-a is 0.6 mg/m³, the highest average concentration of chlorophyll-a is 0.76 mg/m³ in December West Monsoon Season, and the lowest average concentration of chlorophyll-a was 0.53 mg/m³ in October of Transition II Season.

3. The average PFA distribution area is 1,111 km², the highest average PFA distribution is 1,324 km² in the West Monsoon Season, then the lowest area is 924 km² in the Transition II Season.

4. The period of the emergence of PFA is 3-6 months or Seasonal, then in the northern segment covering the North Natuna Sea the appearance of the PFA is strongly influenced by Seasonal current movements, while in the southern segment which includes the Karimata Strait is strongly influenced by river runoff, then the influence of Seasonal current movements.

5. References


