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IDENTIFICATION OF THE TEMPORAL RELATIONSHIP BETWEEN THERMAL FRONT INTENSITY AND SKIPJACK FISHERIES PRODUCTION LANDED AT PPN TERNATE

Identifikasi Hubungan Temporal Intensitas Thermal Front dengan Produksi Perikanan Cakalang yang Didaratkan di PPN Ternate

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ABSTRACT

The convergence of two oceans in Indonesian waters results in complex oceanographic dynamics, including the formation of thermal fronts. Thermal front areas are rich in nutrients, making them valuable for predicting potential fishing grounds. This study aims to identify the relationship between thermal fronts and skipjack tuna fisheries production landed at PPN Ternate, in order to assess whether thermal front data can be used to predict skipjack tuna fishing grounds in the area. The data utilized consists of fisheries production records and sea surface temperature images obtained from the Terra MODIS satellite. The images were processed using the Single Image Edge Detection (SIED) algorithm to map thermal front areas and measure their intensity. The relationship between thermal front intensity and skipjack tuna production was analyzed using Pearson correlation. The results show that thermal front areas are dynamically distributed around PPN Ternate every month, with increased intensity observed in February-March, July-October, and December. However, Pearson correlation analysis indicates no significant relationship between thermal front intensity and skipjack tuna fisheries production.

Keywords: Correlation, Fisheries Production, Fishing Grounds, Nutrients, Skipjack Tuna, Thermal Front

ABSTRAK

Pertemuan dua samudra di perairan Indonesia menghasilkan dinamika oseanografi yang kompleks, termasuk pembentukan thermal front. Area thermal front kaya akan nutrien, sehingga dianggap penting dalam memprediksi daerah penangkapan ikan yang potensial. Penelitian ini bertujuan untuk mengidentifikasi hubungan antara thermal front dengan produksi perikanan ikan cakalang yang didaratkan di PPN Ternate, guna menilai apakah data thermal front dapat digunakan untuk memprediksi daerah penangkapan ikan cakalang di wilayah tersebut. Data yang digunakan terdiri atas catatan produksi perikanan dan citra suhu permukaan laut yang diperoleh dari satelit Terra MODIS. Citra tersebut diolah menggunakan algoritma Single Image Edge Detection (SIED) untuk memetakan area thermal front dan mengukur intensitasnya. Hubungan antara intensitas thermal front dengan produksi ikan cakalang dianalisis menggunakan korelasi Pearson. Hasil penelitian menunjukkan bahwa area thermal front terdistribusi secara dinamis di sekitar PPN Ternate setiap bulan, dengan intensitas yang meningkat pada bulan Februari–Maret, Juli–Oktober, dan Desember. Namun demikian, analisis korelasi Pearson menunjukkan tidak terdapat hubungan yang signifikan antara intensitas thermal front dan produksi perikanan ikan cakalang.

Kata Kunci: Korelasi, Produksi Perikanan, Daerah Penangkapan, Nutrient, Ikan Cakalang, Thermal Front

INTRODUCTION

Indonesian waters located between two oceans have complex oceanographic dynamics, one of which is the thermal front phenomenon. Thermal front is the boundary between two water masses with different temperatures (Maharani *et al.,* 2020). Thermal front can be an indication of potential fishing areas (Simbolon & Tadjuddah, 2008; Nammalwar *et al.,* 2013). Fishing areas can be predicted if there is information available that is a predictor such as thermal front, upwelling, and chlorophyll-a distribution in the waters (Simbolon *et al.,* 2013).

Thermal front areas tend to have high nutrient content (Mustasim *et al.,* 2015). The presence of these nutrients triggers an increase in primary productivity in the form of phytoplankton which is the basis of the food chain for pelagic fish such as skipjack tuna. Therefore, thermal fronts are often used as potential indicators in determining productive fishing areas by combining image data and field surveys (Tangke & Deni, 2013). This condition supports the formation of areas with high prey abundance, which in theory should increase the opportunity for pelagic fishing. Thus, the presence of a thermal front can be considered as one of the important indicators in identifying productive fishing areas.

Studies on the relationship between thermal fronts and pelagic fish distribution have been widely conducted, especially in identifying potential fishing areas. According to Khoir & Safruddin (2023), thermal fronts can be used in predicting fishing areas, although there are only 5 fishing points out of 61 fishing trips that occur in the thermal front area. Research in the Banda Sea shows a positive relationship between the presence of a thermal front and skipjack tuna catches (Prasetya *et al.,* 2022), which strengthens the hypothesis that this oceanographic indicator can be used in estimating fishing areas. However, there have not been many studies that discuss the relationship between thermal fronts and catches in the waters of North Maluku, especially around the Ternate Nusantara Fisheries Port (PPN).

On the other hand, several studies have shown contradictory results regarding the effectiveness of thermal fronts as fishing indicators. According to Savetri (2019), the number of catches in the thermal front area is not significant enough compared to areas outside the thermal front. The results of the study by Mustasim *et al.,* (2015) showed no effect between the thermal front and the abundance of skipjack tuna. This shows that relying solely on the thermal front may not be enough to predict fishing areas accurately, especially in waters with complex oceanographic dynamics such as the Maluku Sea. Therefore, this study was conducted with the aim of identifying the intensity of the thermal front and its temporal relationship to the production of skipjack tuna fisheries landed at the Ternate PPN, so that it can assess the potential use of thermal front data as an indicator in predicting areas and seasons for skipjack tuna fishing in the region.

METHODS

Time and Place

The research data collection was conducted in June 2024 at PPN Ternate. The research was conducted in two stages, where the first stage was the process of observation and field data collection and the second stage was data processing and analysis. The research location is shown in Figure 1.

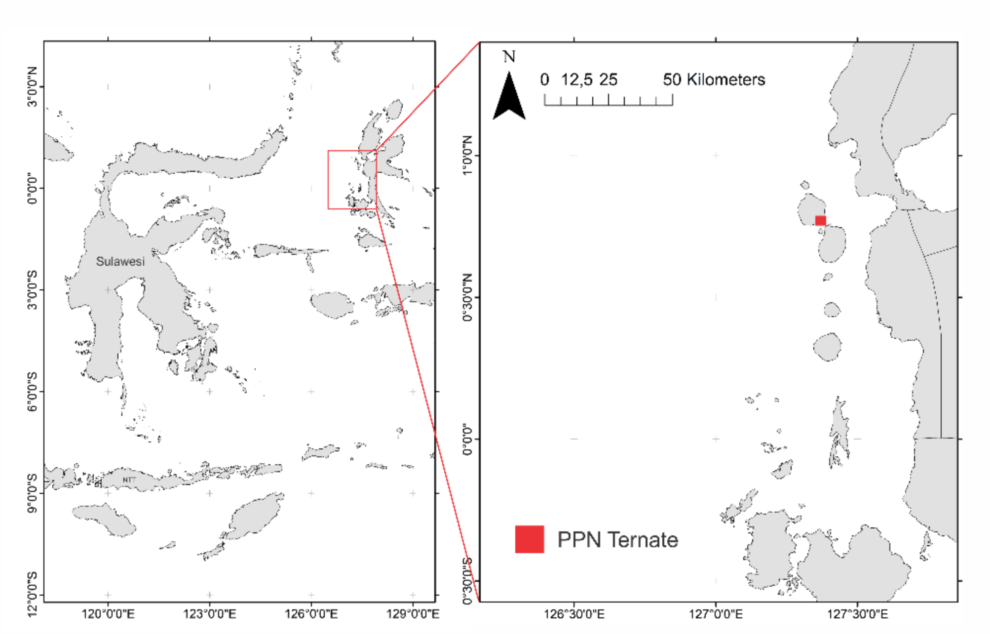

Figure 1. Research Location

Tools and Materials

This research uses various tools and materials that support the process of data collection, processing, and analysis. The tools and materials used in this research are shown in Table 1.

Table 1. Research Tools and Materials

No	Tools and materials	Utility
1	ArcGis and SeaDas	Oceanographic parameter data management
2	Microsoft Excel	Processing fisheries production data
3	Microsoft Word	Preparation of research manuscripts
4	Minitab	Data processing and Pearson correlation analysis
5	Harddisk	Research data storage
6	Laptop	Supporting tools for data processing and analysis

Data Collection Method

The data collected in this study were skipjack tuna fisheries production data for the period 2021 to 2023. Other data were time series data of sea surface temperature with the same time period, obtained from www.oceancolor.gsfc.nasa.com. The downloaded data format is NonConformance (.nc).

Data Analysis

Sea surface temperature image data with a resolution of 4 km was obtained from the Terra MODIS sensor. This data is the main data in the analysis of the distribution of thermal fronts in the waters around PPN Ternate. The algorithm used in determining the thermal front phenomenon is Single Image Edge Detection (SIED). The SIED algorithm works by detecting significant changes in temperature gradients in the image (Cayula & Cornillon, 1992). The use of SIED in determining the front from an image will be more accurate than the visual method (Hamzah *et al.,* 2014). The threshold value for the difference in sea surface temperature in SIED is 0.5ºC (Mustasim *et al.,* 2015). The histogram window size is set to 32 x 32 pixels, with a median filter size of 3. Before the detection process, the image is first subjected to geometric and atmospheric correction to reduce distortion and increase the accuracy of the analysis results.

Furthermore, a Pearson correlation analysis was carried out to test the relationship between thermal front intensity and skipjack tuna production landed at PPN Ternate. Skipjack tuna production data were obtained from monthly statistical reports during the study period, which were then temporally aligned with sea surface temperature image data. This correlation test aims to determine whether the increase in thermal front intensity is positively correlated with the increase in skipjack tuna catches based on the correlation coefficient value. The strength of the relationship between the two variables will be reflected through the correlation coefficient value (Sekaran *et al.,* 2010; Rassiyanti & Pitri, 2024).

RESULTS

Spatial Distribution of Thermal Fronts in the Waters Around PPN Ternate

The spatial map of the distribution of thermal fronts from 2021 to 2023 is shown in Figure 2, Figure 3, and Figure 4. In general, this thermal front distribution map shows quite significant variations in distribution in the waters around the Ternate Nusantara Fisheries Port (PPN). It can be seen that thermal fronts are formed unevenly with concentrations that tend to gather in certain areas. Areas with high thermal front intensity are generally detected around waters with sea surface temperatures ranging from 28°C to 32°C.

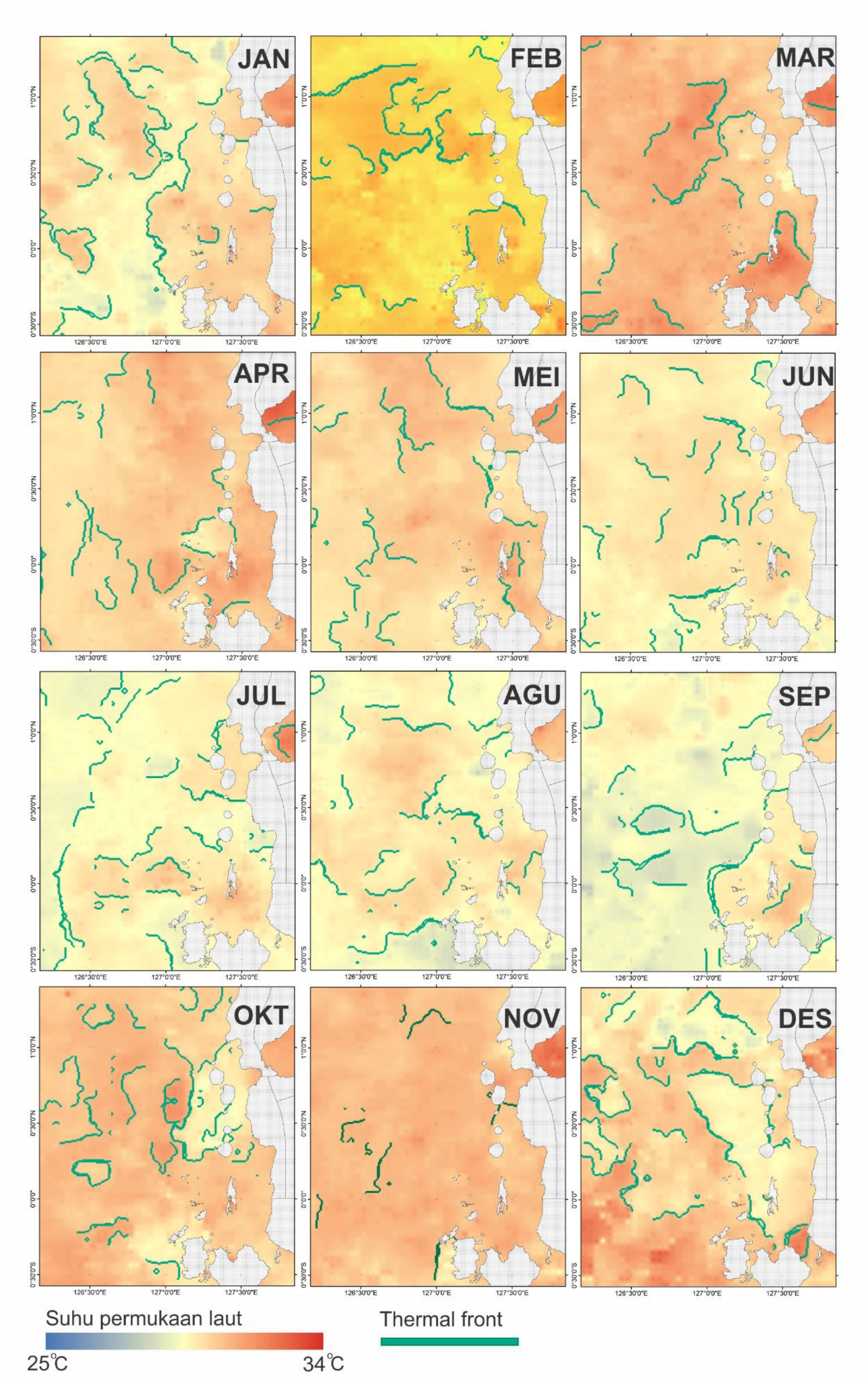

Figure 2. Spatial Distribution of Thermal Fronts in the Waters Around PPN Ternate in 2021

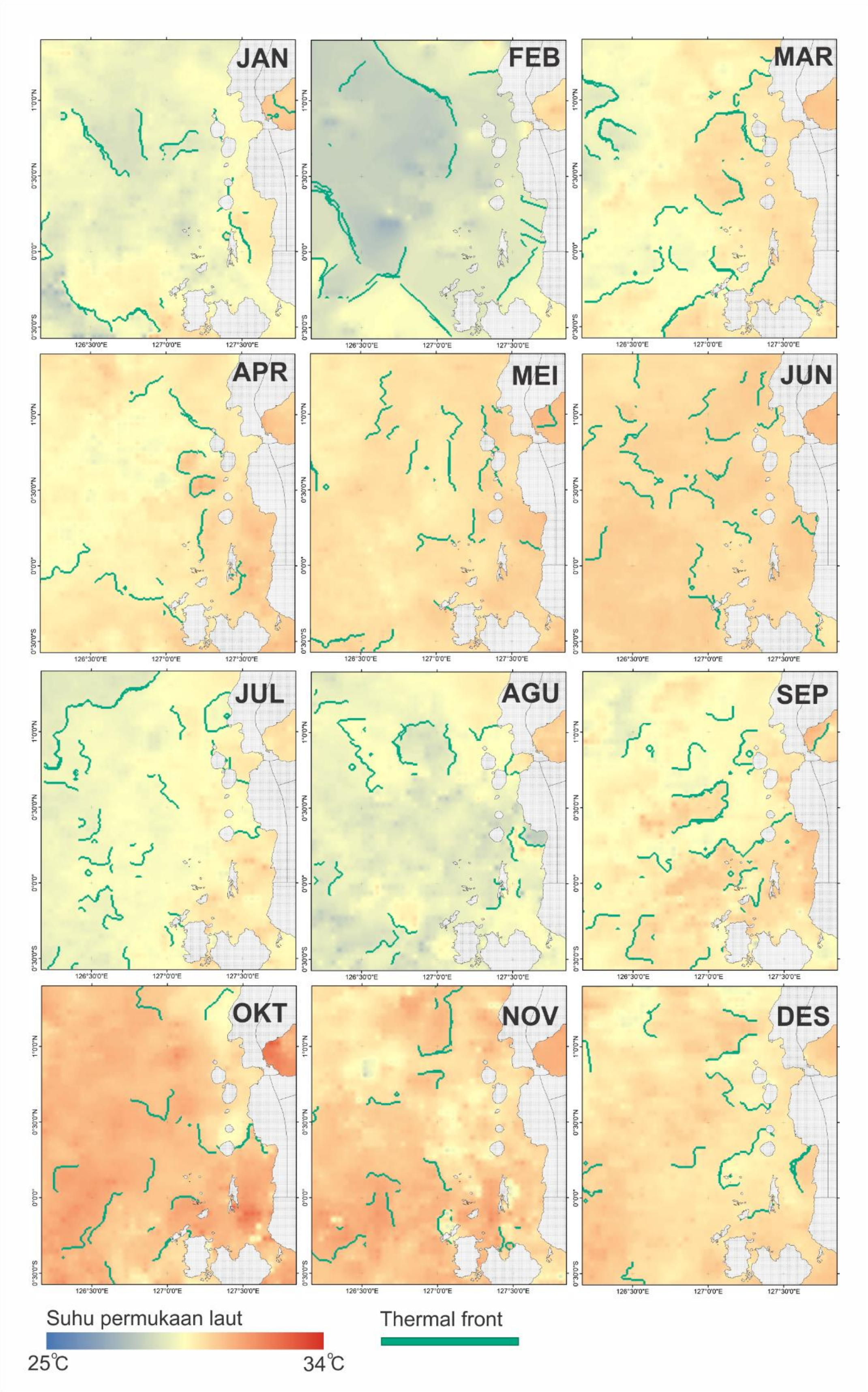

Figure 3. Spatial Distribution of Thermal Fronts in the Waters Around PPN Ternate in 2022

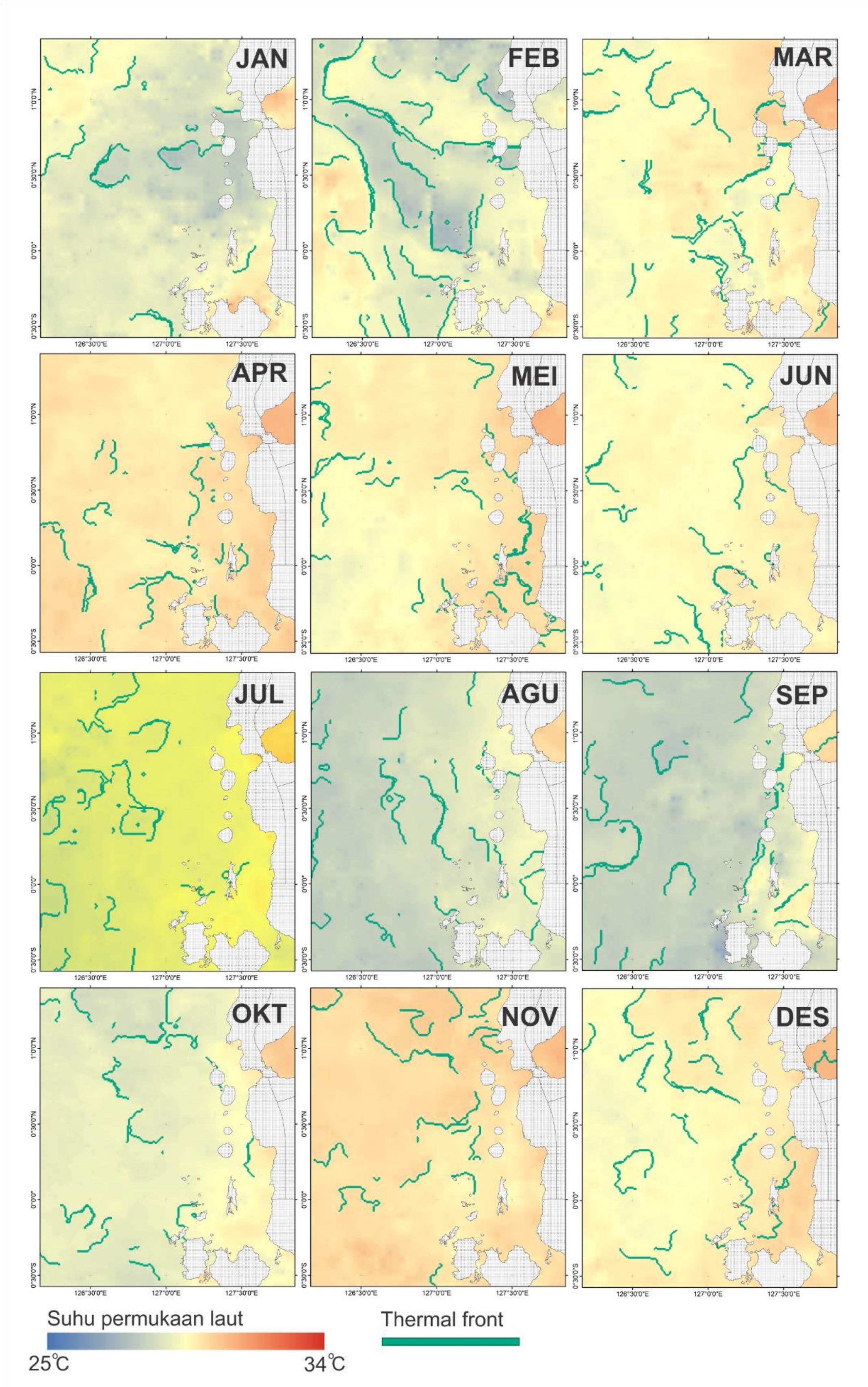

Figure 4. Spatial Distribution of Thermal Fronts in the Waters Around PPN Ternate in 2023

Dynamics of Thermal Front Intensity in the Waters Around PPN Ternate

The dynamics of thermal front intensity in the waters around PPN Ternate are shown in Figure 5. The intensity of the thermal front fluctuates greatly every year. In 2021, the highest peak was in December (2908 points) followed by October (2645 points), while in 2022, there was an extreme spike in March (3401 points), much higher than other months. In 2023, there was also a significant increase in February (3002 points) and December (2829 points), indicating a certain pattern in the intensity of the thermal front.

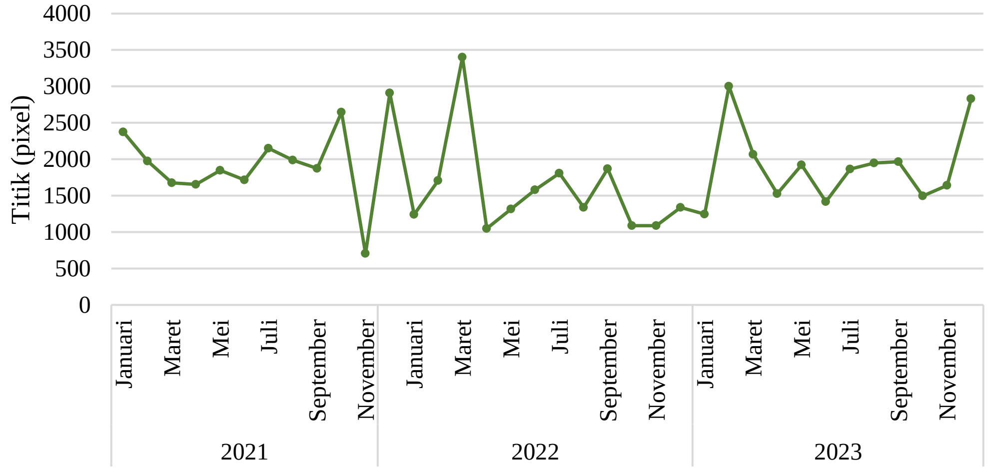

Figure 5. Dynamics of Thermal Front Intensity Throughout 2021-2023 in the Waters Around PPN Ternate

The average monthly intensity of thermal fronts in the waters around PPN Ternate (Table 2) shows an increasing trend in February-March and July-October and December, while the April-June and November periods show lower intensity. Several anomalies are also seen, such as a drastic decrease in November 2021 (704 points) and a sharp spike in March 2022 (3401 points), which are most likely influenced by environmental factors such as changes in sea temperature and ocean currents.

Table 2. Average Monthly Intensity of Thermal Fronts in the Waters Around PPN Ternate

Season	Month	Thermal Front Intensity (points)	
Transition Season 2	September	1903.33	
	October	1743.66	4790.67
	November	1143.66	
West Season	December	2358.66	
	January	1620	6206.34
	February	2227.66	
Transition Season 1	March	2381.33	
	April	1411.33	5489.67
	May	1697	
East Season	June	1570.33	
	July	1940.33	5270.00
	August	1759.33	

Relationship between Thermal Front Intensity and Skipjack Tuna Production in Ternate PPN

Pearson correlation analysis of temporal data on skipjack tuna fishery production in Ternate PPN with the intensity of the thermal front in the surrounding waters during 2021 to 2023 showed no significant relationship between the two. This is indicated by a p-value of 0.728 (more than 0.05) and a correlation coefficient of -0.068. These results mean that the dynamics of the thermal front intensity have no effect on skipjack tuna fishery production in the area.

DISCUSSION

The thermal fronts identified in Figures 2 to 4 show a tendency to form in coastal areas or areas close to islands. These results are in line with the statement of Trinugroho *et al.,* (2019) that coastal areas generally have more thermal front intensity. The distribution of these thermal fronts follows the pattern of sea surface temperatures, where the boundary between warmer and colder water masses forms fairly clear front lines. In addition, the distribution of thermal fronts detected in this study shows a seasonal pattern. In certain months, especially in the middle of the year, there is an increase in the intensity of the thermal front which is likely caused by the movement of the monsoon current (Saraswata *et al.*, 2013) and the Indian Ocean Dipole (IOD) (Lukman *et al.*, 2022) which affect the dynamics of sea surface temperatures.

The meeting of two water masses with significant temperature differences forms a thermal front, which has the potential to be an important indicator in determining fishing areas (Maharani *et al.*, 2020). Areas with denser thermal fronts are estimated to have higher nutrient concentrations. This phenomenon is usually associated with increased water fertility through the upwelling process that brings nutrients from the lower layers to the surface, thus supporting primary productivity in the form of phytoplankton which is a food source for pelagic fish (Nurfani, 2019). Thus, the presence of thermal fronts is often utilized in fisheries to identify potential fishing areas.

Theoretically, thermal fronts can increase fish abundance due to increased primary productivity that supports the marine food chain (Lukman *et al.,* 2022). However, the results of the Pearson correlation analysis between the intensity of the thermal front and the production of skipjack tuna landed at the Ternate Nusantara Fisheries Port (PPN) showed a correlation value of -0.068 with a p-value of 0.728, which indicates a weak negative relationship and is not statistically significant. These results are in line with the research of Mustasim *et al.,* (2015) which stated that there was no significant effect between the thermal front and the catch of skipjack tuna. This lack of relationship indicates that other oceanographic factors may have a more dominant influence in determining the distribution of skipjack tuna than the thermal front.

There are several factors that explain why the thermal front is not significantly temporally related to skipjack tuna production in PPN Ternate. First, the distribution of pelagic fish including skipjack tuna is likely more influenced by other oceanographic parameters such as chlorophyll-a concentration and sea surface temperature (Rahman *et al.*, 2019). The results of Pratama *et al.*, (2022) study showed that skipjack tuna production in waters is more influenced by chlorophyll-a and sea surface temperature. Second, systematically, the thermal front will increase the concentration of chlorophyll-a and water fertility. However, this increase in chlorophyll-a and fertility cannot be directly utilized by skipjack tuna as pelagic fish. There is a time lag until skipjack tuna can utilize it through the food chain. Therefore, if we look at the seasonal pattern of thermal front intensity, which increases in February to March, July to October, and December, the skipjack tuna fishing season tends to start after that. In general, the skipjack tuna fishing season occurs in June and August to November (Herawati *et al.,* 2020) and July to November (Nurani *et al.,* 2021; Pratama *et al.,* 2022). However, further studies are needed to prove the effect of this time lag.

Based on the results of this study, it is necessary to reconsider the method of predicting fishing areas using only thermal front data, especially for skipjack tuna fishing areas in the waters around PPN Ternate. To improve prediction accuracy, it is recommended to combine thermal front analysis with other methods, such as Species Distribution Models (SDMs) which consider various environmental factors simultaneously in predicting species distribution (Elith & Leathwick, 2009). SDMs can help map potential fishing areas better because they consider spatial and temporal aspects simultaneously.

In addition, integrating thermal fronts with other oceanographic parameters can provide a more comprehensive picture of water fertility which ultimately impacts fish abundance. This integrative approach is expected to help fishermen and fisheries managers in determining more effective and sustainable fishing strategies. By utilizing various oceanographic indicators simultaneously, it is hoped that predictions of fishing areas can be more accurate and in accordance with local ecosystem conditions.

CONCLUSION

Based on the research results, the thermal front area is dynamically distributed every month in the waters around PPN Ternate with increasing intensity in February-March and July-October and December. The results of the Pearson correlation analysis showed no significant effect between the thermal front and skipjack tuna fishery production. Therefore, additional data is needed in predicting fishing areas, such as adding the influence of upwelling, current distribution, chlorophyll-a dynamics, salinity, and other oceanographic parameters. A combination of other methods such as adding Species Distribution Models (SDMs) analysis can be done to improve the accuracy of fishing area predictions.

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REFERENCES

Cayula, J.F., & Cornillon, P. (1992). Edge detection algorithm for SST images. *J. Atmos. Ocean. Technol*, 9, 67–80

Elith, J., & Leathwick, J.R. (2009). Species distribution models: Ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution, and Systematics*, 40, 677-697

Hamzah, R., Prayoga, T., & Harsanugraha, W.K. (2014). Identifikasi thermal front dari data satelit terra/aqua modis menggunakan metode Single Image Edge Detection (SIED) (studi kasus: perairan utara dan selatan Pulau Jawa). Seminar Nasional Penginderaan Jauh 2014.

Herawaty, S. Arifin, H., & Usman, L. (2020). Pendugaan musim penangkapan ikan cakalang dengan alat tangkap pancing ulur yang didaratkan di Pangkalan Pendaratan Ikan (PPI) Oeba Kupang. *Jurnal Salamata*, 2(1),12-17

Khoir, M & Safruddin. 2023. Hasil tangkapan ikan tongkol (*Euthynnus* sp.) hubungannya dengan thermal front di Selat Makassar. *Torani*, 6(2), 119-125

Lukman, A.A., Tarsya, A., & Pranowo, W.S. (2022). Thermal front persisten di Perairan Selat Malaka. *Jurnal Ilmiah Platax*, 10(2), 239-250

Maharani, M., Pahlevi, H., & Ayudhia, K.C. (2022). Kajian keandalan thermal front yang terdeteksi dari single image edge detection untuk estimasi sebaran ikan pelagis di perairan Teluk Jakarta. *Jurnal Ilmiah MTG*, 13(2), 39-50. 10.31315/jmtg.v13i3.9399

Mustasim, M., Zinuddin, M., & Safruddin, S. (2015). Thermal dan klorofil-a front hubungannya dengan hasil tangkapan ikan cakalang pada musim peralihan barat-timur di perairan Seram. *Jurnal IPTEKS PSP*, 2(4), 294–304

Nammalwar, P., Satheesh, S., & Ramesh, R. (2013). Applications of remote sensing in the validations of Potential Fishing Zones (PFZ) along the coast of North Tamil Nadu, India. *Indian Journal of Marine Sciences*, 42(3), 283–292

Nurani, T.W., Wahyuningrum, P.I., Iqbal, M., Khoerunissa, N., Pratama, G.B., & Widianti, E. A. (2022). Skipjack tuna fishing season and its relationship with oceanographic conditions in Palabuhanratu Waters, West Java. *Malaysian Applied Biology*, 51, 137-148

Prasetya, A., Hasidu, L.O.A.F., Maharani, Kasim, M., & Mustasim. (2022). Pendugaan thermal front sebagai indikator daerah potensial penangkapan ikan cakalang (*katsuwonus pelamis*) di Laut Banda. *Jurnal Airaha*, 11(2), 297-303

Pratama, G.B., Nurani, T.W., Mustaruddin, & Herdiyeni, Y. (2022). Hubungan Parameter oseanografi perairan terhadap pola musim ikan pelagis di Perairan Palabuhanratu. *Jurnal Teknologi Perikanan dan Kelautan*. 13(1), 67-78

Rahman, M.A., Syamsuddin, M.L., Agung, M.U.K., & Sunarto. (2019). Pengaruh musih terhadap kondisi oseanografi dalam penentuan daerah penangkapan ikan cakalang (*Katsuwonus pelamis*) di Perairan Selat Jawa Barat. *Jurnal Perikanan dan Kelautan*, 10(1), 92-102

Rassiyanti, L., & Pitri, R. (2024). Analisis regresi linier dan korelasi faktor sosio-ekonomi terhadap kemiskinan di Indonesia. *Journal of Data Analysis*, 7(2), 88-94

Saraswata, A.G., Subardjo, P., & Muslim. (2013). Pengaruh monsun terhadap distribusi suhu permukaan laut dan klorofil-a di Perairan Selat Bali. *Jurnal Oseanografi*, 2(1), 79-87

Savetri, V., Syamsuddin, M.L., Rostini, I., & Apriliani, I.M. (2019). Distribusi thermal front dan hasil tangkapan ikan tenggiri (*Scomberomorus commerson*) di Perairan Pangandaran. *Albacore*, 3(2), 217-228

Sekaran, Uma, & Bougie R. (2010). *Research Methods for Business: A Skill Building Approach*. London: John Wiley and Sons, inc.

Simbolon, D., Silvia, & Wahyuningrum, P.I. (2013). Pendugaan thermal front dan upwelling sebagai indikator daerah potensial penangkapan ikan di Perairan Mentawai. *Marine Fisheries*, 4(1), 85-95

Simbolon, D., & Tadjuddah, M. (2008). Pendugaan front dan upwelling melalui interpretasi citra suhu permukaan laut dan clorofil-a di Perairan Wakatobi Sulawesi Tenggara. *Buletin PSP*, 17(3), 362-371

Tangke, U., & Deni, S. (2013). Pemetaan daerah penangkapan ikan madidihang (*Thunnus albacares*) dan ikan cakalang (*Katsuwonus pelamis*) di Perairan Maluku Utara. *Agrikan: Jurnal Agribisnis Perikanan*, 6(1). https://doi.org/10.29239/j.agrikan.6.0.1-1

Trinugoho, T., Satriadi, A., & Muslim, M. (2019). Sebaran thermal front musiman di wilayah perairan Selat Madura menggunakan single image edge detection. *Journal of Marine Research*, 8(4), 416-423.