Detection of Potential Fishing Zones in Aceh Waters Using Satellite-Derived Sea Surface Temperature and Chlorophyll Fronts

Faqih Musyaffa[1]*, Po-Chun Hsu[2]

[1]*Center for Space and Remote Sensing Research, National Central University, Taoyuan City 320317, Taiwan (R.O.C.).* *faqih.musyaffa@gmail.com
[2]*Center for Space and Remote Sensing Research, National Central University, Taoyuan City 320317, Taiwan (R.O.C.). hpochun@csrsr.ncu.edu.tw*

Abstract: Detecting potential fishing zones (PFZs) is crucial for enhancing sustainable fisheries and mitigating environmental variability in Aceh waters, situated in the eastern tropical Indian Ocean. This study investigates the dynamic oceanographic conditions of the region to identify PFZs for tuna (Thunnus sp.), supporting sustainable fisheries management. Long-term multi-source satellite and reanalysis datasets from 1998 to 2024, including sea surface temperature (SST) and chlorophyll-a (CHL) from NOAA Coral Reef Watch and Copernicus Marine Environment Monitoring Service, were analysed alongside ocean current and wind data. These oceanographic variables were compared with annual tuna catch data from 2018 to 2023 provided by BPS-Statistics of Aceh Province. Monthly composite datasets were used to derive SST gradient magnitudes and CHL front zones, delineating thermal and biological boundaries. Results reveal pronounced seasonal variability, with significant SST and CHL fronts particularly evident during the December-February monsoon season. Ocean currents and wind fields exhibit clear seasonal shifts aligned with monsoonal changes. PFZs were identified by overlaying SST-CHL front intersections with wind-current convergence zones and validated using tuna catch records. The findings indicate a positive association between tuna distributions and the presence of thermal and CHL fronts. This approach demonstrates the effectiveness of remote sensing in identifying PFZs. It supports the development of early warning systems and climate-resilient, ecosystem-based fishery management strategies for Aceh and similar regions.

Keywords: sea surface temperature, chlorophyll-a, oceanic front, potential fishing zones

1. Introduction

Sea surface temperature (SST) is a critical factor influencing the distribution of fish species, including tunas, as it affects their metabolic rates, behavior, and migration patterns. Research indicates that optimal SST conditions for yellowfin tuna *(Thunnus albacares)* are typically between 24 °C and 28 °C (Saputra, 2020; Lan et al., 2018). Additionally, variations in SST can lead to the formation of thermal fronts, which are zones of enhanced productivity and concentration of marine life. For instance, Suhadha and Asriningrum (2020) highlight that in Indonesia, including the Aceh region, thermal fronts derived from SST imagery are instrumental in producing daily potential fishing zone (PFZ) information. Chlorophyll-a (CHL) concentrations serve as an indirect measure of phytoplankton biomass and are indicative of primary productivity in marine ecosystems. The

presence of chlorophyll fronts, enhanced by upwelling and nutrient inputs, can foster significant fish aggregation, providing prime fishing opportunities (Chang et al., 2018). Studies conducted in various regions have shown that areas with higher CHL concentrations often correlate with increased fish catch rates (Ningsih et al., 2021). For example, Muhammad et al. (2022) documented that utilizing SST and CHL data enabled effective mapping of PFZs in Aceh Besar, revealing seasonal shifts in their spatial distribution. Complementing these findings, other studies have demonstrated that combining SST with CHL measurements not only improves the accuracy of fishing ground detection but also enhances catch per unit effort (CPUE) for species such as yellowfin tuna (Syah et al., 2020). This multifaceted approach underscores the value of integrating satellite remote sensing techniques to generate reliable and timely PFZ information. Moreover, advancements in remote sensing continue to support fisheries management by providing tools to reduce search effort and fuel consumption while maximizing economic gains (Klemas, 2014). Therefore, understanding the spatiotemporal dynamics of SST and CHL fronts in Aceh waters is essential for developing effective PFZ detection strategies that can support sustainable fisheries and inform data-driven decision-making.

2. Methodology

The study area, as shown in Figure 1, is located along the northern coast of Aceh Province, Indonesia, encompassing the coastal waters between the Indian Ocean and the Andaman Sea. Key geographic features include Banda Aceh City, Aceh Besar Regency, and surrounding islands such as Weh Island (Sabang City), Breuh Island, and Nasi Island. The area includes PPS Kutaraja (marked in red), a central fishing port for pelagic species, particularly Yellowfin Tuna *(Thunnus albacares)*. This region is oceanographically dynamic due to the interaction of currents from both the Indian Ocean and Andaman Sea, making it ecologically and economically important for capture fisheries. To detect fishing potential zones (FPZs), this study used satellite-derived datasets spanning 1998 to 2024, focusing on the detection of sea surface temperature (SST) and chlorophyll-a (CHL) fronts. SST data were sourced from NOAA Coral Reef Watch Version 3.1 (https://coralreefwatch.noaa.gov/), while CHL data were obtained from the Copernicus Ocean Colour Level-4 product at 4 km resolution. Additional environmental parameters included ocean surface current data and wind stress fields from CMEMS (https://marine.copernicus.eu/). All data were processed in NetCDF-4 format and analyzed to generate monthly, seasonal, and annual climatology. Fronts were extracted using spatial gradient magnitude and an edge detection approach applied to satellite imagery, following the method of Shimada et al. (2005). To validate the satellite-derived fronts and assess their relevance to fishing activity, annual tuna catch data from 2018 to 2023 were collected from BPS-Statistics of Aceh Province (https://aceh.bps.go.id/).

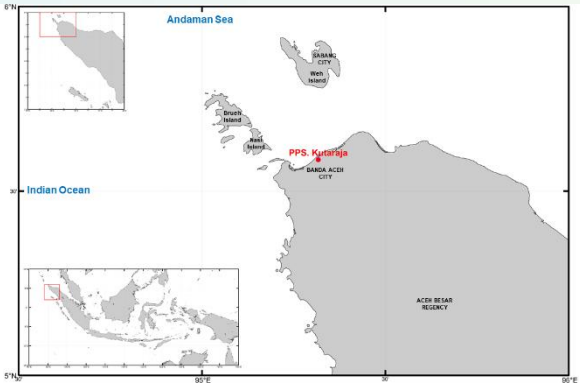

Figure 1: Study area along the northern Aceh coast and its surrounding waters.

3. Results/Findings

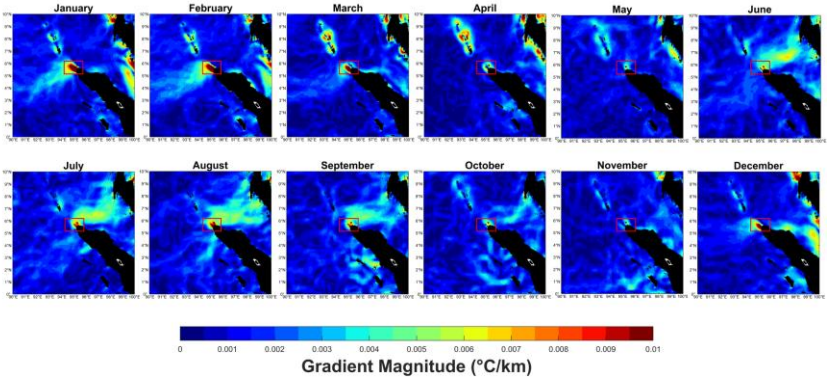

Figure 2: Monthly SST fronts in Aceh Waters (1998-2024)

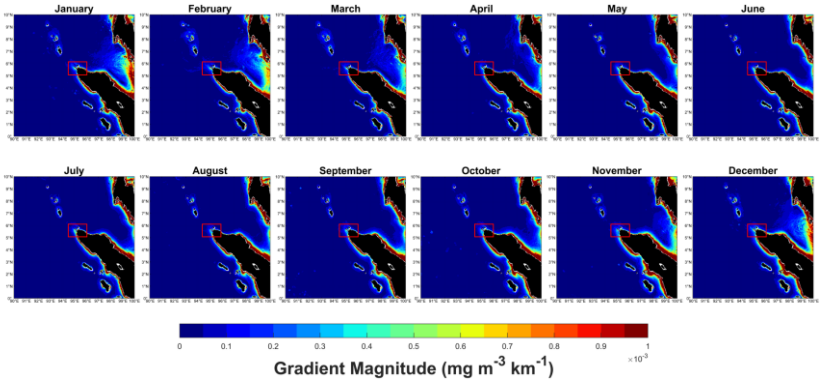

Figure 3: Monthly CHL fronts in Aceh Waters (1998-2024)

Monthly climatology maps of sea surface temperature (SST) and chlorophyll-a (CHL) fronts from 1998 to 2024 reveal clear seasonal patterns in Aceh waters. SST fronts (Figure 2) are strongest from March to June and in December, particularly near Weh Island and the Banda Aceh coast, indicating favorable thermal conditions for fish aggregation during these periods. CHL fronts (Figure 3) peak from January to April and October to December, with high biological activity along coastal and shelf-edge areas. The overlap of strong SST and CHL fronts in March–May and October–December suggests these are key seasons for potential fishing zones (PFZs), especially around PPS Kutaraja. These findings align with seasonal tuna catch trends and highlight the usefulness of satellite-derived fronts for identifying productive fishing grounds.

4. Conclusion

This study demonstrates that satellite-derived SST and CHL fronts effectively identify potential fishing zones in Aceh waters, particularly during March–May and October–December near PPS Kutaraja. These patterns align with seasonal tuna catches, supporting their use for fisheries planning. However, the absence of in situ oceanographic data and limited historical catch records constrain validation and reduce spatial accuracy. Future research should incorporate field measurements and higher-resolution fisheries data to enhance reliability.

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