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THE EFFECT OF SEA SURFACE TEMPERATURE ON SMALL PELAGIC FISH CATCHES IN WPP 573

Pengaruh Suhu Permukaan Laut terhadap Hasil Tangkapan Ikan Pelagis Kecil di WPP 573

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ABSTRACT

Sea surface temperature (SST) is a key oceanographic parameter influencing the distribution and abundance of small pelagic fish in tropical waters. This study aims to analyze the effect of SST on small pelagic fish catches in Fisheries Management Area (FMA) 573. Catch data were obtained from the Fisheries Resource Center of Indonesia (FRCI) for the 2015–2021 period, while SST data were derived from Aqua MODIS satellite imagery with 4 km resolution, processed using Seadas 7.4 software. A simple linear regression was applied to examine the relationship between SST and fish catches. The results indicate a negative relationship, where each 1 °C increase in SST tends to reduce catches by approximately 35 thousand tons. The coefficient of determination (R^2) of 0.531 shows that 53.1% of the catch variability is explained by SST, while the remaining is influenced by other factors such as primary productivity (chlorophyll-a), upwelling intensity, global climate phenomena (ENSO, IOD), and fishing pressure. These findings highlight SST as an important indicator for predicting fishing seasons in FMA 573 and emphasize the need to integrate satellite-based oceanographic data into Ecosystem-Based Fisheries Management (EBFM) to ensure sustainable fisheries in Indonesian tropical waters.

Keywords: Sea Surface Temperature, Small Pelagic Fish, FMA 573, Regression Analysis, Sustainable Fisheries

ABSTRAK

Suhu permukaan laut (SPL) merupakan salah satu parameter oseanografi penting yang memengaruhi distribusi serta kelimpahan ikan pelagis kecil pada perairan tropis. Penelitian ini bertujuan untuk menganalisis pengaruh SPL terhadap hasil tangkapan ikan pelagis kecil pada Wilayah Pengelolaan Perikanan (WPP) 573. Data hasil tangkapan diperoleh dari Fisheries Resource Center of Indonesia (FRCI) periode 2015–2021, sedangkan data SPL berasal dari citra satelit Aqua MODIS dengan resolusi spasial 4 km yang diolah menggunakan perangkat lunak Seadas 7.4. Analisis regresi linier sederhana digunakan untuk menguji hubungan antara SPL dan hasil tangkapan. Hasil penelitian menunjukkan adanya hubungan negatif, di mana setiap kenaikan 1 °C SPL cenderung menurunkan hasil tangkapan sekitar 35 ribu ton. Koefisien determinasi (R^2) sebesar 0,531 mengindikasikan bahwa 53,1% variasi

hasil tangkapan dijelaskan oleh SPL, sedangkan sisanya dipengaruhi faktor lain meliputi produktivitas primer (klorofil-a), intensitas upwelling, fenomena iklim global (ENSO, IOD), dan tekanan penangkapan. Temuan ini menegaskan pentingnya SPL sebagai salah satu indikator musim penangkapan di WPP 573 dan perlunya integrasi data oseanografi berbasis satelit dalam Ecosystem-Based Fisheries Management (EBFM) untuk mewujudkan perikanan berkelanjutan.

Kata Kunci: Suhu Permukaan Laut, Ikan Pelagis Kecil, WPP 573, Regresi Linier, Perikanan Berkelanjutan

INTRODUCTION

Fisheries Management Area (WPP) 573 is one of the important regions in the eastern Indian Ocean of Indonesia that possesses considerable potential for pelagic fish resources. Fishing activities in this area are dominated by small pelagic fish such as lemuru (*Sardinella* sp.), tongkol (*Euthynnus affinis*), and layang (*Decapterus* spp.). Environmental factors such as sea surface temperature (SST), salinity, currents, and chlorophyll-a are important components in determining capture fisheries productivity (Susanto *et al.*, 2001; Sartimbul *et al.*, 2010).

Sea surface temperature plays a fundamental role in the distribution and abundance of pelagic fish. An increase in SST causes stratification of the water column, which inhibits the upward transport of nutrients from deeper layers, thereby reducing plankton availability and affecting the marine food chain (Pauly & Zeller, 2016). Conversely, a decrease in SST is generally followed by an increase in primary productivity due to the occurrence of seasonal upwelling processes (Kunarso *et al.*, 2018).

Changes in sea temperature are also closely associated with global phenomena such as the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). During El Niño phases or positive IOD events, sea temperatures tend to increase and lead to reduced productivity, whereas during La Niña phases or negative IOD events, temperatures decrease and productivity increases (Sartimbul *et al.*, 2010; Susanto *et al.*, 2001). This pattern influences the distribution of small pelagic fish in WPP 573, which is a major current pathway of the eastern Indian Ocean (La Demi *et al.*, 2020).

In addition to oceanographic factors, socio-economic pressures also affect catch yields. Factors such as rising fuel prices, changes in operational costs, and fisheries policies can reduce fishing frequency (Halim & Hidayat, 2020). Therefore, the relationship between SST and catch yields needs to be examined integratively by considering both biophysical and socio-economic factors of fisheries (Pitcher *et al.*, 2009; Tupamahu *et al.*, 2023).

This study aims to examine the effect of sea surface temperature on the catch of small pelagic fish in WPP 573 by utilizing satellite data and catch data over a seven-year period. The results are expected to support ecosystem-based capture fisheries management in tropical Indonesian waters (Zainuddin *et al.*, 2019).

METHODS

This study uses secondary data obtained from two main sources, namely data on small pelagic fish catches and sea surface temperature (SST) data. Catch data were obtained from the Fisheries Resource Center of Indonesia (FRCI) in the form of annual data for the period 2015–2021 for Fisheries Management Area (WPP) 573 with coordinates 6°–15° S and 104°–124° E. These data were used to represent fluctuations in small pelagic fish catches in the study area.

Meanwhile, SST data were obtained from Aqua MODIS satellite imagery with a spatial resolution of 4 km. The imagery used consists of monthly climatological data for the year 2024, which are freely accessible through the official MODIS Ocean Color website (www.oceancolor.gsfc.nasa.gov). Image processing was carried out using SeaDAS 7.4 software with the following steps: (1) image cropping to match the study area, namely the waters of WPP 573, (2) extraction of SST values from the cropped images, (3) exporting data in Mask Pixels format containing

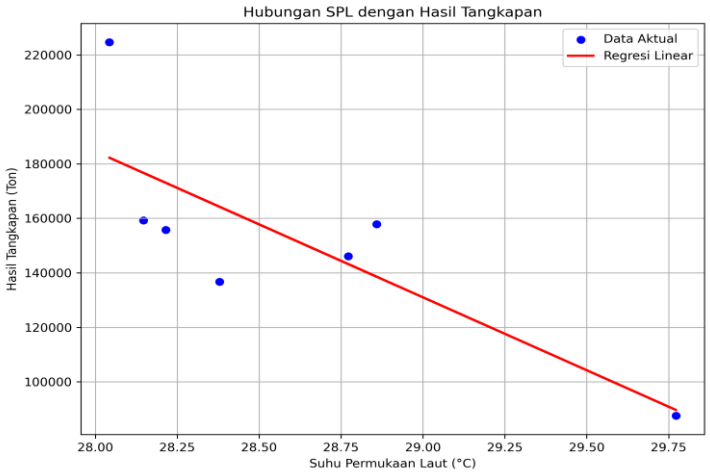
latitude, longitude, and SST values at each point, and (4) further processing using Microsoft Excel to organize the data and save them in .txt format for analysis readiness (Nurhayati *et al.*, 2018).

After both types of data were obtained, processing was carried out using a simple linear regression method to analyze the relationship between SST (independent variable) and small pelagic fish catches (dependent variable). This regression analysis produced a mathematical equation used to explain the direction and magnitude of the effect of SST on catch yields. In addition, the coefficient of determination (R^2) was calculated to determine the extent to which variations in catch yields can be explained by changes in sea temperature.

RESULTS AND DISCUSSION

Table 1. Sea Surface Temperature Data and Small Pelagic Fish Catches in WPP 573 (2015–2021)

Year	Temperature (°C)	Catch (Tons)	Regression Prediction (Ton)
2015	28.15	159,215	179,176
2016	29.77	87,510	92,736
2017	28.38	136,674	166,913
2018	28.22	155,757	175,671
2019	28.04	224,664	185,294
2020	28.86	157,843	135,774
2021	28.77	146,032	140,530



The Influence of Sea Surface Temperature and Catch Results

Linear regression analysis between sea surface temperature (SST) and small pelagic fish catches in WPP 573 in the 2015–2021 period produced the following equation:

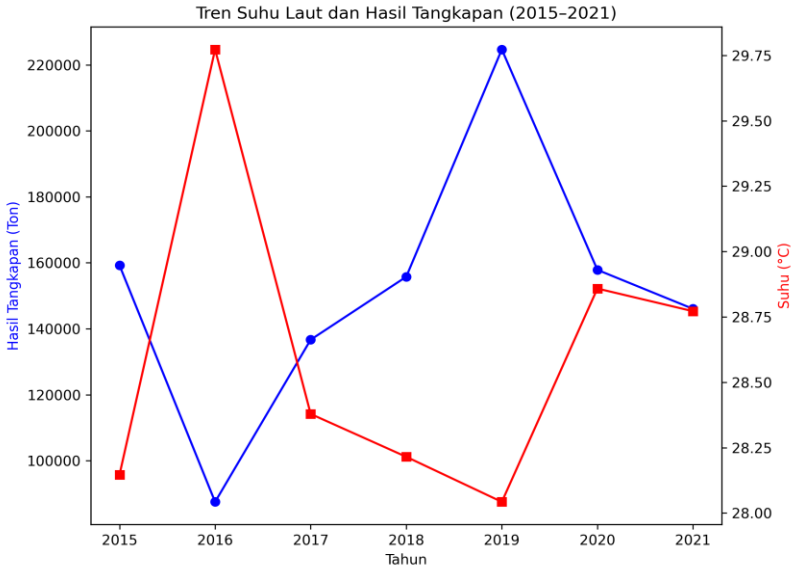
$$Y=-53.532\times X+1,683,447.10Y = -53.532 \times X + 1,683,447.10Y=-53.532\times X+1,683,447.10$$

With YYY representing the catch yield (tons) and XXX representing sea surface temperature (°C). A negative regression coefficient indicates an inverse relationship between SST and catch yield. Thus, an increase in SST of 1°C implies a decrease in catch yield of approximately 53,532 tons. The coefficient of determination (R^2) of 0.638 further indicates that 63.8% of the variation in catch yield can be explained by changes in SST, while the remainder is influenced by other factors (Sativa *et al.*, 2025).

These results indicate that SST is one of the dominant environmental factors that subsequently influences the availability of small pelagic fish in a given aquatic region. Small pelagic fish are sensitive to temperature fluctuations due to their close role within the planktonic food web. Lower temperature conditions generally support higher primary productivity, thereby increasing fish stocks. Conversely, higher temperatures can cause water column stratification, resulting in reduced nutrient availability at the surface and decreased phytoplankton productivity, which serves as the primary food source for pelagic fish.

High sea surface temperatures cause stratification of the water column, which inhibits vertical mixing processes and reduces nutrient availability in the euphotic layer. This condition leads to a drastic decline in phytoplankton, which serves as the primary food source for zooplankton and small pelagic fish (Kunarso *et al.*, 2018). Conversely, when sea temperatures are relatively lower, the surface water layer becomes richer in nutrients and promotes increased primary productivity. This was observed in 2019, when an average sea temperature of 28.04°C was associated with the highest catch yield (224,664 tons).

In general, the trend in catch yield shows a decline in 2016 when sea surface temperature reached its highest point (29.77°C), with the lowest catch yield of 87,510 tons. Conversely, in 2019, with relatively lower temperatures (28.04°C), catch yields increased significantly to 224,664 tons. This demonstrates an indication that lower temperature conditions tend to support the productivity of small pelagic fisheries, presumably due to increased water fertility (primary productivity) resulting from oceanographic dynamics.



External Dynamics Affecting Catch Results

While the SPL has a significant influence, a number of other external factors contribute to catch fluctuations in WPP 573, including:

Global Climate Phenomena (ENSO and IOD)

WPP 573 is located in waters that are strongly influenced by global climate phenomena such as the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). In years characterized by El Niño anomalies or positive IOD events, sea surface temperatures in western Indonesian waters generally increase due to reduced upwelling and diminished transport of cold water masses from the south. These conditions lead to a decline in aquatic productivity and small pelagic fish catches. Conversely, during La Niña periods or negative IOD phases, upwelling activity tends to intensify,

transporting nutrient-rich water masses to the surface and increasing small pelagic fish stocks (Nursan *et al.*, 2022).

This correlation was clearly observed in 2016, when a strong El Niño event caused a global high-temperature anomaly, accompanied by a decline in catch yield to only 87,510 tons. A similar pattern was also reported by Kunarso *et al.* (2018), who found that increased sea temperatures due to El Niño resulted in reduced pelagic fish catches in the Flores Sea and Bone Bay. This phenomenon illustrates the close relationship between ocean dynamics and fluctuations in fish catch yields (Tupamahu *et al.*, 2023).

Upwelling and Primary Productivity

In addition to being influenced by global climate anomalies, seasonal upwelling dynamics in the eastern Indian Ocean constitute an important factor in determining the abundance of small pelagic fish in WPP 573. Strong upwelling increases chlorophyll-a concentrations, enriching waters with nutrients that support the planktonic food web. Conversely, weak upwelling reduces primary productivity, even when temperature does not increase significantly.

According to Susanto *et al.* (2001), seasonal upwelling in the southern waters of Java and Sumatra occurs between July and September, coinciding with the east monsoon season. During this period, catch yields tend to increase because the distribution of small pelagic fish becomes more concentrated in nutrient-rich waters. Therefore, annual catch data in WPP 573 reflect the cumulative effects of upwelling strength and regional sea temperature conditions.

Fishing Pressure (Fishing Effort)

In addition to oceanographic conditions, catch yields are also influenced by fishing intensity (fishing effort) and socio-economic factors. An increase in the number of fishing fleets, the use of non-selective fishing gear, and weak enforcement can trigger overfishing, which reduces small pelagic fish stocks even when environmental conditions are favorable (Pauly & Zeller, 2016).

During 2016–2018, data from the Ministry of Marine Affairs and Fisheries indicated a significant increase in the number of small vessels operating in WPP 573 waters, potentially intensifying pressure on pelagic fish stocks. In addition, fluctuations in fuel prices and export restriction policies strongly influence fishers' behavior. When operational costs increase, fishers tend to reduce fishing frequency, which subsequently affects the decline in total annual catch yields (Halim & Hidayat, 2020).

Research by Marni *et al.* (2024) shows that imbalances between fishing effort and resource availability lead to coastal ecosystem degradation. Therefore, adaptive ecosystem-based policies are required to maintain the sustainability of fish stocks (Pitcher *et al.*, 2009).

Ecological Conditions and Fish Migration Patterns

The results of this study confirm that sea surface temperature can be used as a primary indicator in predicting the potential catch of small pelagic fish in tropical Indonesian waters. For more adaptive fisheries management, satellite-derived information on sea temperature and chlorophyll-a should be integrated into the Ecosystem-Based Fisheries Management (EBFM) system, so that the use of remote sensing data such as Aqua MODIS and Sentinel-3 imagery can assist in monitoring sea surface temperature conditions and predicting potential fishing grounds (Zainuddin *et al.*, 2019).

This approach enables decision-making based on ecosystem conditions rather than solely on catch yields. Furthermore, enhancing fishers' capacity to utilize digital technologies based on satellite imagery (such as Aqua MODIS or Copernicus Sentinel-3) can help them determine potential fishing locations and optimal fishing times. Thus, the sustainability of small pelagic fish resources in WPP 573 can be maintained through synergy between marine environmental monitoring, regulation of fishing effort, and coastal community empowerment.

The findings of this study indicate that sea surface temperature is a critical indicator in determining fluctuations in small pelagic fish catch yields. Therefore, fisheries management in WPP 573 needs to integrate satellite-based oceanographic information, such as sea surface temperature and chlorophyll-a data, into fishing season planning. The Ecosystem-Based Fisheries Management

(EBFM) approach is highly relevant to be implemented so that management focuses not only on catch yields but also on the supporting ecosystem conditions.

In addition, improving fishers' capacity in utilizing information technology, such as satellite data–based applications, can assist in identifying potential fishing areas. In this way, fisheries productivity can be maintained without increasing the risk of overexploitation.

CONCLUSION

This study demonstrates that sea surface temperature has a significant influence on small pelagic fish catch yields in WPP 573. Regression analysis results indicate a negative relationship, in which increasing sea temperature tends to reduce catch yields. The coefficient of determination ($R^2 = 0.531$) indicates that approximately 53.1% of the variation in catch yields can be explained by variations in sea surface temperature, while the remainder is influenced by other factors such as chlorophyll-a availability, upwelling intensity, global climate phenomena (ENSO, IOD), as well as fishing pressure and fisheries policy dynamics.

These findings confirm that sea surface temperature can be used as an important indicator in predicting the potential catch of small pelagic fish in tropical Indonesian waters. Therefore, fisheries management in WPP 573 should integrate satellite-based oceanographic information with ecosystem-based fishing strategies such as Ecosystem-Based Fisheries Management. In addition, enhancing fishers' capacity to utilize oceanographic information technology is also key to supporting fisheries sustainability while preserving small pelagic fish resources in the region.

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