International Journal of Contemporary Sciences (IJCS)
Vol. 4, No. 4, 2026: 1385-1398

Mapping Optimal Sea Surface Temperature for Skipjack Tuna in Pangandaran Waters to Support Small-Scale Fisheries

Gilar Budi Pratama[1*], Aisyah[2]
Department of Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran
Corresponding Author: Gilar Budi Pratama gilar.pratama@unpad.ac.id

ARTICLEINFO

Keywords: Fishing Ground, Sea Surface Temperature, Skipjack Tuna, Oceanographic

Received : 15 February
Revised : 20 March
Accepted: 30 April

ABSTRACT

Small-scale fisheries play an important role in supporting coastal livelihoods, including in Pangandaran waters. Skipjack tuna (*Katsuwonus pelamis*) distribution is strongly influenced by sea surface temperature (SST). This study aims to map the optimal SST range for skipjack tuna in 2024 and analyze its spatial–temporal dynamics as an indicator of potential fishing grounds. SST data from Copernicus Marine Service (0.083° resolution, monthly) were analyzed descriptively based on optimal temperature ranges from previous studies. Results show SST ranged from 26.21 °C to 30.02 °C with clear seasonal patterns. Suitable conditions occurred mainly in January, May, July, and August, particularly during the southeast monsoon associated with upwelling. SST can serve as an initial indicator for fishing ground identification but should be combined with other oceanographic parameters

DOI: https://doi.org/10.55927/2a7wyx80
E-ISSN: 3047-4078
https://journalijcs.my.id/index.php/ijcs

INTRODUCTION

Small-scale capture fisheries play a strategic role in supporting food security and the livelihoods of coastal communities in Indonesia (Amura & Pirhel, 2021; Kusdiantoro et al., 2019), including in Pangandaran waters. These fisheries contribute approximately 80% of total domestic fish consumption (Saksono et al., 2023). One of the main target species is skipjack tuna (*Katsuwonus pelamis*), which has high economic value and makes a significant contribution to pelagic fisheries production (Maruanaya et al., 2025). However, the success of skipjack fishing is strongly influenced by complex oceanographic dynamics, particularly sea surface temperature (SST) (Gaol & Sadhotomo, 2007; Irwansya et al., 2026). As a result, small-scale fishers often face uncertainty in determining optimal fishing locations.

Sea surface temperature (SST) is a key oceanographic parameter that influences fish distribution and behavior (Freitas et al., 2021). Temperature regulates physiological processes, prey distribution, and fish movement and migration patterns (Tadjuddah, 2005). In addition, SST serves as an indicator of upwelling, where nutrient-rich waters stimulate phytoplankton growth. Skipjack tuna are known to prefer a specific optimal temperature range that supports metabolic activity and feeding (Sala & Manuhutu, 2020; Pratama et al., 2022). Therefore, spatial and temporal variations in SST can be used as potential indicators for identifying productive fishing grounds.

Several studies have examined the relationship between SST and skipjack tuna distribution (Suhermat, 2024; Irwansya et al., 2026; Pratama et al., 2022). These studies indicate that the relationship between temperature and fish abundance is nonlinear and location-specific. However, most research has focused on statistical relationships without producing practical spatial outputs, such as optimal temperature maps that can be directly utilized by fishers, particularly in small-scale fisheries.

In contrast, studies specifically mapping optimal temperature for skipjack tuna in southern Java waters, especially in Pangandaran, remain limited. This region exhibits distinctive oceanographic dynamics, including the influence of the southeast monsoon, which triggers upwelling and causes significant temperature variability throughout the year (Sundoko et al., 2025). Understanding this variability at a temporal scale is crucial, as it affects fish distribution and fishing success during specific periods.

Based on these conditions, an approach is needed that not only identifies the relationship between temperature and catch but also maps the spatial distribution of optimal temperature within a defined time period. This study proposes mapping the optimal temperature for skipjack tuna in Pangandaran waters during 2024 by integrating high-resolution SST data with small-scale fishers' catch data. This approach is expected to produce more operational and practical spatial information for fishing activities.

This study aims to map the optimal temperature range for skipjack tuna in Pangandaran waters in 2024 and to analyze its relationship with small-scale fishers' catches. The results are expected to provide a scientific basis for developing oceanography-based fishing ground information, thereby improving the efficiency and sustainability of small-scale capture fisheries.

LITERATURE REVIEW

The relationship between sea surface temperature (SST) and pelagic fish abundance is a key aspect in fisheries oceanography. SST plays an important role in regulating physiological processes in fish, including metabolism, growth, and migration activity. Changes in SST can trigger pelagic fish to move toward more suitable environmental conditions, thereby influencing their distribution and abundance. Several studies have shown that oceanographic parameters such as SST, chlorophyll-a, salinity, and ocean currents significantly affect the distribution patterns and abundance of pelagic fish (Saifudin et al., 2014; Sadly & Awaluddin, 2017; Ma'mun et al., 2019).

In skipjack tuna (*Katsuwonus pelamis*), SST is closely related to both abundance and catch rates. Previous studies indicate that skipjack exhibit a preference for specific temperature ranges that support their biological activities, with an optimal range of 27–29°C and an ideal condition around 28°C (Rahman et al., 2019). In addition, seasonal SST variability influences fishing productivity, where increased skipjack catches are often associated with periods of suitable thermal conditions (Pratama et al., 2022). This suggests that SST not only determines spatial distribution but also contributes to variations in fishery productivity.

Furthermore, the effect of SST on skipjack abundance is closely linked to its interaction with chlorophyll-a. SST influences plankton distribution, which forms the base of the marine food web. Although skipjack do not directly consume phytoplankton, higher chlorophyll-a concentrations enhance the availability of zooplankton and small fish as their primary prey (Simbolon & Girsang, 2009). Optimal conditions for skipjack abundance generally occur when suitable SST coincides with chlorophyll-a concentrations of approximately 0.2–0.25 mg/m^3 (Rahman et al., 2019). Therefore, SST plays both direct and indirect roles in determining skipjack abundance through its influence on habitat conditions and marine productivity.

METHODOLOGY

This study was conducted in Pangandaran waters, which are part of the southern Java Sea and are known as one of the fishing grounds for pelagic species exploited by small-scale fishers. The analysis focused on the period from January to December 2024 to describe the spatial and temporal variability of sea surface temperature (SST) over a full annual cycle.

The primary dataset used in this study was SST obtained from the Copernicus Marine Service, specifically the Global Ocean Physics Reanalysis (GLORYS) product. This dataset is generated using the NEMO (Nucleus for European Modelling of the Ocean) model, which integrates satellite observations and in situ measurements to produce a comprehensive representation of ocean conditions. The SST data have a spatial resolution of 0.083° × 0.083° and a monthly temporal resolution, making them suitable for regional-scale analysis in the study area (Pratama et al., 2025). The data were downloaded in raster format and used to describe SST distribution throughout 2024.

Optimal Temperature for Skipjack Tuna

This study did not use catch data as an analytical variable but instead focused on interpreting environmental conditions based on the optimal temperature range for skipjack tuna derived from previous studies. The optimal temperature range for *Katsuwonus pelamis* was determined through a synthesis of relevant literature, as summarized in Table 1.

Table 1. Optimal Temperature Range for Skipjack Tuna

Study Area	Optimal Temperature	Reference
Southern Java waters	Southeast monsoon: 24–28.5 °C Northwest monsoon: 28.3–29.2 °C	Suhermat (2024)
Maluku Sea	Transitional season: 28–28.9 °C	Pamungkas et al. (2020)

The temperature range from southern Java waters was used as the primary reference due to its similar oceanographic characteristics to the study area, while data from the Maluku Sea were used as a comparison to strengthen biological interpretation.

Data Processing and Analysis

Data processing involved extracting SST values within the study area boundaries and classifying them into southeast and northwest monsoon periods to account for seasonal variations in optimal temperature ranges. Each SST value was then compared with the predefined optimal range. Areas with SST values within this range were interpreted as suitable habitats for skipjack tuna, while areas outside the range were considered less suitable.

The processed results were presented as monthly thematic maps illustrating the spatial distribution of suitable and unsuitable temperature conditions for skipjack tuna throughout 2024. The analysis was conducted descriptively by examining spatial patterns of optimal temperature, monthly variability, and seasonal differences. This exploratory approach aims to provide an initial assessment of temperature suitability in supporting fishing activities, particularly for small-scale fisheries.

RESEARCH RESULT

Sea Surface Temperature Dynamics in 2024

Throughout 2024, sea surface temperature (SST) in Pangandaran waters exhibited noticeable variability. The monthly mean SST dynamics are presented in Figure 1.

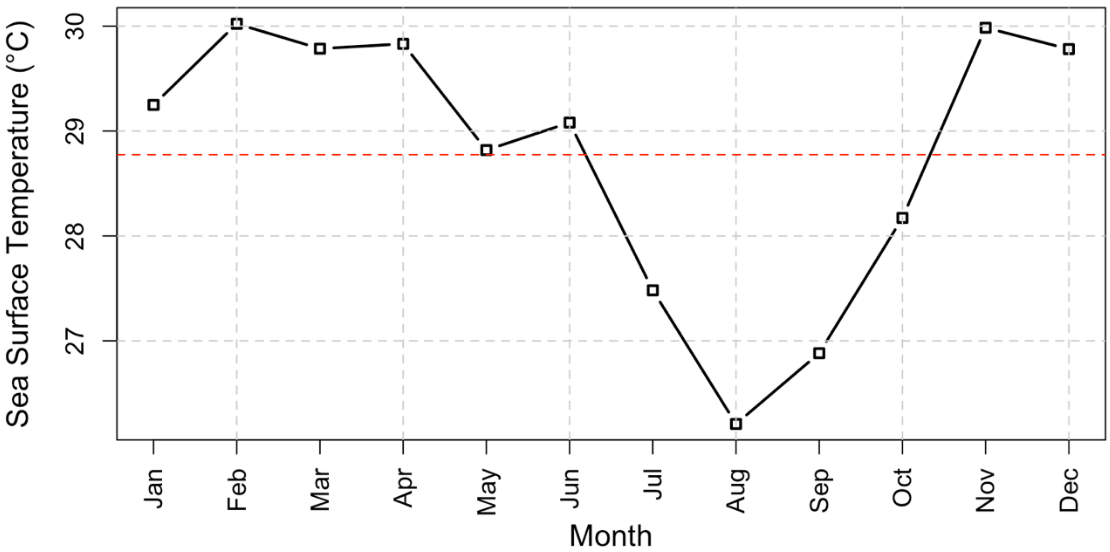

Figure 1. Monthly mean sea surface temperature in Pangandaran waters during 2024

The average SST in Pangandaran waters during 2024 showed clear monthly variations, ranging from 26.21 °C to 30.02 °C. During the early-year period (January–April), SST remained relatively high, with average values of 29.25 °C, 30.02 °C, 29.79 °C, and 29.83 °C, respectively. The highest temperature was recorded in February, while the other months in this period also exhibited warm conditions exceeding 29 °C.

Entering May and June, SST began to decrease to 28.82 °C and 29.08 °C, respectively. A more pronounced decline occurred from July to September, with average temperatures of 27.48 °C in July, reaching the lowest value in August at 26.21 °C, and slightly increasing again in September to 26.88 °C. SST then increased toward the end of the year, with values of 28.17 °C in October, rising significantly to 29.98 °C in November, and remaining relatively stable at 29.78 °C in December.

Spatial Distribution of Optimal Sea Surface Temperature in 2024

The spatial distribution of SST in Pangandaran waters at the beginning of 2024 (January–April) is presented as monthly maps in Figure 2.

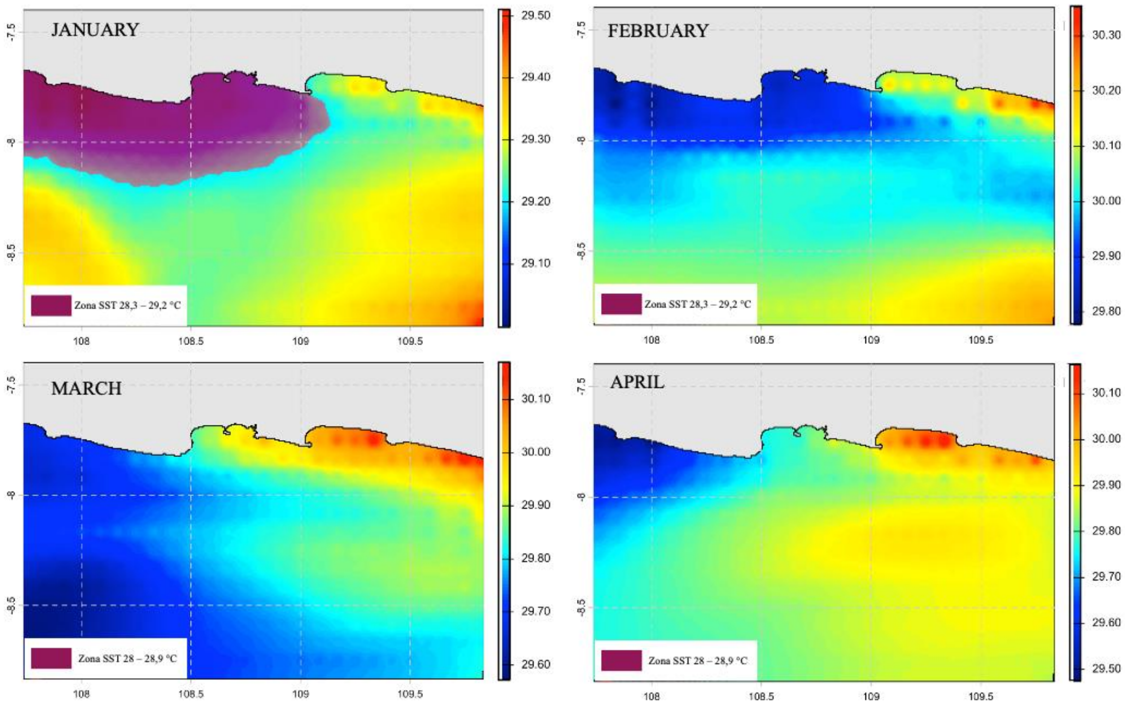

Figure 2. Spatial distribution of sea surface temperature (SST) from January to April 2024

SST distribution during January–April was dominated by relatively warm conditions. In January, temperatures were lower in the northern (coastal) areas and increased toward the south. During this period, only January showed coastal areas with SST conditions suitable for skipjack tuna. In February, SST increased across the study area, particularly in the eastern region, where the highest values were observed. In March, a clearer temperature gradient appeared, with lower temperatures in the west and higher temperatures toward the east. This pattern continued into April, where high SST expanded across the central to eastern parts of the waters.

The spatial distribution of SST during the mid-year period (May–August) is presented in Figure 3.

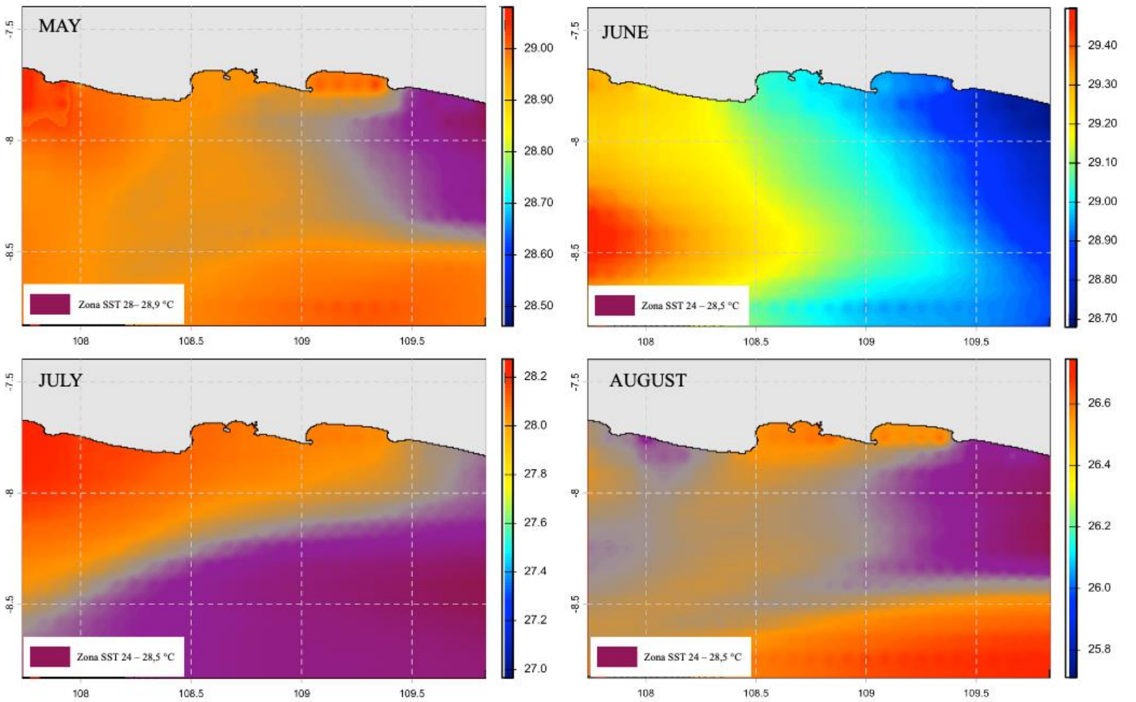

Figure 3. Spatial distribution of sea surface temperature (SST) from May to August 2024

SST in May was still dominated by warm conditions with relatively homogeneous distribution, although a decrease began to appear in the eastern part of the waters. A more distinct change occurred in June, where a strong west–east gradient developed, with higher temperatures in the west and lower temperatures toward the east. This cooling pattern intensified in July, when SST decreased more extensively, particularly in the southern and eastern parts of the study area. During July, SST conditions were predominantly within the optimal range for skipjack tuna, extending from the eastern coastal areas toward offshore (southern) waters. The cooling reached its peak in August, with lower SST values widely distributed, especially in offshore areas.

The spatial distribution of SST at the end of 2024 (September–December) is presented in Figure 4. SST in September remained relatively low, particularly in the northern and central parts of the waters, with temperatures increasing toward the south. In October, SST increased significantly and was dominated by warmer conditions, although some cooler areas remained in the eastern region. In November, the distribution became more homogeneous, with high temperatures dominating most of the study area, especially in the central and eastern waters. This pattern continued into December, when SST reached higher values and became widely distributed, showing a general increase from west to east. Throughout the September–December period, SST conditions were generally not within the optimal range for skipjack tuna.

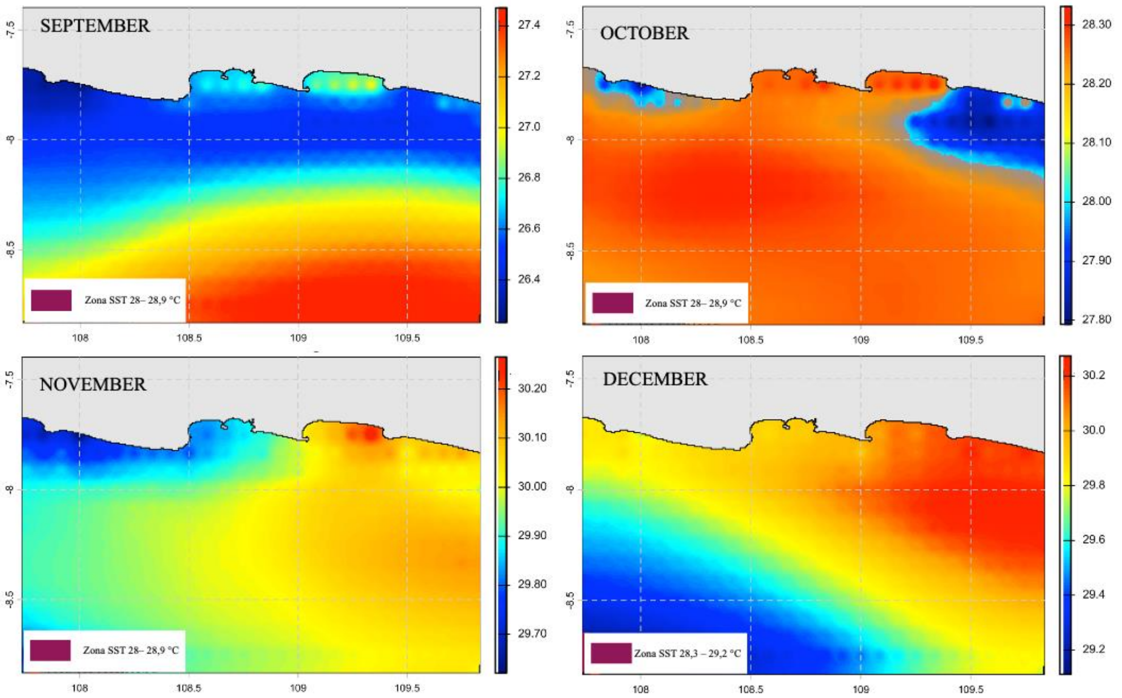

Figure 4. Spatial distribution of sea surface temperature (SST) from September to December 2024

DISCUSSION

Sea surface temperature (SST) variability in Pangandaran waters during 2024 exhibited a clear seasonal pattern consistent with the oceanographic dynamics of southern Java waters. This pattern was characterized by higher temperatures at the beginning and end of the year, and a significant decrease during the mid-year period. These changes are closely associated with the monsoon system, where the northwest monsoon tends to produce warmer waters, while the southeast monsoon induces upwelling that lowers SST (Sundoko et al., 2025).

During the early-year period (January–April), relatively high SST reflects the dominance of warm water masses due to weak vertical mixing. This condition leads to a more stable water column but is generally associated with lower productivity. Although SST during this period falls within or near the upper optimal range for *Katsuwonus pelamis*, excessively high temperatures may limit vertical fish distribution and reduce prey availability in surface layers (Pratama et al., 2025). According to Adnan (2010), higher temperatures tend to reduce fish presence in surface waters, as fish migrate to deeper layers, resulting in decreased catch rates because fishing gear cannot effectively reach deeper distributions.

In the mid-year period (May–August), SST decreased significantly, reaching its lowest value in August. This condition is associated with intensified upwelling along the southern Java coast, which brings colder, nutrient-rich waters to the surface (Susilo & Wibawa, 2016; Yuhendrasmiko et al., 2016; Wisha et al., 2017). This cooling enhances habitat suitability for skipjack tuna, particularly due to increased primary productivity that supports food availability (Pratama et al., 2025). SST during this period generally falls within the lower optimal range (24–28.5 °C), which supports feeding activity and aggregation of pelagic fish (Azwar, 2016).

During the late-year period (September–December), SST increased again as upwelling weakened and conditions transitioned toward the northwest monsoon (Lasut et al., 2022; Latifah et al., 2024). This warming led to a more homogeneous temperature distribution dominated by warm conditions across the study area. However, the transitional period, particularly in September and October, still exhibited relatively suitable temperature conditions combined with moderate productivity, making it a potentially important phase for skipjack presence.

When compared with previously reported optimal temperature ranges, January, May, July, and August 2024 were identified as periods with suitable SST conditions for skipjack tuna, although spatial suitability varied. The southeast monsoon period tends to provide more favorable conditions in terms of productivity, while the northwest monsoon offers more stable but less productive conditions. These findings are consistent with previous studies on skipjack fishing seasons in the Indian Ocean, including Pangandaran waters, where peak fishing seasons generally occur during the late northwest monsoon and the southeast monsoon (Nurani et al., 2021; Siringoringo et al., 2024).

Overall, these results indicate that SST can be used as an initial indicator for identifying potential fishing grounds. However, skipjack distribution is influenced not only by temperature but also by other factors such as food availability, ocean currents, and broader oceanographic structures. Therefore, SST-based information should be integrated with other oceanographic parameters to improve the accuracy of fishing ground predictions, particularly to support small-scale fisheries.

CONCLUSIONS AND RECOMMENDATIONS

Sea surface temperature (SST) in Pangandaran waters during 2024 exhibited a clear seasonal pattern, ranging from 26.21 °C to 30.02 °C. This pattern was characterized by higher temperatures at the beginning and end of the year and a decrease in mid-year due to upwelling processes. This variability has direct implications for the habitat suitability of skipjack tuna. Suitable temperature ranges for skipjack were generally observed during specific periods, particularly in January, May, July, and August, with spatial variability influenced by oceanographic dynamics. The southeast monsoon tends to provide more optimal conditions due to increased ocean productivity associated with cooler SST, while the northwest monsoon offers more stable but less productive conditions.

Overall, SST can be used as an initial indicator for identifying potential skipjack fishing grounds. However, to produce more accurate and operational information, SST analysis should be integrated with other oceanographic parameters such as chlorophyll-a, ocean currents, and additional environmental factors. This integrated approach is essential to support the efficiency and sustainability of small-scale capture fisheries.

ADVANCED RESEARCH

This study is limited by the use of a single oceanographic parameter, namely sea surface temperature (SST), as the primary indicator for identifying potential fishing grounds. Future research should integrate additional oceanographic variables such as chlorophyll-a, ocean currents, sea surface height, and thermal fronts to improve the accuracy of habitat identification for skipjack tuna. More advanced modeling approaches, including *species distribution models* (SDM), *generalized additive models* (GAM), and machine learning techniques, should also be explored to better capture the nonlinear relationships between environmental variables and fish abundance.

Furthermore, the integration of real-time fishery catch data with satellite-based oceanographic data is essential to develop more operational and practical fishing ground information systems. Future studies should also consider interannual variability and the influence of large-scale climate phenomena such as ENSO and the Indian Ocean Dipole (IOD) on temperature dynamics and fish distribution. A more comprehensive approach is expected to support the development of adaptive and accurate fishing ground prediction systems, contributing to sustainable fisheries management, particularly for small-scale fisheries.

ACKNOWLEDGMENT

The authors would like to express their gratitude to all parties who contributed to this study. Special thanks are extended to the Copernicus Marine Service for providing access to sea surface temperature data used in this research. Appreciation is also given to small-scale fishers in Pangandaran, whose activities inspired this study.

REFERENCES

Adnan. (2010). Analisis suhu permukaan laut dan klorofil-a data inderaja hubungannya dengan hasil tangkapan ikan tongkol (*Euthynnus affinis*) di perairan Kalimantan Timur. *Jurnal Amanisal, 1*(1), 1–12.

Amura, D., & Pirhel. (2021). Financial analysis of capture fisheries business in Outer Ambon Bay as a sustainable fisheries management effort. *Jurnal Triton, 17*(1), 46–56.

Azwar, M., Emiyarti, & Yusnaini. (2016). Critical thermal ikan *Zebrasoma scopas* yang berasal dari Perairan Pulau Hoga Kabupaten Wakatobi. *Jurnal Sapa Laut, 1*(2), 60–66.

Freitas, C., Villegas-Ríos, D., Moland, E., & Olsen, E. M. (2021). Sea temperature effects on depth use and habitat selection in a marine fish community. *Journal of Animal Ecology, 90*, 1787–1800. https://doi.org/10.1111/1365-2656.13497

Gaol, J. L., & Sadhotomo, B. (2007). Karakteristik dan variabilitas parameter oseanografi Laut Jawa hubungannya dengan distribusi hasil tangkapan ikan. *Jurnal Penelitian Perikanan Indonesia, 13*(3), 1–12.

Irwansya, Haya, L. O. M. Y., & Tadjuddah, M. (2026). Analysis of potential zones for cakalang (*Katsuwonus pelamis*) fishing based on remote sensing technology in Bone Bay waters. *Jurnal Sains dan Inovasi Perikanan, 10*(1), 1–10. https://doi.org/10.33772/jsipi.v10i1.947

Kusdiantoro, Fahrudin, A., Wisudo, S. H., & Juanda, B. (2019). Capture fisheries in Indonesia: Portraits and challenges of sustainability. *Jurnal Sosial Ekonomi Kelautan dan Perikanan, 14*(2), 145–162. https://doi.org/10.15578/jsekp.v14i2.8056

Lasut, A. Y., Siregar, D. C., & Ninggar, R. D. (2022). Variabilitas spasial parameter oseanografi di Perairan Sulawesi Utara. *Buletin Meteorologi, Klimatologi dan Geofisika, 2*(3), 1–8.

Latifah, A. L., Wulandari, S. Y., & Kunarso. (2024). Hubungan suhu permukaan laut (SPL) dan klorofil-a terhadap hasil tangkapan yellowfin tuna (*Thunnus albacares*) yang didaratkan di Pelabuhan Tamperan Pacitan. *Indonesian Journal of Oceanography, 6*(3), 197–208.

Ma'mun, A., Priatna, A., Amri, K., & Nurdin, A. (2019). Hubungan antara kondisi oseanografi dan distribusi spasial ikan pelagis di Wilayah Pengelolaan Perikanan Negara Indonesia 712 Laut Jawa. *Jurnal Penelitian Perikanan Indonesia, 25*(1), 1–14.

Maruanaya, Y., Solissa, M. I., Mistina, R. S., & Tuhumena, L. (2025). Analysis of skipjack tuna (*Katsuwonus pelamis*) catches using handline fishing by Sanoba fishermen in Nabire waters, Papua. *Jurnal Perikanan Kemasan, 6*(1), 20–34. https://doi.org/10.58950/jpk.v6i1.81

Mudlika, A., Nugraha, R. A., & Subekti, S. (2023). Peran suhu dan klorofil dalam upwelling di perairan tropis. *Jurnal Ilmu Kelautan Indonesia, 13*(1), 34–45.

Nurani, T. W., Wahyuningrum, P. I., Iqbal, M., Khoerunnisa, N., Pratama, G. B., Widianti, E. A., & Kurniawan, M. F. (2021). Dynamics of skipjack and longtail tuna fishing season in Palabuhanratu waters. *Marine Fisheries, 12*(2), 149–160.

Pamungkas, A. D., Kusdinar, A., & Halim, S. (2020). Hubungan SPL dan salinitas terhadap hasil tangkapan cakalang pada KM Samudra Jaya di Laut Maluku. *Jurnal Penyuluhan Perikanan dan Kelautan, 14*(1), 13–26.

Pratama, G. B., Baihaqi, F., & Aisyah. (2025). Literature study: Effect of oceanographic parameters on pelagic fish abundance. *Octopus, 13*(2), 66–73.

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

Pratama, G. B., Wijayanti, L. A. S., Maqbul, I., Muhyun, A. A., Sahar, R. A., Ayu, R. G., & Firdaus, M. R. (2025). Multi-algorithm species distribution modeling for skipjack tuna fishing ground detection in the Indian Ocean: A case study of Indonesian FMA 572. *Environmental Quality Management, 35*(1), e70166. https://doi.org/10.1002/tqem.70166

Rahman, M. A., Syamsudin, M. L., Agung, M. U. K., & Sunarto, S. (n.d.). Pengaruh musim terhadap kondisi oseanografi dalam penentuan daerah penangkapan ikan cakalang (*Katsuwonus pelamis*) di perairan selatan Jawa Barat. *Jurnal Perikanan dan Kelautan Unpad, 10*(1).

Saifudin, Fitri, A. D. P., & Sardiyatmo. (2014). Aplikasi sistem informasi geografis (SIG) dalam penentuan daerah penangkapan ikan teri (*Stolephorus spp*) di Perairan Pemalang (Jawa Tengah). *JFRMUT, 3*(4), 66–75.

Saksono, H., Nissa, Z. N. A., & Saudi, S. (2023). Small-scale fisher's livelihood strategies: Findings from case studies in several Indonesian coastal areas. *Jurnal Perikanan, 25*(1), 9–18.

Sala, E., & Manuhutu, B. (2020). Analisis suhu optimal habitat ikan pelagis. *Jurnal Sumberdaya Perikanan, 5*(2), 99–105.

Sadly, M., & Awaluddin. (2017). Sistem penjejak ikan untuk pemantauan kualitas lingkungan perairan dan prediksi lokasi penangkapan ikan menuju pengelolaan perikanan berkelanjutan. *Jurnal Teknologi Lingkungan, 18*(1), 29–36.

Simbolon, D., & Girsang, H. S. (2009). Hubungan antara kandungan klorofil-a dengan hasil tangkapan tongkol di daerah penangkapan ikan Perairan Palabuhanratu. *JLPI, 15*(4), 297–305.

Siringoringo, E. O. H., Simbolon, D., Wahju, R. I., & Purwangka, F. (2024). Produktivitas dan pola musim penangkapan cakalang di Wilayah Pengelolaan Perikanan 572. *Jurnal Penelitian Perikanan Indonesia, 30*(2), 99–109.

Suhermat, M. (2024). Pemodelan kesesuaian habitat ikan cakalang menggunakan penginderaan jauh di Perairan Selatan Jawa Barat–Banten. *Jurnal Ilmu Lingkungan, 22*(3), 667–671. https://doi.org/10.14710/jil.22.3.667-671

Sundoko, A., Kusumaningsih, A. R. P., Haryati, A., Isnaini, J. A. S., Nugroho, A., Ta'alidin, Z., Azuga, N. A., Nurjaya, I. W., Landu, A., & Amal, I. (2025). *Oseanografi perikanan*. LSO Kreatif.

Susilo, E., & Wibawa, T. A. (2016). Utilization of satellite oceanography data to predict lemuru fishing ground based on food chain and statistical GAM approach. *Jurnal Kelautan Nasional, 11*(2), 77–87.

Tadjuddah, M. (2005). Peran suhu dalam pertumbuhan ikan. *Jurnal Ilmu Perikanan Tropis, 1*(1), 45–50.

Wisha, U. J., Al Tanto, T., & Ilham, I. (2017). Spatial distribution of sea surface temperature in West Sumatera seawaters associated with Indian Ocean Dipole (IOD) event in transitional seasons (August–October). *Jurnal Ilmiah Geomatika, 22*(1), 21–28.

Yuhendrasmiko, R., Kunarso, K., & Wirasatriya, A. (2016). Identifikasi variabilitas upwelling berdasarkan indikator suhu dan klorofil-a di Selat Lombok. *Journal of Oceanography, 5*(4), 530–537.