

Analysis of the Relationship Between Sea Surface Temperature, Chlorophyll-a, and Spanish Mackerel (*Scomberomorus Commerson*) Catch in the Java Sea

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ABSTRAK

Pati regency is a coastal area that contributes significantly to Indonesia's fisheries sector. One of its major fishing ports, PPP Bajomulyo, serves as a hub for fishing activities, with catches ranging from small to large pelagic fish, including Spanish mackerel (*Scomberomorus commerson*). This study aims to examine the relationship between oceanographic parameters and Spanish mackerel catch volumes at PPP Bajomulyo over the 2021-2023 period. A survey-based approach incorporating satellite image overlay was employed. The analysis of non-linear relationships between variables was conducted using Generalized Additive Model (GAM), implemented in RStudio. Satellite image processing was performed using SeaDAS, while spatial analysis was carried out in ArcGIS. The findings reveal that the interaction between sea surface temperature (SST) and chlorophyll-a concentrations accounted for 11,44% of catch variability. Elevated SST above 29,5 °C were associated with increased catch rates, whereas extreme temperature (>35 °C or <28 °C) corresponded with significant declines. Chlorophyll-a exerted a relatively weak influence on catch, suggesting that although it serves as a proxy for primary productivity, Spanish mackerel distribution is more strongly governed by thermal conditions and prey availability. The study further identified that optimal fishing grounds were predominantly located in northern Central Java waters, particularly during seasons characterized by favorable oceanographic conditions.

INTRODUCTION

Pati Regency is recognized as a region that makes a substantial contribution to the national fisheries sector. Located on the northern coast of Central Java and directly bordering the Java Sea to the north and east, Pati's capture fisheries production reached 70,978,080 tons in 2022 (Ministry of Marine Affairs and Fisheries, 2024). This achievement is supported by the presence of seven fishing ports, including the Pelabuhan Perikanan Pantai (PPP) Bajomulyo, which serves as a center for fishing activities and the distribution of catches to various regions (Kurohman *et al.*, 2018; Triyantoro *et al.*, 2021).

In addition to fishing activities, Pati has also shown significant growth in fish processing industries. Various processing businesses have flourished in the region, including milkfish processing (Ni'am & Mei, 2019), fish crackers (Prasetyowati *et al.*, 2020), smoked fish (Betanews, 2020), pindang (Damayanti, 2015), and semi-processed products such as fish nuggets and fish balls (Maghfiroh *et al.*, 2023). One key commodity in this industry is the Spanish mackerel, which holds high economic value and enjoys steady market demand both

locally and internationally (Retnoningtyas *et al.*, 2023; Salim *et al.*, 2020). However, catch data for Spanish mackerel do not always match the level of demand. According to data from the Ministry of Marine Affairs and Fisheries (MMAF), the total catch of Spanish mackerel in Pati in 2021 was only around 155.62 tons (MMAF, 2025).

The distribution and abundance of large pelagic species like Spanish mackerel are influenced by oceanographic factors such as sea surface temperature and chlorophyll-a, as well as broader environmental conditions (Fadhilah *et al.*, 2020; Fofied *et al.*, 2024). External factors like climate change and anthropogenic activities also impact the population dynamics and distribution of Spanish mackerel (Effrosynidis *et al.*, 2020). Spatial distribution studies and potential fishing zone mapping based on oceanographic parameters have been widely conducted, especially for small pelagic species such as scad mackerel (*Decapterus macrosoma*) (Dwiyanti *et al.*, 2022) and sardine (*Sardinella lemuru*) (Susilo & Wibawa, 2017). Studies on large pelagic species have also been undertaken, for instance, on little tuna (*Euthynnus affinis*) in Banten Bay (Nagi *et al.*, 2023), skipjack (*Katsuwonus pelamis*) and tuna (*Thunnus sp.*) in the Sawu Sea National Marine Park (Wangge *et al.*, 2021), as well as in Eastern Indonesia (Syakib & Handiani, 2023). Research on Spanish mackerel is beginning to emerge in several areas, such as Pangandaran (Juliana & Indra, 2021) and Tunda Island (Widianingsih *et al.*, 2023). However, studies specifically examining the relationship between oceanographic parameters and Spanish mackerel catch in the Java Sea remain scarce. Spatial relationship analysis is needed to explain the causes of low local catches and to provide scientific information for sustainable fisheries resource management.

RESEARCH METHODOLOGY

Research Materials

The materials used in this study include sea surface temperature (SST), chlorophyll-a, and catch data of Spanish mackerel collected from the Pelabuhan Perikanan Pantai (PPP) Bajomulyo, Juwana, Pati. The study area map is presented in Figure 1.

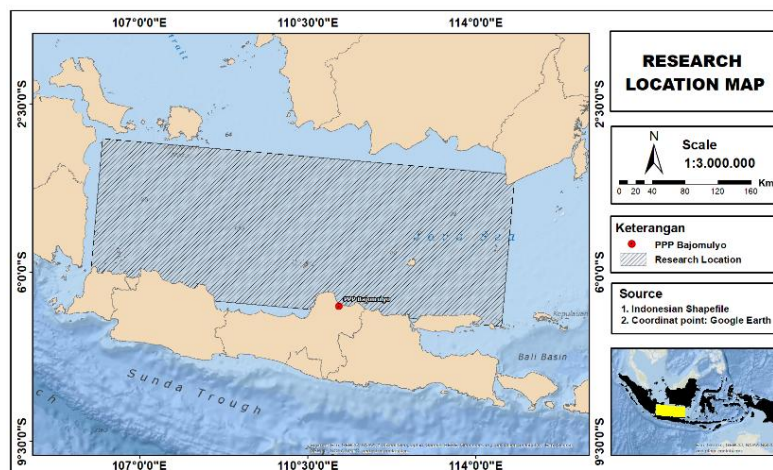


Figure 1. Research Location Map

Research Approach

This research employed a survey method with an analytical quantitative approach to analyze the relationship between oceanographic factors and Spanish mackerel (*Scomberomorus commerson*) catch. The analytical approach was implemented using the

Generalized Additive Model with a Negative Binomial distribution (GAM-NB), aimed at identifying non-linear relationships between oceanographic parameters and the number of Spanish mackerel catches.

Data Analysis

Catch data from PPP Bajomulyo were filtered based on the target species, namely Spanish mackerel, and limited to the study period of 2021 to 2023, with catch units expressed in kilograms.

This study utilized the Generalized Additive Model (GAM) to analyze the relationship between oceanographic parameters—specifically sea surface temperature (SST) and chlorophyll-a—and the catch of Spanish mackerel (*Scomberomorus commerson*). The use of GAM was based on the typically non-linear nature of the relationship between oceanographic variables and fish distribution, which makes it more flexible than standard linear or polynomial regression methods (Susilo & Wibawa, 2017; Zuur *et al.*, 2009).

The GAM was implemented in RStudio using the `gam` function from the `mgcv` package, assuming that the catch quantity (in kg) is influenced by the predictor parameters SST and chlorophyll-a (Sambah *et al.*, 2020). The `mgcv` package facilitates generalized additive modeling (GAM and BAM) as well as generalized additive mixed modeling (GAMM). The plots produced by this package depend on the predictor functions and are used to estimate the optimal values of these predictors (Wood *et al.*, 2016).

According to Padmaningrat *et al.* (2017), mapping of Spanish mackerel fishing grounds was carried out in several stages. The first stage involved determining the optimal SST and chlorophyll-a ranges for Spanish mackerel catch based on statistical analysis and previous research. The processed and downloaded data were then handled using the SeaDAS software. Within SeaDAS, the data underwent image cropping. After the cropping process, the data were further processed in Microsoft Excel to remove “NaN” values, which are typically caused by obstructing objects such as clouds that could affect the accuracy of the analysis. The final stage involved visualizing the processed data in map format using ArcGIS (Fofied *et al.*, 2024).

RESULTS AND DISCUSSION

Sea Surface Temperature (SST)

Sea surface temperature (SST) is one of the key oceanographic parameters that significantly influences metabolic rates, thereby affecting the distribution and abundance of Spanish mackerel (Fardilah *et al.*, 2024; Yang *et al.*, 2022). Based on SST analysis in the Java Sea from 2021 to 2023 (Figure 2), the water temperatures showed a wide variation ranging from 25°C to 39°C, with an average around 29°C. The seasonal SST pattern revealed more stable temperatures during the first transitional and dry seasons, while the second transitional and wet seasons exhibited more extreme fluctuations. These findings are consistent with Maulina *et al.* (2019), who reported similar SST variability in the Java Sea between 2016–2018, with peak temperatures typically occurring during transitional seasons.

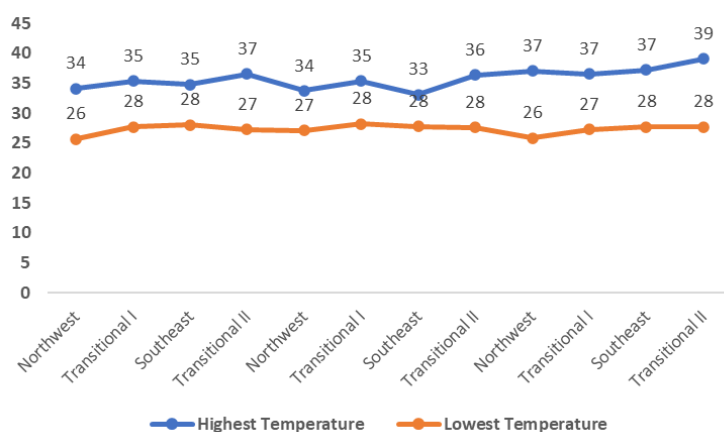


Figure 2. Distribution of Sea Surface Temperature (2021–2023)

At the end of 2023, SST recorded an extreme increase, starting from 36°C during the first transitional season and peaking at 39°C in the second transitional season. This condition indicates the likelihood of a major weather anomaly, such as El Niño, which according to BMKG (2023), began intensifying in July 2023 and reached its peak between August and September 2023.

Chlorophyll-a

Chlorophyll-a is a key indicator of primary productivity in marine environments, reflecting the availability of phytoplankton as a food source for zooplankton and small pelagic fish, which in turn support predator species such as Spanish mackerel (Agung *et al.*, 2018; Fardilah *et al.*, 2024). A temporal analysis of chlorophyll-a distribution from 2021 to 2023 showed that seasonal concentration patterns were inconsistent, though with some upward trends during certain seasons.

In 2021, the highest chlorophyll-a concentration occurred in the second transitional season. In 2022, the peak concentration shifted to the wet season. According to Setyaningrum *et al.* (2023), a similar phenomenon was observed with chlorophyll-a levels doubling during the wet season. In 2023, a dual-peak pattern was noted, with high concentrations in both the wet and first transitional seasons. This suggests that land-derived nutrient input remains significant early in the year, even during transitions toward the dry season (Suhanda *et al.*, 2024; Timur *et al.*, 2024). The increase in chlorophyll-a during the wet season is likely driven by high rainfall transporting nutrients from land or nearby islands (Hu *et al.*, 2021; Rahman *et al.*, 2019). Conversely, Ningrum *et al.* (2022) noted that surface wind patterns from Asia during the wet season bring high rainfall but result in lower chlorophyll-a concentrations.

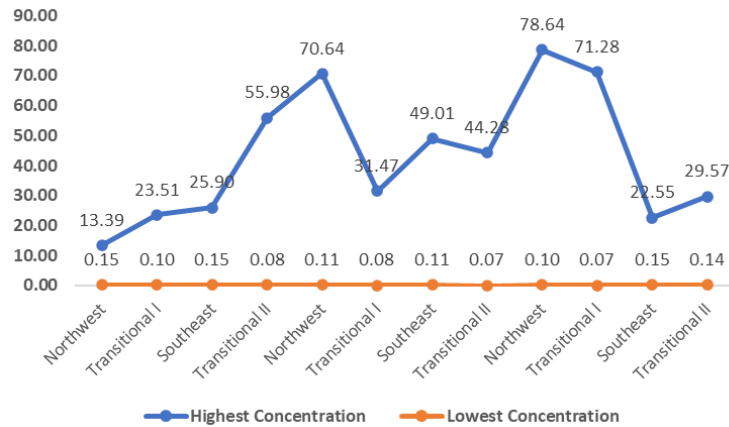


Figure 3. Chlorophyll-a Distribution

Generalized Additive Model (GAM) Analysis

Based on the GAM results, SST emerged as the oceanographic factor with the strongest influence on Spanish mackerel catch. Although the p-value for SST in Model 1 was 0.144, the Cumulative Deviance Explained (CDE) was 9.03%, indicating a meaningful contribution to catch variability. When combined with chlorophyll-a in Model 3, the p-value for SST decreased to 0.115, and the CDE increased to 11.44%. This confirms SST’s greater influence compared to chlorophyll-a in explaining Spanish mackerel catch variability in the study area, aligning with the findings of Nguyen and Nguyena (2017), who reported a significant correlation between Spanish mackerel catch and SST.

Table 1. GAM Model Results

No.	Model	Parameter	P-value	CDE	AIC
1	Model 1	SPL	0,144	9,0316568	254,3704
2	Model 2	Chl_a	0,932	2,08672225	252,6601
3	Model 3	SPL	0,115	11,43594	256,1766
		Chl_a	0,318		

Previous studies have identified the optimal temperature range for Spanish mackerel. Syamsuddin *et al.* (2018) suggested that Spanish mackerel prefer waters with temperatures ranging from 29°C to 30°C. In Nha Trang, Vietnam, 93% of Spanish mackerel catches occurred at SSTs between 26°C and 30°C (Nguyen and Nguyena, 2017). Similarly, Syamsuddin *et al.* (2023) reported that Spanish mackerel distribution in the Java Sea was concentrated around 29°C. The spline plot in Figure 5 illustrates a nonlinear pattern where Spanish mackerel catch increases with SST above 29.5°C.

SST is closely linked to fish physiological processes, particularly metabolic rates. Low temperatures can slow metabolism, hinder growth, and reduce feeding activity, while high temperatures can lower dissolved oxygen levels and cause stress or mortality (Pratama *et al.*, 2022). Thus, temperature is a key factor influencing fish distribution. However, the wide confidence intervals in Figure 5. indicate high variability, possibly due to other factors outside the model parameters such as ocean currents, salinity, wave height, and fishing gear type (Lestari *et al.*, 2020; Juliana & Indra, 2021).

Chlorophyll-a showed a weaker influence on Spanish mackerel catch. In Model 2, where chlorophyll-a was the sole predictor, the p-value was 0.932, indicating no significant relationship. The CDE was only 2.09%, further supporting the conclusion that chlorophyll-a

does not substantially explain catch variability. Although chlorophyll-a contributes to primary productivity, the modeling results suggest it is not a major factor affecting Spanish mackerel distribution in the Java Sea. Harahap *et al.* (2020) also reported a low statistical correlation between chlorophyll-a and fish catch.

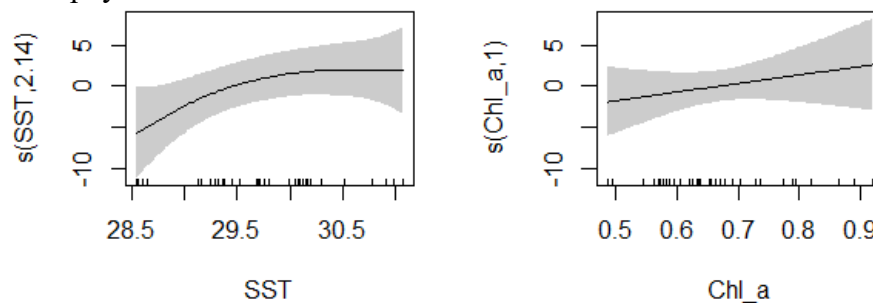


Figure 4. GAM Plot

The near-flat relationship between chlorophyll-a and Spanish mackerel catch in Figure 5 indicates no clear pattern between the two variables, implying that Spanish mackerel presence is driven by other factors. As pelagic fish do not directly consume phytoplankton, their abundance depends on small pelagic fish that feed on phytoplankton. Since Spanish mackerel are migratory, their movements are heavily influenced by the presence of small pelagic prey (Situmorang *et al.*, 2018). This is further supported by Kasim *et al.* (2014), who found a strong relationship between large pelagic predators such as skipjack and mackerel and the abundance of small pelagic prey. Despite lacking statistical significance, chlorophyll-a still holds ecological relevance for Spanish mackerel distribution (Pratama *et al.*, 2022).

CONCLUSION

Based on the results of the analysis, it can be concluded that sea surface temperature (SST) is the most influential parameter affecting Spanish mackerel (*Scomberomorus commerson*) catches, with an optimal temperature range between 29°C and 30°C. In contrast, chlorophyll-a exhibited a weaker influence. Spatially, potential fishing grounds for Spanish mackerel were predominantly located in the northern waters of Central Java, particularly during seasons characterized by optimal oceanographic conditions.

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