Spatial And Temporal Distribution of Nike Fish Related to Oceanographic Parameters in Teluk Tomini, Gorontalo, Using Satellite Imagery

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Abstract. Goby larvae, locally known as Nike fish, are essential for coastal fisheries and the marine ecosystem in Teluk Tomini, Gorontalo. This study explored the relationship between oceanographic parameters and the spatial and temporal distribution of Nike fish using satellite imagery. Oceanographic data, including sea surface temperature (SST), chlorophyll-a, salinity, and currents, were collected from Aqua MODIS and Global Ocean Physics Reanalysis satellite imagery from 2019 to 2021. Fishing data on location and duration were also collected. The analysis revealed that lower SST and calm currents correlated with longer fishing durations and higher capture frequencies, particularly in Leato Utara. Chlorophyll- and salinity had limited influence on fishing activities, showing weak or negligible correlations with capture frequency. Furthermore, regression analysis indicated that the proximity of fishing locations to river estuaries did not significantly impact the fishing frequency, suggesting that other factors may influence fishing patterns. These results underscore the importance of SST and currents in Nike fish behavior and distribution. Satellite imagery provides valuable insights into spatial and temporal oceanographic changes, enabling better management of fisheries. Understanding these dynamics can guide sustainable fishing practices, contributing to the long-term conservation of Nike fish populations in Teluk Tomini.

Keywords: Nike Fish, Oceanographic Parameters, Spatial Distribution, Satellite Imagery, Teluk Tomini.

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1 Introduction

Teluk Tomini is known for its rich biodiversity and unique amphidromous fish populations. Goby larvae, locally known as Nike fish, play a pivotal role in the coastal ecosystems of Gorontalo. These fish are known for their unique amphidromous life cycle, migrating from the sea to riverine environments to complete their developmental stages. This migration is crucial for their survival and reproduction, making them an integral part of both marine and freshwater ecosystems. The study of their patterns provides valuable insights into the ecological dynamics of the region, which is essential for local fisheries and biodiversity conservation [1], [2].

The influence of oceanographic parameters—such as sea surface temperature (SST), salinity, currents, and chlorophyll-*a* concentrations—on marine life is well-documented. These factors are vital in shaping the distribution and life cycles of aquatic organisms, including fish larvae. SST and salinity, for example, directly affect the metabolic rates and migration patterns of marine species, while chlorophyll-*a* levels are indicative of primary productivity, essential for the food webs supporting these communities [3][4]. Currents not only influence the dispersion of larvae but also the distribution of the nutrients on which they feed. Despite the acknowledged importance of these parameters, there remains a significant gap in localized studies focusing specifically on their impact on Nike fish populations in Teluk Tomini.

Globally, research leveraging satellite imagery to analyze oceanographic conditions has provided insights into environmental influences on marine organisms at large scales. However, in the context of Teluk Tomini, such studies are scarce, leaving a gap in the comprehensive understanding needed for effective resource management. Satellite imagery offers a broader view and continuous monitoring capability that ground-based methods cannot match[5], making it a potent tool for ecological studies in expansive and logistically challenging environments like Teluk Tomini.

This research aims to bridge these gaps by utilizing satellite imagery to analyze the relationship between the location and duration of Nike fish capture and the varying oceanographic parameters. By integrating geographic information system (GIS) technology with advanced statistical analyses, this study seeks to delineate how environmental factors specifically affect Nike fish distribution and behavior. The outcomes of this research are expected to contribute significantly to the existing body of knowledge on marine ecology, providing a foundation for developing targeted, effective management and conservation strategies for the Nike fish populations in Teluk Tomini. Through this approach, the study will not only enhance our understanding of the ecological patterns that dictate the distribution of Nike fish but also bolster the sustainability of the fisheries that depend on them.

2 Material and Methods

2.1 Study Area

The study was conducted in Teluk Gorontalo, part of Teluk Tomini in Gorontalo province, Indonesia (Fig 1). The observation locations were divided into two regions (western and eastern) using river estuaries as benchmarks. The western region includes Pohe, Tanjung Kramat, and Bongo in the Hulonthalangi subdistrict. The eastern region includes Leato Utara, Leato Selatan, and Huangobotu in the Dumbo Raya and Bone Bolango subdistricts. This stratification provided a practical approach for comparing how oceanographic conditions varied across different geographical regions. Data collection and processing took place between February and June 2023.

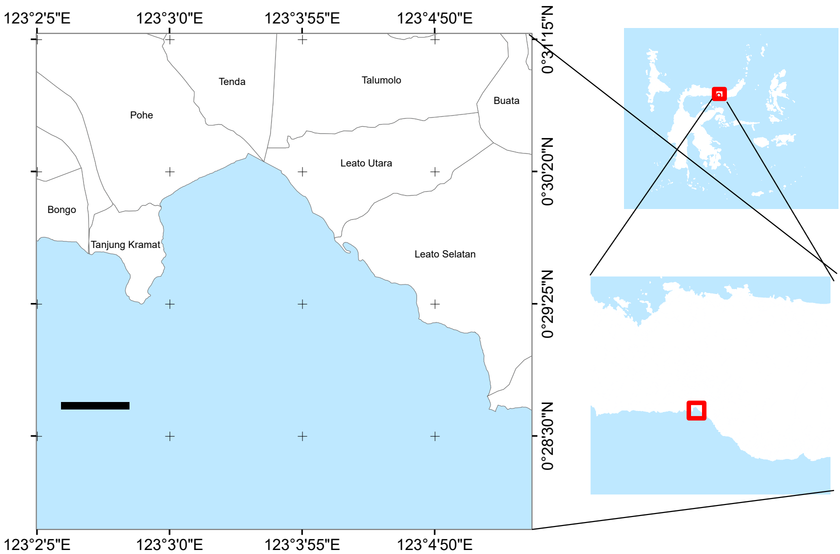

Fig. 1. The site location of Teluk Tomini

2.2 Data Collection

Oceanographic data were collected from Aqua MODIS and Global Ocean Physics Reanalysis satellite imagery, while data on the location and duration of Nike fish capture were sourced from previous field studies (Sahami, unpublished 2023). Monthly averages from 2019 to 2021 were used for the following parameters:

- Chlorophyll-*a*: This measures the abundance of phytoplankton, providing insights into marine primary productivity and the availability of food for Nike fish larvae [6], [7].

- Sea Surface Temperature (SST): Variations in temperature directly affect fish metabolism, behavior, and migration patterns [8], [9].
- Salinity: Significant changes can influence the migration, reproduction, and distribution of Nike fish [10], [11].
- Currents: Currents distribute nutrients and phytoplankton and help transport fish larvae from spawning grounds to nursery habitats.

In addition to satellite data, field observations and local fisheries records were analyzed to validate the temporal and spatial fishing activity data. Capture locations and the number of days of active fishing were mapped, and their proximity to river estuaries and other geographical features were noted.

2.3 Data Analysis

The data analysis was designed to identify relationships between oceanographic parameters and the location and duration of Nike fish capture using GIS software. The analysis used temporal and spatial interpolation to derive monthly averages for 2019-2021, ensuring comprehensive and consistent comparisons across multiple years.

Spatial distribution patterns of each oceanographic parameter were mapped using interpolation techniques. Geographic Information System (GIS) software helped visualize and analyze the patterns.

The relationships between oceanographic parameters and Nike fish capture locations were examined using Excel Toolpack, which provided a correlation matrix. Following [12], correlation coefficients were calculated using the formula:

$$r = \frac{n.(\sum XY) - (\sum X)(\sum Y)}{\sqrt{(n.\ \sum X^2 - (\sum X)^2).\ (n.\ \sum Y^2 - (\sum Y)^2}} \quad (1)$$

Wherel The "r" values range from -1 to 1, where r = 1 indicates a perfect positive correlation, r = -1 indicates a perfect negative correlation, and r = 0 shows no correlation.

To determine the influence of fishing frequency on distance from the estuary, a simple linear regression was conducted using the formula from [13]:

$$Y = a + bX \quad (2)$$

where: Y is the dependent variable (distance from the estuary), a is the regression constant, b is the regression coefficient, and X is the independent variable (fishing frequency).

The t-test was used to evaluate the significance of the regression results, with α=0.05 for a two-tailed test. The degrees of freedom (df) were calculated as $n-k-1$, where "n" is the total number of data points, and "k" is the number of independent variables. Following the guidelines set by [13] and [14], these statistical analyses provided insights into the relationships between oceanographic parameters and the spatial-temporal patterns of Nike fish fishing activities.

3 Result and Discussion

We analyzed oceanographic parameters such as chlorophyll-*a*, sea surface temperature (SST), salinity, and currents from 2019 to 2021. These parameters, derived from Aqua MODIS and Global Ocean Physics Reanalysis satellite imagery, are known to influence Nike fish distribution patterns.

3.1 Result

Chlorophyll-*a*. Chlorophyll-*a* concentrations represent phytoplankton levels, crucial for supporting primary production, and providing a food source for Nike fish larvae. During the study period, chlorophyll-*a* concentrations fluctuated significantly. The lowest concentration (0.141 mg/m³) occurred in December 2019, while the highest (1.161 mg/m³) was in September 2021. Seasonal and spatial variations were evident, with currents and nutrient availability playing crucial roles in influencing phytoplankton distribution [15], [16].

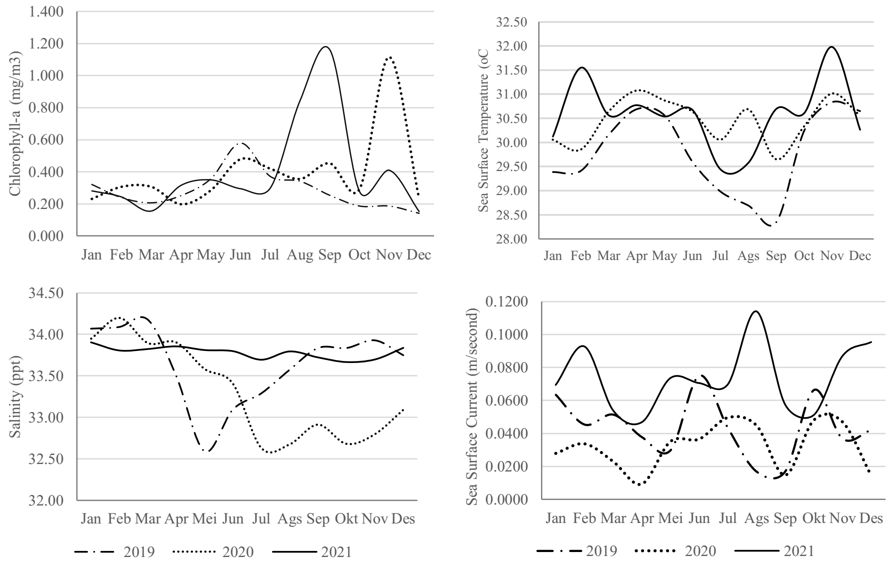

Fig. 2. The average monthly oceanographic parameters of Chlorophyll-*a* (upper left), Sea Surface Temperatures, SST (upper right), Salinity (Lower left), and Sea surface currents (lower right) extracted from satellite data.

Sea Surface Temperature (SST). SST ranged from 28.35°C (September 2019) to 31.98°C (November 2021), with noticeable seasonal and geographical variations influenced by changing weather patterns and ocean currents (Fig. 1). The SST variation directly impacted fish distribution and behavior [17]. In this study, SST correlated inversely (cooler waters) to increased fishing frequency and longer capture durations of Nike fish (Table 1; Table 2).

Salinity. Salinity levels fluctuated between 32.59 ppt (May 2019) and 34.20 ppt (February 2020). The variations were influenced by freshwater input from rivers, evaporation rates, and ocean currents. While salinity impacts fish migration and larval survival, its effect on Nike fish capture was less pronounced [18].

Currents. Ocean currents, ranging from 0.009 m/s (April 2020) to 0.114 m/s (August 2021), displayed distinct seasonal patterns. Currents affect nutrient transport and the dispersal of fish larvae, impacting their capture [19]. Lower current speeds generally resulted in longer fishing durations (Table 2).

Table 1. Coefficients correlation (r) of the capture number of the nike fish to the average of oceanographic parameters.

Heading level	Number of Nike Fish Capture	Chl-a (mg/m^3)	SST (°C)	Salinity (ppt)	Currents (m/s)
Number of Nike Fish Capture	1				
Chl-a (mg/m^3)	0.123921	1			
SST (°C)	-0,31791	-0,20996	1		
Salinity (ppt)	0,003672	-0,46563	0,160353	1	
Currents (m/s)	-0,44648	-0,01057	-0,02008	-0,16868	1

Table 2. Coefficients correlation (r) of the the nike fish capture duration to the average of oceanographic parameters.

Heading level	Duration of Nike Fish Capture	Chl-a (mg/m^3)	SST (°C)	Salinity (ppt)	Currents (m/s)
Duration of Nike Fish Capture	1				
Chl-a (mg/m^3)	0,083084	1			
SST (°C)	-0,60679	-0,20996	1		
Salinity (ppt)	0,032423	-0,46563	0,160353	1	
Currents (m/s)	-0,1274	-0,01057	-0,02008	-0,16868	1

Fishing Location and Duration. The capture frequency was highest in Leato Utara (18 instances, 2019-2021), possibly due to favorable oceanographic conditions. Conversely, Leato Selatan and Huangobotu had the lowest frequency, each with only one instance. October 2019 had the longest capture period (10 days). Fishing duration correlated with oceanographic parameters like SST and currents, which are essential in influencing fish behavior [3].

Correlation Analysis. A correlation analysis revealed that chlorophyll-*a* had a weak correlation with fishing location (r = 0.12). SST (r = -0.32) and currents (r = -0.45) had stronger inverse correlations, indicating that cooler temperatures and lower current speeds are conducive to fishing activities.

Fishing duration showed a moderate correlation with SST (r = -0.60), implying that longer durations occurred in cooler waters. Chlorophyll-*a* and salinity did not significantly correlate with fishing duration.

Regression Analysis. A regression analysis showed no significant impact of distance from estuaries on fishing frequency (R^2 = 0.195). This suggests that fishing activities are influenced by other factors beyond the proximity to river mouths.

3.2 Discussion

The results illustrate that oceanographic parameters like sea surface temperature (SST) and currents significantly impact the spatial and temporal distribution of Nike fish. These parameters are crucial for determining the locations where Nike fish are most likely to spawn and aggregate, influencing the success of fishing activities. SST's strong negative correlation with fishing location and duration indicates that Nike fish tend to prefer cooler waters. This aligns with previous research showing that temperature affects fish metabolism and behavior, particularly for species sensitive to environmental changes [20].

Salinity and Chlorophyll-*a*, however, had weaker correlations with fishing location and duration. This suggests that while these parameters play a role in the ecosystem, their impact on Nike fish distribution is less direct compared to SST and currents. The weak correlation with salinity might be attributed to the amphidromous nature of Nike fish, which are adapted to withstand variations in salinity due to their migratory patterns between freshwater and marine environments. Chlorophyll-*a* concentrations, which reflect the abundance of phytoplankton, provide an indication of primary productivity in the area. While essential for the marine food web, its influence on Nike fish frequency and duration capture seems indirect.

These findings emphasize the crucial role of satellite imagery in monitoring oceanographic parameters and understanding their effects on Nike fish populations. The ability to detect changes in SST, currents, salinity, and chlorophyll-*a* over large spatial and temporal scales provides a comprehensive view of the marine environment. The Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery plays a crucial role in monitoring oceanographic parameters such as sea surface temperature, chlorophyll-*a* [21], [22], currents [23], and salinity [24], [25], across large areas efficiently and cost-effectively. Researchers have actively used satellite images to evaluate seawater quality, including the analysis of Total Suspended Solids (TSS), Algae Bloom, and chlorophyll-*a*, providing an efficient alternative to traditional methods [26]. Additionally, satellite images have been applied in predicting potential pelagic fish catch zones, highlighting their versatility in marine and coastal studies [27]. In Teluk Tomini, our current study used MODIS satellite data to understand Nike fish behavior and distribution, revealing those variations in SST, currents, and chlorophyll-*a* significantly influence fishing locations and durations. This information is invaluable for creating sustainable Nike fish fishing practices in Teluk Tomini, ensuring that this vital resource is managed effectively for the long term. Moreover, the broader applicability of satellite imagery in monitoring and managing coastal resources effectively demonstrates its potential to support sustainability efforts in other regions as well [28], [29].

Furthermore, the analysis of satellite imagery data provides insights that complement traditional in-situ sampling, offering a broader understanding of ecological patterns. Fisheries managers can utilize these findings to design targeted conservation strategies that protect the spawning and nursery grounds of Nike fish while maintaining the livelihoods of local fishing communities. By understanding the specific oceanographic conditions that favor Nike fish aggregation, management practices can be adjusted seasonally and geographically to prevent overfishing and support ecosystem health.

Overall, integrating satellite imagery with statistical analyses enables a deeper understanding of the intricate relationship between oceanographic parameters and Nike fish behavior. It provides a scientific basis for developing adaptive management strategies that balance conservation with sustainable resource utilization, benefiting both the ecosystem and local economies.

4 Conclusion

This study shows that sea surface temperature (SST) and current, analyzed using Aqua MODIS and Global Ocean Physics Reanalysis data, are two oceanographic parameters that significantly affect the location and duration of Nike fishing in Tomini Bay, Gorontalo. Colder waters and slower currents are preferred conditions, while both parameter variations of salinity and chlorophyll-*a* show weaker correlations of Nike fishing duration and location. These findings underscore the value of satellite imagery for fisheries management, offering important insights for future optimal and sustainable fisheries management practices. By integrating satellite data with statistical analysis, this study provides a deeper understanding of how environmental factors shape the distribution of Nike fish, including its location and duration of fishing, which is ultimately expected to provide recommendations for effective and sustainable resource management in Tomini Bay.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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