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Augmented Reality-Enabled WEBGIS for Navigation and Decision Support of Potential Kawakawa (*Euthynnus affinis*) Fishing Grounds

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***Abstract*—** Indonesian fishers face challenges in locating potential fishing grounds due to the variability of chlorophyll-a and sea surface temperature (SST) influenced by climate change. This study aims to develop a WebGIS-based system integrated with Augmented Reality (AR) to support the identification and navigation of potential fishing zones for Euthynnus affinis. The study applies a quantitative approach using multi-temporal satellite data of chlorophyll-a and SST. Spatial analysis with overlay techniques is used to identify suitable fishing areas. The results are visualized in a WebGIS platform. An AR module with GPS-based markerless tracking is developed to provide real-time navigation, including distance, direction, and coordinates. The results show that the system can effectively identify and display potential fishing zones. The AR feature provides clear and interactive navigation for users in the field. This system improves fishing efficiency and supports sustainable fishing practices under dynamic ocean conditions.

Keywords— Augmented Reality (AR), Chlorophyll-a, *Euthynnus affinis*, fishing grounds, Remote sensing, Sea surface temperature (SST), Spatial analysis, WEBGIS.

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I. INTRODUCTION

Captures fisheries range from industrial-scale harvesting to small and recreational practices, capture fisheries contributing approximately 90 million metric tons of fish annually and playing a crucial role in sustaining global food security [1]. In this Global Context, Food and Agriculture Organization of the United Nations (FAO), reports that China, Indonesia, and Peru consistently rank among the world's leading fish-producing countries [2]. With their vast potential, capture fisheries are essential for providing daily protein and nutrients to communities while also supporting significant national economic development. However, because this sector is directly dependent on natural ecosystems, fishers often face various challenges in the field that can affect their total catch.

Fisheries ecological intelligence is essential for the effective management of fishery resources. Fishers possess extensive knowledge of natural resource dynamics, environmental variability, and the technical aspects of fishing operations [3]. Indonesia is an archipelagic country with approximately 70% of its territory consisting of marine waters [4], making fisheries an important sector for food security and livelihoods. However, Indonesian fishers face significant challenges in determining potential fishing zones for target species due to fluctuations in chlorophyll-a concentrations and sea surface temperature driven by the climate crisis. The Indonesian maritime environment, which consists of coastal ecosystems and small islands, is highly vulnerable to environmental changes caused by both natural and anthropogenic factors. Natural factors include climate change, coastal abrasion, and accretion, while anthropogenic factors include unsustainable resource utilization, land-use conversion, shipping traffic, and anchoring activities due to the absence of mooring buoys [5]. These factors contribute to dynamic water quality conditions, which in turn influence the distribution and availability of fish resources.

One of the most important and widely consumed fishery commodities in Indonesia is mackerel tuna due to its affordability and high nutritional value. Several species of mackerel tuna are found in Indonesian waters, including frigate tuna (*Auxis thazard),* bullet *tuna (Auxis rochei)*, longtail tuna *(Thunnus tonggol)*, and kawakawa *(Euthynnus affinis*), as well as other tuna species such as skipjack tuna [6]. The primary production area for kawakawa *(Euthynnus affinis)* in Indonesia is located in the waters of Banten Bay [7].

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Panjang Island is one of the parts of Banten Bay with the largest geographical area among the surrounding islands, located at coordinates 6.42167 to 6.47000° S and 106.36917 to 106.42667° E. However, despite its great potential, this island has experienced environmental degradation due to transportation activities and industrial waste disposal, which have impacted its ecosystems, including mangroves, seagrass beds, and coral reefs [8]. On the other hand, in terms of aquatic productivity, mangrove ecosystems contribute up to 80%, particularly for economically important fish commodities, due to the correlation between mangroves and the food chain as a nutrient source for fish [9]. Thus, the climate crisis driven by industrial activities can affect the stability of aquatic environments, both in terms of coastal ecosystems and the physical and chemical properties that serve as nutrient sources for fish.

Industrial activities in Cilegon City often cause environmental problems due to waste containing heavy metals such as cadmium (Cd) and copper (Cu), which flow from river estuaries into the sea. As a result, fish living in both freshwater and marine environments indirectly consume contaminated water. Therefore, this condition affects the quality of fish catches, causing them to fail to meet quality standards and making them unsafe for consumption [10]. Each fish species has a certain tolerance to environmental changes in its waters; however, polluted habitats make it difficult for fish to adapt. Dynamic and contaminated habitats can trigger biological stress in fish, which in turn affects the distribution of their habitats [11].

According to Collette & Nauen (1983), kawakawa *(Euthynnus affinis)* is a small tuna species that migrates and is distributed across tropical and subtropical waters, including coastal areas, within a temperature range of 18–29°C. This species is highly sensitive to environmental changes in its habitat. Through migration, kawakawa can survive by seeking waters that meet its tolerance limits, allowing it to adapt to dynamic marine conditions influenced by climate change [12].

However, this condition creates challenges for fishers, as fishing grounds tend to shift farther offshore. In Indonesia, particularly in Panjang Island, most fishers rely on traditional knowledge passed down through generations for navigation and fishing practices. As fishing grounds move further away, fuel consumption increases significantly, leading to higher operational costs and economic challenges for local fishers [13]. Moreover, fishers often rely on conventional estimation methods to locate fishing grounds, which makes it difficult to accurately identify areas with high catch potential [14]. Therefore, technological solutions are needed to assist fishers in efficiently locating potential fishing grounds.

Technologies such as Geographic Information Systems (GIS) can facilitate fisheries management and fishing activities. GIS is a software-based system widely used in various fisheries management operations and has been recommended by the Food and Agriculture Organization (FAO) [15]. In addition, GIS has been extensively applied in fisheries management across coastal regions worldwide [16]. For instance, in Taiwan, GIS-based analytical models have improved communication among stakeholders in the development of marine spatial planning maps [17].

Similarly, in Indonesia, GIS has been applied as a modeling tool in the maritime sector, particularly for supporting marine conservation and effective capture fisheries management. GIS plays a significant role in complex spatial analysis that supports decision-making processes, especially in resource management contexts. Moreover, this approach is considered cost-efficient, making it suitable for large-scale and long-term applications [25].

Thus, GIS is a valuable tool for supporting the prediction and planning of future marine resource utilization based on current spatial and environmental conditions.

In today's rapidly evolving technological era, Geographic Information Systems (GIS) are increasingly integrated with advanced visualization technologies such as Augmented Reality (AR). Traditional GIS outputs are typically presented in two-dimensional (2D) formats, which may limit spatial perception and reduce the intuitiveness of data interpretation. Consequently, users may experience challenges in understanding spatial relationships and deriving meaningful conclusions from map-based representations. Augmented Reality offers a potential solution by bridging the gap between 2D and 3D visualization through the enhancement of geospatial data representation. By overlaying GIS data onto the real-world environment, AR enables more intuitive, interactive, and immersive interpretation of spatial information [18].

Based on these challenges, an innovative WEBGIS system is required to support more efficient capture fisheries activities. This system is integrated with Augmented Reality (AR) as a navigation tool to guide fishers toward high-potential fishing grounds for *Euthynnus affinis.* The development of this system has the potential to directly improve fishers' productivity while supporting sustainable fisheries practices in Panjang Island. This study aims to develop a WEBGIS-based system capable of mapping potential kawakawa fishing grounds in an interactive and accurate manner. It is expected that this system will not only rovide economic benefits to coastal communities while also contributing to sustainable fisheries management in Indonesia.

II. METHOD

This study was conducted from September to October 2024 at the Computer Laboratory of Universitas Pendidikan Indonesia, with the study area located in Panjang Island, Banten.

The research employed a quantitative approach based on spatial data processing and system development. The methods used include oceanographic data analysis and the implementation of Augmented Reality (AR) technology on a WEBGIS platform to visualize potential fishing locations. The data used in this study were secondary data. Secondary data analysis is a cost-effective, accessible, and efficient method for utilizing existing datasets to address new research questions [19].

The type of data used consists of TERRA MODIS satellite imagery, which was accessed through the official website (https://modis.gsfc.nasa.gov/data).

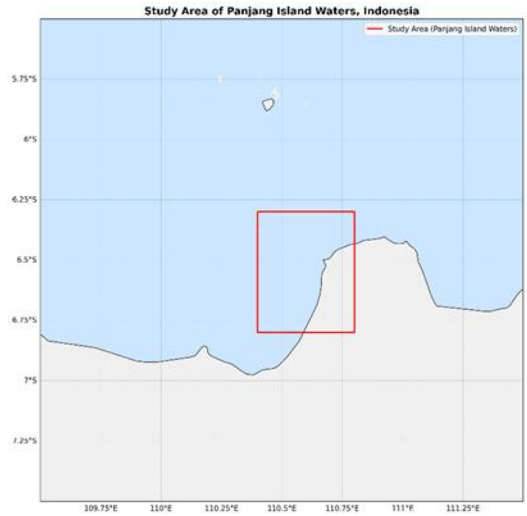

Figure. 1. Study Area of Panjang Island Waters.

B. Research Methodology

The research methodology consists of several stages, including data collection, data processing, analysis, and the development of an Augmented Reality-based WEBGIS using the waterfall model. The stages of the waterfall model are presented in **Figure 2**, while the system design is illustrated in **Figure 3.**

1) Analysis

At the analysis stage, the previously downloaded satellite imagery data were processed using the Python programming language in Google Colab, utilizing mapping libraries such as SciPy and NumPy. This process generated an oceanographic spatial classification corresponding to the habitat of *Euthynnus affinis*, where the optimal temperature range of 29.92–30.98°C and chlorophyll-a concentration of 0.99–1.13 mg/m³ are assumed to represent the highest potential fishing grounds [7].The results of this analysis serve as the basis for developing a web-based application, specifically a decision support system for identifying potential fishing grounds of *Euthynnus affinis.*

2) Design

At the design stage, the development of the user interface and user experience (UI/UX) was carried out to ensure that the system provides an optimal user experience. The UI/UX design of the website was developed using Figma, which was utilized to design the layout of the main features, including WEBGIS, navigation modules, and other supporting functionalities. The use of Figma enabled iterative prototyping and visual validation of interface components prior to system implementation, thereby improving design consistency and usability. In addition, the system design was modeled using a use case diagram **(Figure 2)**, which illustrates the relationship between actors and system activities.

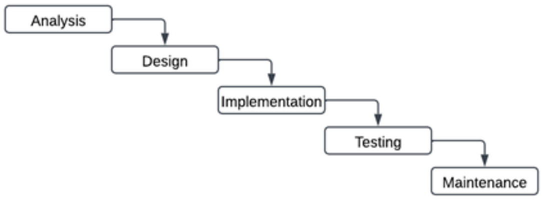

Figure 2. Waterfall Method

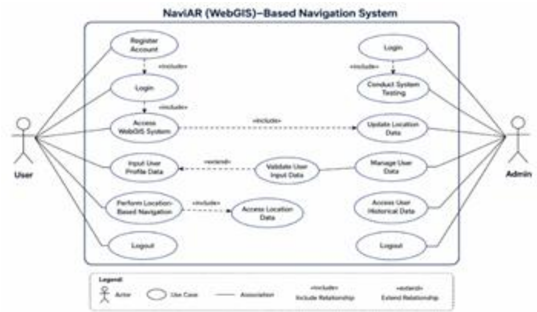

Figure 3. Use Case Diagram

The NaviAR system involves two primary actors, namely the admin and the user. However, the scope of this study focuses on user interactions, particularly in accessing and utilizing the Augmented Reality (AR) camera and WEBGIS features to obtain information on potential fishing ground locations.

3) Implementation, Testing, and Maintenance

In the developed scenario, the system is designed as a Decision Support System (DSS) to assist users in identifying optimal fishing ground locations based on processed oceanographic data. Users can access the website, input personal data through a registration form, and utilize navigation features based on WEBGIS and GPS-integrated Augmented Reality (AR), which are combined with spatial oceanographic datasets. This integration allows the system to deliver geospatial information in an interactive and user-oriented manner **(Figure 2).** The system was developed as a web-based application using Visual Studio Code with PHP as the programming language and PhpMyAdmin for database management. This architecture was chosen to support efficient data handling, system scalability, and ease of integration with geospatial and AR-based modules.

The implementation stage aimed to ensure that the decision support system can effectively process and integrate oceanographic data into an interactive and responsive application interface, enabling users to obtain spatially relevant fishing ground recommendations. In addition, the system design emphasizes real-time interaction and accessibility, which are important aspects in geospatial decision-support applications. To ensure that the system functions according to user requirements, testing was conducted using the Black-box Testing method, focusing on key functionalities such as homepage access, AR-based navigation features, and interactive map visualization in the WEBGIS module. Black-box Testing is effective in evaluating system functionality from the user perspective without requiring analysis of internal code structure, making it suitable for validating functional requirements in web-based applications [24].

III. RESULTS AND DISCUSSION

A. Spatial Analysis

Oceanographic parameters that can be used to predict potential fishing grounds include sea surface temperature (SST) and chlorophyll-a [20]. **Figure 4** shows the spatial distribution of SST and chlorophyll-a in the Panjang Island area.

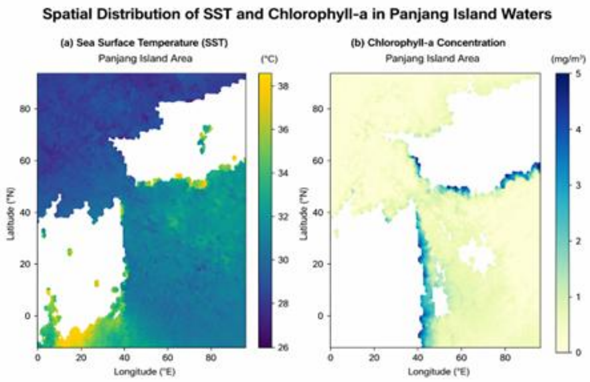

Figure 4. Spatial distribution of (a) sea surface temperature (SST, °C) and (b) chlorophyll-a concetration (mg/m3) in the waters Surrounding Panjang Island.

The SST distribution in Panjang Island waters (Figure 3, left panel) shows that the southern part of the study area (30–34 °C) partially falls within the optimal temperature range for *Euthynnus affinis* (29.92–30.98 °C), indicating favorable thermal conditions for habitat suitability. In contrast, the northern region (28–29 °C) lies slightly below the optimal range, suggesting less favorable conditions that may influence the spatial distribution and migration patterns of the species. Sea surface temperature (SST) is a key environmental parameter affecting *Euthynnus affinis*, as this species, classified as a small tuna, physiologically and behaviorally follows habitat preferences similar to other tuna species in response to oceanographic conditions [30].

Based on its topography, the waters surrounding Panjang Island are located in Banten Bay and form part of the Java Sea, which is characterized by complex oceanographic dynamics. Consequently, SST variability in this region is influenced by freshwater input from major rivers in Java as well as seasonal phenomena such as the monsoon [31]. Through the monsoon system, SST distribution is further affected by other oceanographic variables, particularly ocean currents. Seasonal variability plays a significant role in influencing oceanographic conditions and the distribution of potential fishing grounds. During the monsoon cycle, surface water movement is strongly affected by wind-driven circulation. In the western monsoon, water masses tend to flow from the northern regions through the Natuna Sea, Java Sea, and Flores Sea, whereas during the eastern monsoon, the flow reverses from the south [33].

Previous studies indicate that the contribution of ocean currents to temperature distribution is approximately 26.95%, suggesting that the majority of SST variability (>70%) is governed by other factors, especially monsoonal wind systems. These winds drive mechanisms such as Ekman transport and Ekman pumping, which in turn induce upwelling and downwelling processes [32]. Such processes play a crucial role in redistributing water masses and nutrients, thereby influencing marine environmental conditions and ecosystem productivity.

For chlorophyll-a, the distribution is primarily concentrated in coastal areas, with values ranging from 2–5 mg/m³. These relatively high concentrations indicate elevated primary productivity, likely driven by nutrient inputs from terrestrial sources and oceanographic processes such as upwelling. However, these values exceed the optimal range for *Euthynnus affinis,* which has been reported to be between 0.99–1.13 mg/m³ [7].

In addition, the optimal sea surface temperature for *Euthynnus affinis* ranges from 29.92–30.98 °C [7]. This indicates that although certain areas within the study region exhibit suitable thermal conditions, the elevated chlorophyll-a concentrations in coastal zones may reflect environmental conditions that are not entirely optimal for the species. Therefore, the identification of potential fishing grounds cannot rely on a single parameter, but rather requires the integration of multiple oceanographic variables, including temperature, primary productivity, and hydrodynamic processes.

Figure 5 presents the predicted distribution map of *Euthynnus affinis* generated based on the spatial distribution of SST and chlorophyll-a in the Panjang Island waters, Banten.

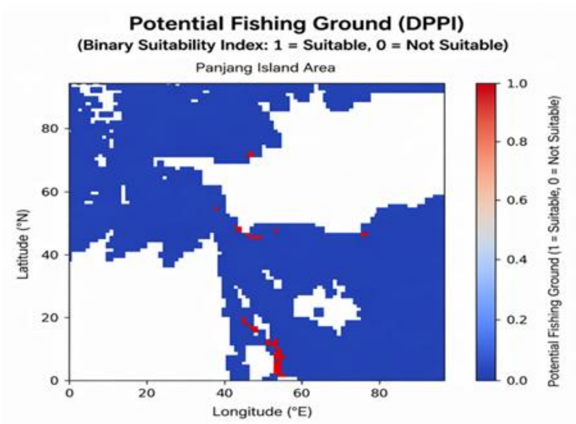

Figure 5. Spatial distribution of the Potential Fishing Ground (DPPI) in the waters surrounding Panjang Island. The Map represents a binary suitability index where 1 indicates suitable areas for fishing and 0 indicates not suitable areas, derived

The results indicate that the environmental conditions in the study area are suitable for the presence of *Euthynnus affinis*, particularly in the northern and southeastern waters of Panjang Island. These areas are identified as potential fishing grounds based on the spatial overlap of suitable oceanographic parameters. The spatial pattern shows that suitable fishing grounds are not uniformly distributed but tend to form localized clusters, especially along transitional areas between coastal and offshore waters. This suggests that *Euthynnus affinis* does not occupy the entire study area, but rather aggregates in specific zones where environmental conditions are optimal.

Furthermore, the concentration of suitable areas near coastal boundaries indicates the influence of nutrient-rich waters, which are commonly associated with higher biological productivity. These conditions may enhance prey availability, thereby attracting pelagic species such as *Euthynnus affinis*. However, the relatively limited spatial extent of suitable zones also implies that optimal habitat conditions are spatially constrained, reinforcing the importance of precise location-based identification for fishing activities.

These seasonal dynamics contribute to changes in the spatial distribution of pelagic fish, including *Euthynnus affinis*, which tend to migrate in response to environmental conditions that support their survival. Previous studies have shown that potential fishing grounds vary seasonally, with higher occurrences during the western monsoon due to the formation of thermal fronts and enhanced water mixing. Furthermore, the interaction between water masses of different temperatures can lead to the formation of thermal fronts, which are known to increase biological productivity and attract fish aggregation. In contrast, during transitional and eastern monsoon periods, weaker wind conditions reduce water mixing, limiting nutrient distribution and resulting in a more localized fish distribution near coastal areas [34].

In addition, the fragmented distribution of suitable areas suggests that environmental parameters such as SST and chlorophyll-a interact in a complex manner, resulting in heterogeneous habitat suitability. This highlights that the prediction of potential fishing grounds requires the integration of multiple oceanographic variables rather than relying on a single parameter. The predicted fishing ground map provides a basis for a decision-support system, which is integrated with a WEBGIS-based Augmented Reality platform developed in this study, referred to as NaviAR.

B. *System Implementation and System Testing*

The predicted potential fishing grounds for Euthynnus affinis, obtained from previous analyses, were subsequently used as the basis for determining geographic coordinates. These coordinates were then integrated into the NaviAR platform, a web-based information system combined with augmented reality (AR) technology to support the spatial visualization of potential fishing areas. Within the NaviAR website, users interact through a camera-based interface that captures real-time environmental images, which are then processed by the system to generate augmented reality outputs integrated with spatial data analysis for more interactive visualization.

The integration of WEBGIS and AR can enhance predictive analysis, particularly in image and spatial data processing, as it allows high-performance algorithms to operate efficiently while enabling the fusion of data from multiple system interfaces [23]. **Figure 6** shows the landing page interface of the NaviAR website, which serves as the main entry point for users to access the system.

Figure 6. NaviAR Landing Page

Figure 7. NaviAR Main Page

Through this interface, users can obtain information regarding predicted fishing grounds and visualize spatial data through the integrated WEBGIS and AR features. The integration of fishing grounds prediction with WEBGIS and augmented reality (AR) technologies enables a more interactive and intuitive visualization of spatial information. This system is expected to support decision-making processes for fishermen by providing accessible and spatially explicit information about potential fishing locations in the waters surrounding Panjang Island. This finding is consistent with previous studies highlighting the advantages of augmented reality in navigation, where AR enhances user guidance by presenting directional information directly within the user's field of view rather than relying solely on conventional two-dimensional maps [26]. In addition, AR has been reported to provide more persistent spatial visualization and higher positional accuracy in navigation systems [27]. Furthermore, AR visualization can improve navigation performance by reducing visual clutter while maintaining task efficiency [28].

As users scroll down the website, the main page (home) and its features are displayed, as illustrated in **Figure 7**. Through this page, users can access the main menus, including AR Camera, WEBGIS, and Contact, as well as general information about Panjang Island and *Euthynnus affinis.* When users access the AR camera feature, NaviAR displays the surrounding environment through the device camera and provides real-time geographic information, including latitude and longitude coordinates as well as the distance to the predicted fishing grounds.

A directional marker in the form of an arrow indicator is used to guide users toward the potential fishing location. This feature has been designed based on UI/UX principles to ensure user comfort and ease of use. This design approach is consistent with previous studies, which state that although augmented reality enhances navigation and spatial understanding, AR-based systems may reduce user attention to physical environmental cues, potentially raising safety concerns in maritime applications. Therefore, careful interface design is required to balance digital guidance and real-world situational awareness [29]. This feature aims to assist users in identifying their current coordinates as well as the coordinates of the potential fishing grounds for *Euthynnus affinis*, along with the estimated distance that must be traveled. The interface of this feature is shown in **Figures 8 and 9.**

Figure 8. NaviAR Camera Interface

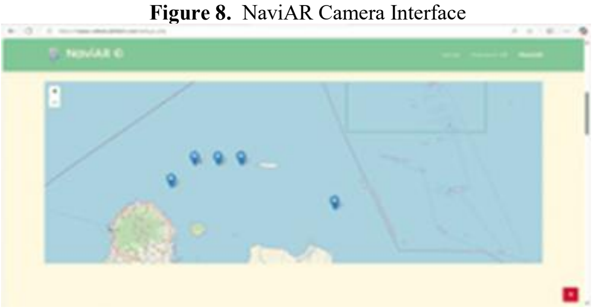

Figure 9. Potensial Fishing Grounds location feature (WEBGIS)

System maintenance and evaluation are necessary to ensure that all features operate properly. In this study, system testing was conducted using the Black-box testing approach, particularly for system functions that require user interaction, as well as the main features of the NaviAR website, including the Home page, AR Camera, and WEBGIS modules. One advantage of black-box testing is that the system can be evaluated without examining the internal program structure, making it suitable for testing complex platforms that integrate WEBGIS functionalities. Previous studies have also applied this method to evaluate the functionality of WEBGIS-based systems [22]. The complete testing procedure is presented in **Table 1.**

The testing results indicate that all main system features operated properly according to the predefined scenarios. Black-box testing yielded a 100% functional success rate, confirming that all functionalities performed as expected. These findings demonstrate that the NaviAR system operates effectively and can be utilized as a decision-support tool for identifying potential fishing grounds based on oceanographic data. Furthermore, the integration of WEBGIS and AR visualization enables users to access spatial fishing information in a more intuitive and interactive manner. The successful implementation of all tested functionalities also indicates that the system is technically reliable for delivering real-time geospatial information and navigation support. Such reliability is critical in spatial decision-support applications, where system responsiveness and functional consistency directly influence user trust and operational effectiveness. Moreover, the combination of interactive mapping and AR-based directional guidance may enhance user engagement and improve the practical accessibility of fishing grounds information in the field.

TABLE 1.
BLACK-BOX TESTING

ID	Use Case	Test Scenario	Input / Initial Condition	Test Procedure	Expected Result
1	Accessing the Website	The user opens the application URL	Browser with an active WiFi connection	Open the NaviAR URL using a web browser	The main page of the website is successfully displayed without errors
2	Filling User Data Form	The user enters their name and vessel name	Data input form is displayed	Fill in all required fields and click the submit button	The data is successfully stored and the user's name is displayed
3	Location Navigation	The user activates the AR Camera feature to display directional markers and distance to the fishing zone	Device GPS and camera are enabled	Click the “Activate Camera” button on the AR Camera page and point the camera toward the fishing zone marker	The camera displays the user's latitude and longitude coordinates and the distance to the fishing zone in real time

IV. CONCLUSION

The spatial analysis of oceanographic parameters, including sea surface temperature (SST) and chlorophyll-a concentrations, revealed areas in Panjang waters that are environmentally suitable for *Euthynnus affinis*. These predictions were derived from MODIS satellite imagery and processed using Google Colaboratory, enabling the identification of potential fishing grounds based on optimal thermal and productivity conditions for the target species. By integrating these predictions with Augmented Reality (AR) technology in the NaviAR system, users can not only visualize the spatial distribution of potential fishing grounds but also receive real-time guidance toward these locations. The system displays coordinates, distances, and directional markers, making the information interactive and actionable for decision-making in fisheries operations. This approach represents a novel integration of remote sensing, spatial analysis, and AR technology in the context of small-scale and coastal fisheries. It provides a data-driven, user-friendly tool that can enhance the efficiency and sustainability of fishing activities, supporting fishermen in identifying productive fishing locations while minimizing effort and environmental impact.

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