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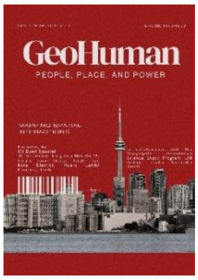

Mapping Fishing Locations Based on Fishermen's Local Ecological Knowledge in Kahyapu Village, Enggano Island

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ABSTRACT

Enggano Island is one of the outermost islands in Bengkulu Province and has high biodiversity. Kahyapu Village is one of the fisheries centers on Enggano Island. Mapping fishing locations is important because it documents and visualizes the local knowledge of fishermen through easy-to-understand maps. This study aimed to identify and map the fishing locations of Kahyapu Village fishermen based on their experience and local knowledge, using participatory mapping methods and Sea Surface Temperature (SST) and chlorophyll-a data as supporting data. Primary data were collected through a survey method, including direct interviews with fishermen and the use of participatory maps. Secondary data on oceanographic parameters, such as sea surface temperature and chlorophyll a, were obtained from the NASA OceanColor database using Aqua MODIS Level 3 satellite imagery. The results of this study show that, overall, the mapping indicates 15 Fishing Locations points visited by fishermen from Kahyapu Village, with Kiaba Bay, Tanjung Kuabi, Podipo, and Borneo being the most frequently visited locations. These 15 fishing locations are based on the experience and local knowledge of the fishermen of Kahyapu village in carrying out fishing activities, especially for coral fish species with gill net fishing gear that the fishermen of Kahyapu village often use, and relatively carry out fishing on the edge, not far from land due to considerations of operational equipment, safety, and inherited fishing habits.

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Introduction

Enggano Island is one of the outermost islands in Bengkulu Province and has high marine biodiversity. Administratively, the island is part of North Bengkulu Regency, where the main comparative advantage of the region is the capture fishery sector. Kahyapu Village, one of the six villages in the Enggano District, has been identified as a key fisheries center. Cahyadinata et al., (2019) found that 20.89 percent of 881 households on Enggano Island were involved in the capture fisheries subsector. Most of the Kahyapu Village population depends on fishing for their livelihood, and it is the focus of marine-based economic development in the border region.

However, the potential of Kahyapu Village has not been optimally and sustainably utilized in terms of fishery resources. The biggest challenge for local fishermen is the absence of reliable information on fishing locations. Fishing location knowledge is oral and passed on from generation to generation, leading to inefficiency in fishing operations in terms of time and operational costs (fuel). Fishing activities are often speculative in the absence of spatial documentation and can hinder the efficiency of fishery production in the area. The situation in Kahyapu is a common case in other small-scale fisheries in Indonesia, which holds great potential but is inefficiently utilized, as fishermen only use oral knowledge without maps or written spatial data (Imamshadiqin et al., 2025; Paulangan et al., 2020).

To overcome these barriers, the establishment of a geographic information system (GIS) through participatory mapping methods is required. In this approach, the fishermen of Kahyapu Village were the main subjects in data collection to document and visualize their local knowledge in the form of digital maps. In addition to participatory data, the integration of oceanographic parameters through the analysis of Aqua MODIS satellite imagery is also important, especially Sea Surface Temperature (SST) and chlorophyll-a concentration (Yusrizal et al., 2023). These two parameters are important indicators for determining primary water productivity and the presence of fish stocks (feeding locations) (Purwanto et al., 2021).

Previous studies have mapped fishing locations using either participatory methods, such as interviews and Focus Group Discussions (James, 2025; Kockel et al., 2020; Paulangan et al., 2020) or satellite imagery data (SST and chlorophyll) (Li et al., 2024; Putri et al., 2021), the latter relying on secondary data without incorporating local knowledge. This study aims to bridge this gap by linking participatory mapping results from the community with marine environmental conditions derived from satellite imagery data. This study builds upon previous studies that have demonstrated the effectiveness of participatory mapping for the spatial analysis of small-scale fisheries, particularly in data-poor contexts (Damastuti & de Groot, 2019; Grati et al., 2022; Silvano & Hallwass, 2020). This aligns with the characteristics of Kahyapu Village on Enggano Island, which is situated in the outermost small island region, where local fishers engage in fishing activities.

Therefore, this study aimed to explore the potential of fishery resources and optimize GIS technology for local fishermen. This study is expected to contribute to the practical application of fisheries geography, specifically through participatory mapping, within the local context of an outermost small island. Furthermore, it aims to advance applied GIS science by conducting a spatial analysis of marine environmental conditions (Sea Surface Temperature and chlorophyll) based on local fishing ground locations identified by fishers from Kahyapu Village.

Methodology

This study applies a spatial descriptive approach with a participatory mapping method of fishermen integrated with a Geographic Information System (GIS). Participatory mapping was used to identify and map fishing locations based on the experience and knowledge of fishermen in Kahyapu Village. This method uses the local ecological knowledge of fishermen to fill the gap in DPI spatial data and then transforms it into a digital map that can be analyzed (Borges et al., 2021; Kitolelei et al., 2022). Data collection was divided into primary and secondary data.

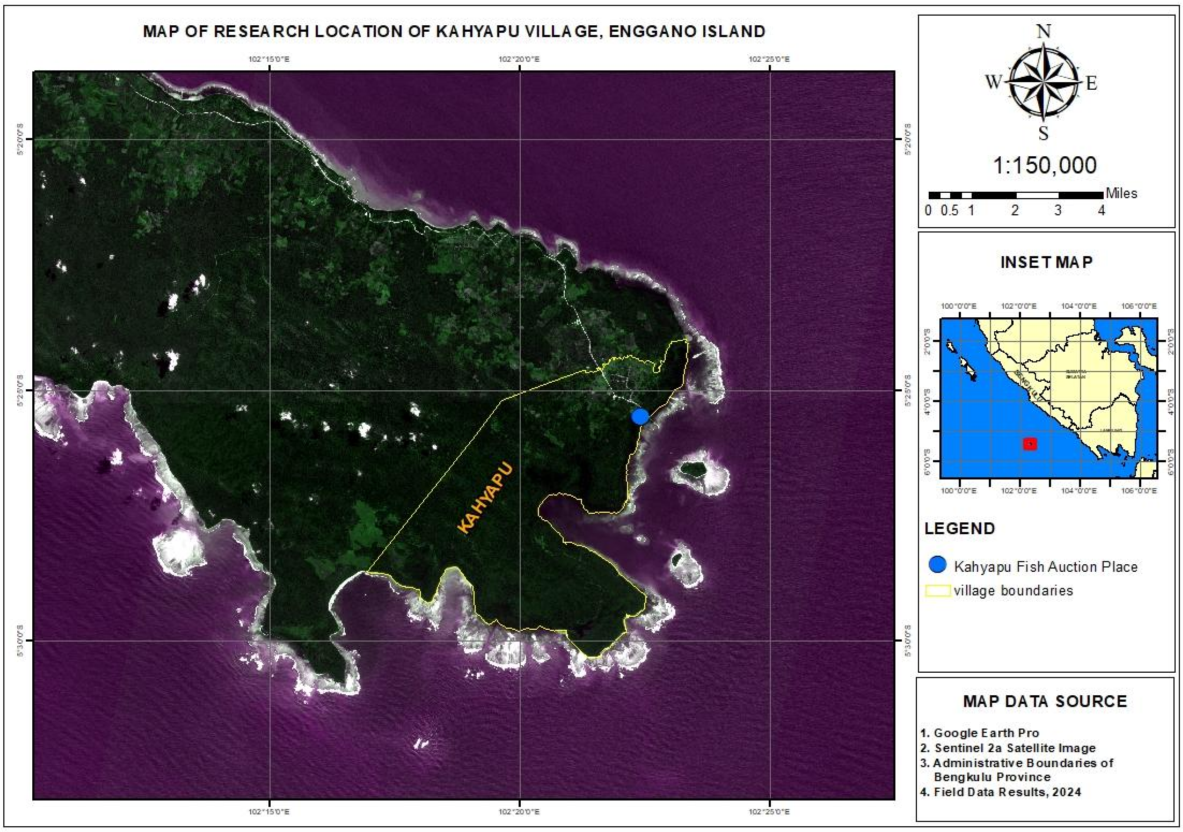

Figure1. Research Location Map

Primary data were collected through surveys by conducting direct interviews with 15 local fishermen using structured questionnaires to obtain comprehensive information regarding their fishing activities in the Kahyapu Village. The respondents were selected using a snowball sampling method, initiated through key informants from the local fishing community, and continued until data saturation was reached. The selection criteria strictly required respondents to be active fishermen residing and operating in the Kahyapu Village. During the interviews, demographic and operational profiles were recorded, including age, fishing experience, and type of fishing gear utilized. These characteristics are further detailed in the Results and Discussion section as part of the fisherman profile description.

In addition to the questionnaire, a participatory mapping approach was employed to accurately delineate and capture spatial information on the fishing locations utilized by the fishermen in Kahyapu Village. The mapping process was conducted during direct interviews using printed maps of the coastal and marine areas of Kahyapu Village and its vicinity. Fishermen were first provided with a general geographical context before being asked to identify, mark, and assign local names to their specific fishing locations. Discrepancies in the identified locations among fishermen were carefully recorded and cross-referenced, which primarily emerged due to seasonal variations and changing weather patterns that dictated fishing behavior. Mapped locations were validated using a triangulation technique; if multiple independent fishermen independently indicated identical or highly overlapping fishing zones, the location was considered validated.

Observations were subsequently conducted by directly visiting or following the fishing locations visited by fishermen to record coordinate points using GPS in multiple locations and to measure water quality at multiple fishing locations. Aqua MODIS Level 3 products were used to acquire secondary oceanographic data, including chlorophyll-a and sea surface temperature (SST), from the NASA database. The spatial resolution of these data was 4 km, and the temporal resolution was monthly. To precisely correspond with the timeframe of the primary field data collection, satellite imagery was concentrated in December 2024. This period corresponds to the west monsoon season, which is typically distinguished by the region's distinctive oceanographic shifts and abundance of rainfall. Spatial examination was performed using ArcGIS software. The vector data of fishing sites, acquired through fishermen's participatory mapping, were combined with raster oceanographic layers (SST and chlorophyll-a) via a spatial overlay analysis. Raster cell values were specifically extracted at the relevant coordinate points to elucidate the environmental conditions of the waters at the fishing locations of Kahyapu Village. This approach is in line with many studies that relate fish distribution with a combination of SST and chlorophyll-a to describe environmental conditions at fishing locations (Muskananfola et al., 2021; Widodo et al., 2025).

Result and Discussion

Result

Kahyapu Village is located in the southern part of Enggano Island, and most of its residents work as fishermen, and it is the biggest producer of biological resources on the island. The researchers observed that Kahyapu Village has a Fish Auction Place and a fishing boat landing area (as shown in Figure 2); therefore, fishing activities are the backbone of the local economy.

Figure 2. Kahyapu Fish Auction Place

Kahyapu Village fishermen have a unique system of mutual assistance based on their customs and culture. If a resident or fisherman from Kahyapu Village or Enggano Island wants to build a boat, they help each other. The Enggano have a system of mutual help among members of the same tribe, handed down from ancestors and from generation to generation, regardless of religion. This is called "paho'ahai," a special way of helping each other with a member of the tribe's work. If a member of the tribe needs help with a job, they will call up a few people for help. The number required is determined by the size of the job. For example, you need a boat and a large workforce of 20-30 people to build it. Residents cannot simply rely on their relatives (kaudara) but need help from the maoa (tribal settlement area).

Kahyapu Village fishermen primarily require boats to expand their operational capacity. The fishermen of Kahyapu Village use a wooden outboard motor boat (PMT) with a power of 5-8 HP. The average size of the fishing boat on Enggano Island is 9 m long, 2 m wide, and 1 m high, so it has a Gross Tonnage (GT) of 4-5 GT. Apriliani et al., (2020) said that the type and size of the boat/ship greatly affect the fishing process and fish catch. The Gross Tonnage (GT) on a big boat will also produce a big catch. The shape of the boat/ship used by the fishermen in Kahyapu Village is shown in Figure 3.

Figure 3. Fishing Boats of Kahyapu Village

Studies and interviews indicate that the fishermen still use simple fishing gear and operate close to the shore or in shallow waters. Gill nets are the most commonly used fishing gear by fishermen for reef fish. Research and interviews with fishermen in Kahyapu Village showed that the nets were set up horizontally along the ocean current around the shallow waters to create a U-shape in the shallow waters of the fishing area. The nets were then left for half an hour until the fish became entrapped in the mesh. Apart from gill nets, fishermen in Kahyapu Village also use long lines and fishing rods.

Table 1. Types of Fish Caught by Fishermen in Kahyapu Village, Enggano Island

No	Fishing Gear	Types of Fish Caught		
		Local Name	**Indonesian name**	**Latin name**
1	2 inch Gill Net	Pinang-Pinang	Pinang-pinang	*Upeneus sp.*
		Kape-Kape	Kape-Kape	*Pentaprion sp.*
		Kerong-Kerong	Kepala Batu	*Johnius sp.*
		Nawi	Kakap Merah	*Lutjanus sp.*
		Gebur	Kuwe	*Caranx sp.*
		Jompol	Belanak	*Crenimugil sp.*
		Cabe-Cabe	Baronang	*Siganus sp.*
		Kotak-Kotak	Kotak	*Ostracion sp.*
		Jabung	Ayam-Ayam	*Abalistes sp.*
		Todak	Todak	*Tylosurus sp.*
		Layur	Beledang	*Trichiurus sp.*
		Maco	Pepetek	*Leiognathus sp.*
		Gabus Laut	Gabus Laut	*Saurida sp.*
		Senangin	Senangin	*Eleutheronema sp.*
		Gembolo	Kembung	*Rastrelliger sp.*
2	2 inch Gill Net	Tamban	Tembang	*Sardinella sp.*
3	Gillnet Millennium 4-inch	Tenggiri Batang	Tenggiri Batang	*Scomberomorus sp.*
4	Fishing rod	Kerapu	Kerapu	*Epinephelus sp.*
		Jenihin	Kakap muara	*Lutjanus sp.*

Research and interviews with fishermen in Kahyapu Village revealed 19 types of fish caught by fishermen in Kahyapu Village, as shown in Table 1. Fishermen in Kahyapu Village catch several types of fish. The most common types are reef fish (fish that live near coral) in shallow waters. The diversity of this type of catch shows that the Enggano Waters, especially the shallow waters, still have good fishery productivity. According to the fishermen, the types of fish, mostly caught, are Jompol fish (*Crenimugil sp.*), Pinang-Pinang fish (*Upeneus sp.*), Nawi fish (*Lutjanus sp.*), jenihin fish (*Lutjanus johni*) and Baronang fish (*Siganus sp.*) The results of the participation of fishermen in Kahyapu Village also found that there were no specific differences in the types of fish caught between fishing locations. However, some fishing locations, such as those in Kiaba Bay and Harapan Bay, are not in other fishing locations, such as Layur, Maco, Senangin, Gabus Laut, and Gembolo. Fishermen say that these fish can only be found in the muddy fishing locations of the bays. The fishermen of Kahyapu Village usually take all the fish caught in their nets to sell without sorting them by type or price. This is because many of the fish caught in the nets are already weak or dead after being in the nets for so long. However, fishermen will throw fish back when they are still young enough to grow and are still alive when taken out of the nets.

Table 2. Fishing locations of Kahyapu Village fishermen, Enggano Island

No	Region Name	Distance (km)	Longitude	Latitude
1	Pulau Dua	2.20	102°23'10.72"T	5°26'26.98"S
2	Sawang Bengkok	4.83	102°23'23.80"T	5°23'58.02"S
3	Teluk Harapan	4.99	102°21'38.84"T	5°27'36.21"S
4	Pulau Merbau	6.08	102°23'6.71"T	5°28'22.18"S
5	Sawang Pari	8.12	102°22'5.22"T	5°22'51.85"S
6	Tanjung Kuabi	8.87	102°22'31.58"T	5°29'11.79"S
7	Borneo	9.90	102°22'19.48"T	5°29'40.07"S
8	Podipo	11.52	102°21'41.62"T	5°30'16.52"S
9	Kemiu	13.54	102°20'52.13"T	5°29'52.08"S
10	Teluk Kiaba	13.99	102°20'37.36"T	5°29'51.58"S
11	Tanjung Labuho	23.75	102°16'16.25"T	5°29'56.32"S
12	Merpas	25.99	102°16'32.60"T	5°29'1.38"S
13	Batu Layar	29.11	102°15'57.97"T	5°30'59.98"S
14	Pulau Satu	37.66	102°13'14.82"T	5°28'13.32"S
15	Sawang Bugis	45.72	102°10'50.78"T	5°25'3.22"S

The results of the participatory mapping of fishermen in Kahyapu Village show that there are 15 fishing locations visited by fishermen in Kahyapu Village around the waters of Enggano Island. The fifteen locations are Sawang Pari, Sawang Bengkok, Pulau Dua, Teluk Harapan, Pulau Merbau, Tanjung Kuabi, Borneo, Podipo, Kemiu, Teluk Kiaba, Merpas, Tanjung Labuho, Batu Layar, Pulau Satu and Sawang Bugis. These locations were scattered from east to west in the waters of Enggano Island. The results of participatory mapping of Kahyapu Village fishermen also found that the fishing locations of Kahyapu Village fishermen are in relatively shallow coastal waters with a coral and sandy substrate base and an average depth of 1-2 meters.

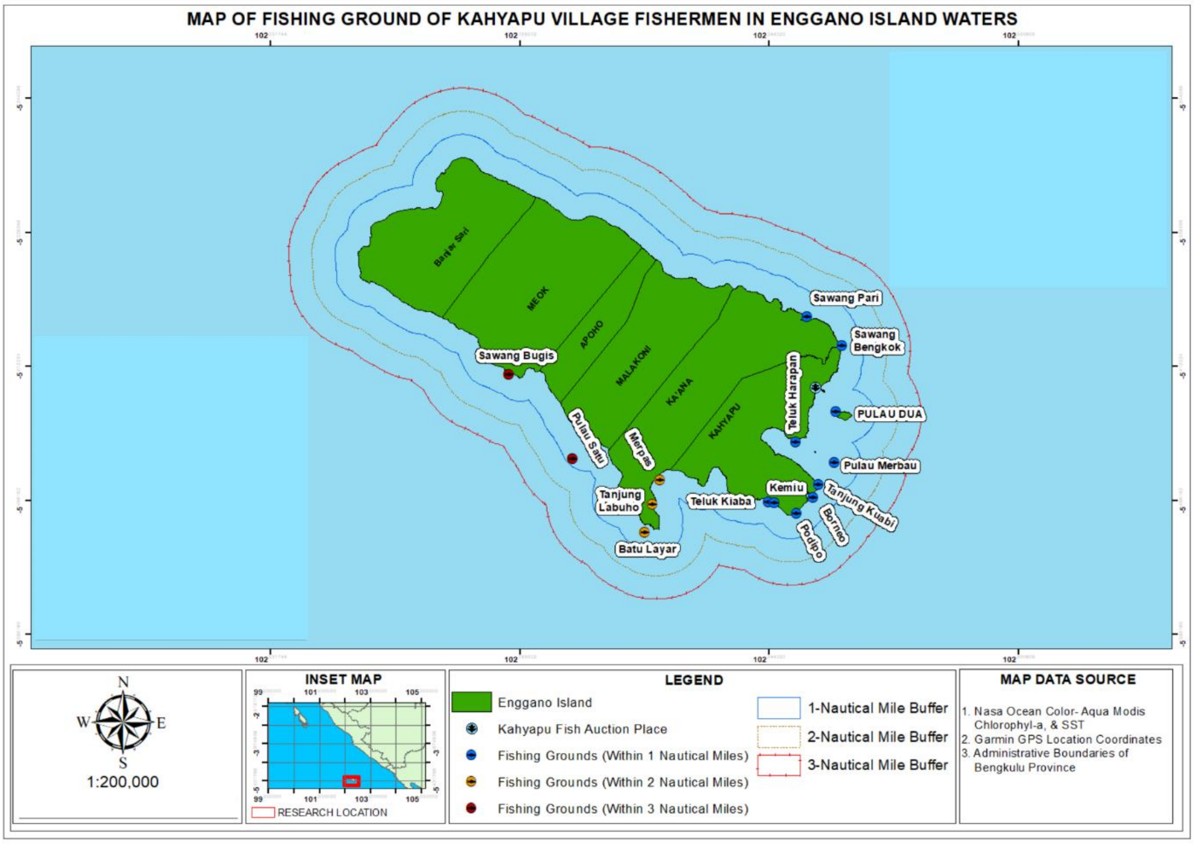

Figure 4. Map of Fishing locations for Fishermen in Kahyapu Village

The results of participatory mapping indicate that the fishing ground of the fishermen of Kahyapu Village is more likely to be found around the coast and not in the open waters, with a distance of 1-2 miles from the mainland with relatively shallow depths and rocky waters. This condition supports the presence of reef fish, including demersal fish, the main target of Kahyapu Village fishermen. This is because the boat size is small, and the fishing equipment is still simple. Moreover, it also shows that the selection of fishing locations by fishermen from Kahyapu Village is inseparable from the suitability of habitat conditions for the types of fish that are usually caught. In addition, the fishing activities of the fishermen of Kahyapu Village in the waters of Enggano Island did not show a significant change in fishing patterns over time, both from month to month and year to year. The main reasons that fishermen do not move to more distant fishing locations, even though the potential in other locations may be greater, are experience, safety factors, fuel efficiency, and traditional habits. Kahyapu Village fishermen tend to fish spread out in the south-west of Enggano Island waters.

The results of the interviews and participation showed that the visit level of all fishing locations is not the same, with some fishing locations of Kiaba Bay, Tanjung Kuabi, Podipo, and Borneo are often visited by fishermen from Kahyapu Village. Based on the information of the fishermen of Kahyapu Village, these four places were selected because the distance is relatively close, the water conditions are quite suitable, and according to them, they prefer fishing locations that are known based on experience, and in being consistent in the area that already has results, even if the results are small or moderate. Fishermen from Kahyapu Village rarely go to far places such as Pulau Satu and Sawang Bugis because the journey takes a long time and the operating costs are high.

The results of the spatial processing of sea surface temperatures at fishing locations in Kahyapu Village, Enggano waters, in December, showed relatively homogeneous temperature conditions, ranging from 28 to 31°C. All fishing locations were similar, with no extreme temperatures in the water. Kahyapu Village fishermen target reef fish that live at the bottom, but stable sea surface temperatures are important for maintaining a comfortable fish habitat and aquatic biological activity. Thus, the fishing locations in the Enggano waters of Kahyapu Village are still at a temperature suitable for reef fish to thrive.

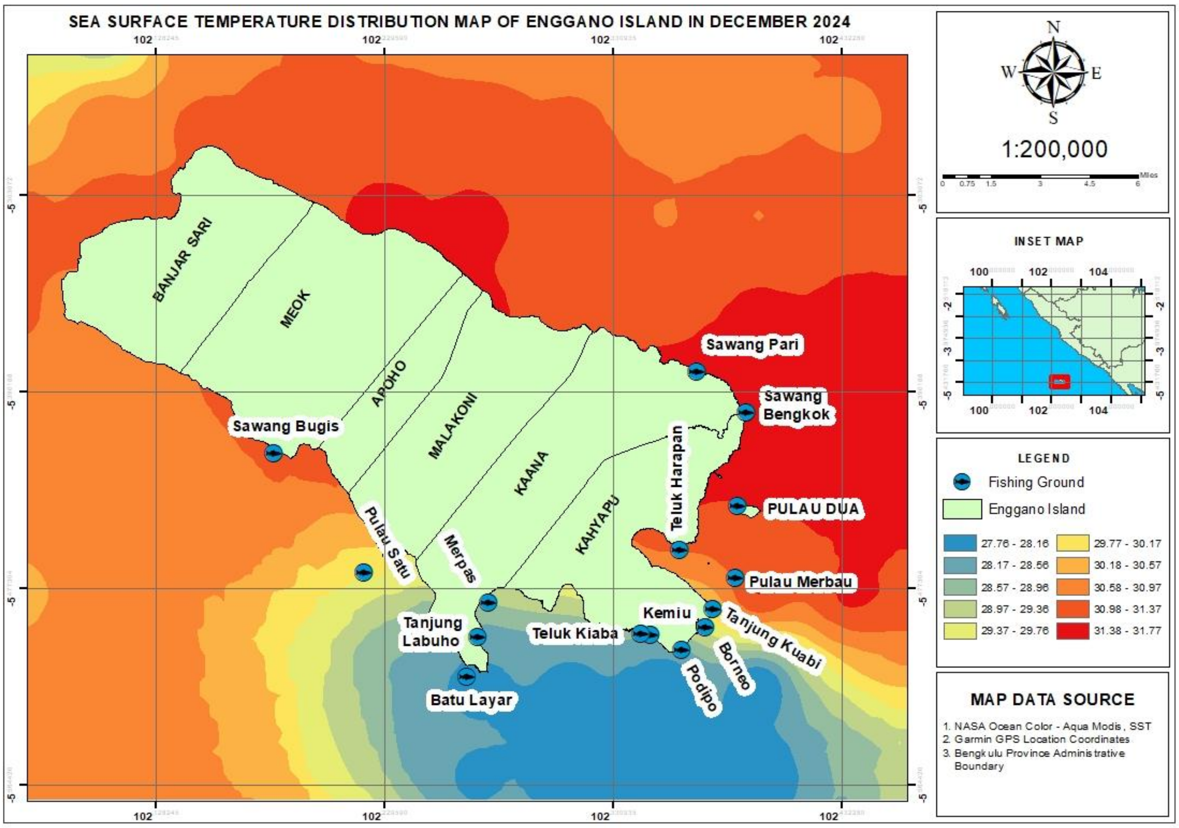

Figure 5. Sea Surface Temperature Map on Enggano Island December 2024

The results of the spatial processing of the distribution map of chlorophyll-a in the fishing locations of Kahyapu Village fishermen in December had a value between 0.13-0.17 mg/m3, indicating that the variation in water productivity levels was relatively moderate. The spatial processing from this range of chlorophyll-a is in accordance with the characteristics of Enggano Island, which is in the open sea waters facing directly to the Indian Ocean. This spatial processing illustrates and supports the results of participatory mapping of the statements of Kahyapu Village fishermen that some fishing locations that are often visited by Kahyapu Village fishermen, such as Kiaba Bay, Tanjung Kuabi, Podipo, and Borneo, have relatively higher chlorophyll-a values than some other DPIs. This shows that the fishing locations used by the Kahyapu Village fishermen are in relatively productive waters that support the existence of small organisms, which are food sources for reef fish, which are the target catch of the Kahyapu Village fishermen.

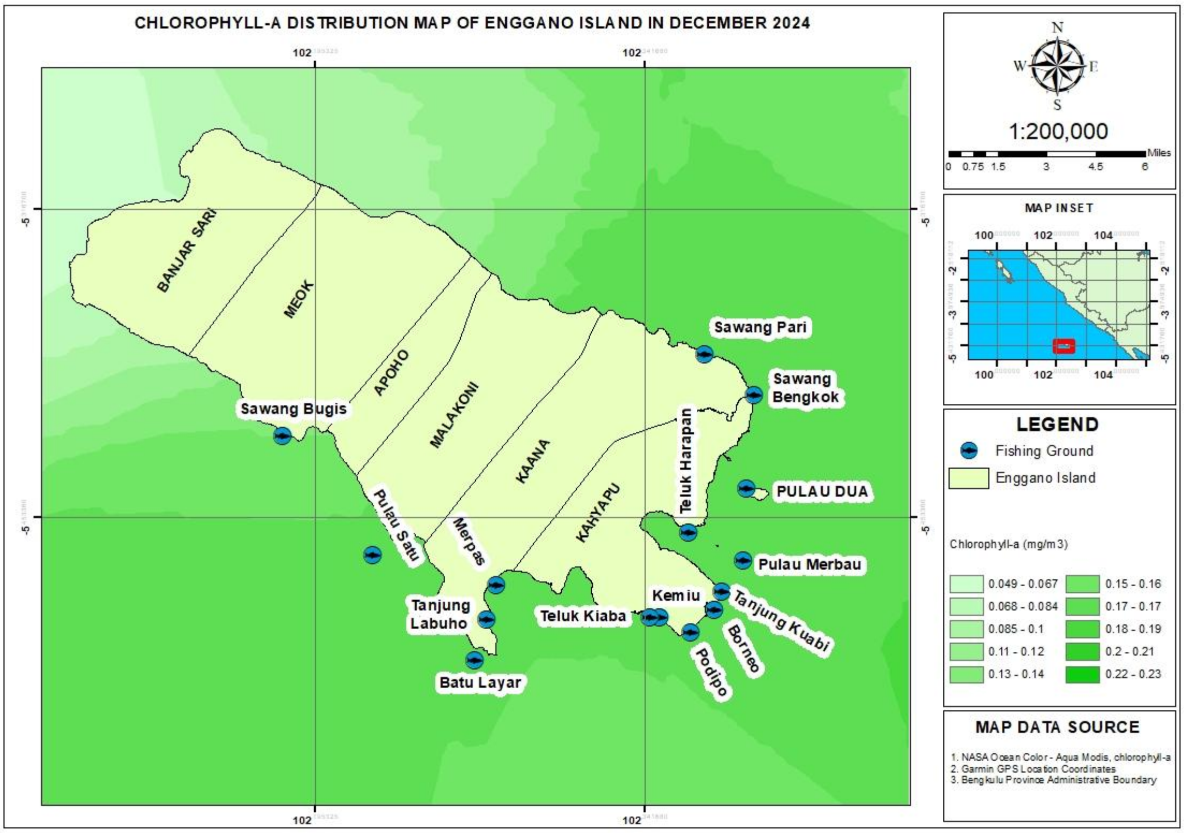

Figure 6. Chlorphyll-A distribution Map on Enggano Island December 2024

Food availability in water affects fish abundance. Fish are found at high and medium trophic levels in the environment. Fish depend on biomass at lower trophic levels, such as phytoplankton. Chlorophyll-a, which provides acidic chemicals for fish and primary producers in aquatic ecosystems, is concentrated in phytoplankton. After being eaten by zooplankton, this phytoplankton is then used as food by small fish and eventually by demersal fish (either directly or by detritus that sinks to the bottom). Therefore, rather than serving as a determinant of the fishing locations of Kahyapu Village fishermen, the chlorophyll-a parameter map enhances the findings of the participatory mapping of Kahyapu Village fishermen in explaining the state of water productivity at the fishing locations.

Discussion

The main factors for the limited operational area of fishermen in Kahyapu Village are limited fleet facilities and fishing technology. The characteristics of fisheries in this area are still small-scale (small-scale fisheries) (Lisna et al., 2022), as indicated by the employment of wooden outboard motor boats (PMT) with a size of 4-5 GT with gill nets operated horizontally in a U-shape. In theory, the gross capacity (GT) of a fleet of vessels is highly positively correlated with the cruising range, operating efficiency, and overall catch volume (Rousseau et al., 2024). Owing to the small size of the boats, fishermen prefer to fish in places close to the coast to reduce safety risks at sea and operational costs, notably fuel oil (Basurto et al., 2024). This phenomenon of fishermen's perseverance in traditional shipping methods and routes is widespread in outer island fishing villages, whose space for mobility is heavily controlled by elements of geographical proximity and limited capital (Matich et al., 2025).

The state of fishing locations in shallow coastal seas (1-2 m deep) with coral and sand substrates directly affects the community structure of the caught biota. The presence of 19 species of fish, mostly dominated by reef fish groups such as *Crenimugil sp., Upeneus sp., Lutjanus sp.,* and *Siganus sp.,* indicates that the fishing locations of Kahyapu fishermen are directly adjacent to the coral reef ecosystem, which serves as a feeding ground and spawning ground for these fish (Fahmi et al., 2018). The commonality of fish species obtained at the 15 observation stations also supports the presence of ecological connectedness and dispersion in the same environment along the shallow waters of Enggano Island. Consistent fishing patterns over time and the lack of substantial year-on-year variations reflect the fishermen's adaptation to the seasonal behavior of reef fish and their strong connection to local wisdom in sustaining their traditional fishing sites (Selgrath et al., 2018).

Oceanographic data show that the seas surrounding Enggano Island in December have very good environmental conditions for the survival of reef fish, although primary productivity is limited. The sea surface temperature range of 28-31 °C is homogeneous and within the optimal range for coral growth and tropical fish metabolism, although the highest limit (30-31 °C) is extremely close to the coral heat stress threshold and can produce bleaching if maintained for a long time (Goreau & Hayes, 2024). In contrast, chlorophyll-a concentrations of 0.13–0.17 mg/m^3 reflect the typical features of open oceanic waters directly near the Indian Ocean, where the input of nutrients from land is comparatively low (Paul et al., 2024). The chlorophyll-a content was moderate, but fishery productivity in the shallow seas of Kahyapu was well maintained. This is because the energy and nutrients are predominantly supplied by primary productivity from benthic ecosystems, such as seagrass and coralline algae (Ariasari et al., 2024).

Methodologically, the participatory mapping method adopted in this project was successful in rebuilding 15 primary fishing sites based on the empirical track records and preferences of the fishermen in Kahyapu Village. However, this fishing distribution map is still unable to describe the temporal dynamics of changes in fishing locations because it is descriptive in nature, particularly the fluctuations between western and eastern seasons that often change the migration patterns of marine biota (Olmos et al., 2023). The complexity of dynamic oceanographic factors highlights that the results of this mapping should be interpreted prudently as a spatial representation based on the local experiences of fishermen and not to determine the level of sustainable stock potential or quantitatively model the habitat suitability index for fisheries.

The 15 traditional fishing locations that Kahyapu fishers persistently visit are indicative of a calculated behavioral mechanism influenced by risk perception and structured spatial choices (Sultan, 2020). The decision to restrict their fishing mobility to shallow waters (1–2 m deep) with coral and sandy substrates is a highly rational strategy to mitigate maritime safety risks and optimize fuel costs, given the technical limitations of their 4–5 GT wooden outboard motorboats. The continuous navigation across specific tracks, which span from Sawang Pari in the east to Sawang Bugis in the west, demonstrates how Local Ecological Knowledge (LEK) dictates searching efficiency from the perspective of fisheries geography. Fishers utilize a shared mental map developed over generations of empirical observations rather than moving randomly. This map enables the anticipation of the homogeneous distribution of target reef fish groups (including *Crenimugil sp.* and *Lutjanus sp.*) across the shallow shelf of Enggano Island.

Furthermore, the precise spatial differentiation, as reported by fishers, that certain muddy bay habitats, such as Kiaba Bay and Harapan Bay, contain specific species not found in open reef stations, such as Layur (*Trichiurus sp.*) or Maco (*Leiognathus sp.),* highlights the high resolution of community-based ecological mapping (Lahellec et al., 2025). This level of detail verifies LEK's ability to identify micro-habitats with precision that complements macro-scale oceanographic data. Finally, the behavioral contradiction of capturing all weakened net-caught fish to avoid economic waste while purposely releasing live youngsters back into the sea is an informal socioecological ethic (Gómez, 2022). This practice demonstrates that their spatial activity is not only extractive but is embedded within a human-environment interaction, where local wisdom is the basis for immediate economic survival and the long-term resilience of their ancestral fishing ground.

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Competing Interests

The author(s) declare (s) no conflict of interest.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to ethics related to protecting the privacy and confidentiality of research participants but are available from the corresponding author upon reasonable request.

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