JIPK. Volume 17 No 1 February 2025
Sinta 1 (Decree No: 158/E/KPT/2021)

e-ISSN:2528-0759; p-ISSN:2085-5842
Available online at https://e-journal.unair.ac.id/JIPK

JIPK
(JURNAL ILMIAH PERIKANAN DAN KELAUTAN)
Scientific Journal of Fisheries and Marine

Check for updates

Research Article

Chlorophyll-a and Sea Surface Temperature Analysis Based on Shark Fishing Ground Landed at the Fish Landing Base of Ujong Baroh, West Aceh

Afdhal Fuadi*, **Muhammad Rizal**, **and Dimas Kusumayadi**

Department of Fisheries, Faculty of Fisheries and Marine Sciences, University of Teuku Umar, Meulaboh, West Aceh, 23681. Indonesia

ARTICLE INFO
Received: March 06, 2024
Accepted: May 25, 2024
Published: June 01, 2024
Available online: Feb 11, 2025

*) Corresponding author:
E-mail: afdhalfuadi@utu.ac.id

Keywords:
Fishing Ground
Shark
Chlorophyll-a
Sea Surface Temperature

Abstract

Sharks are top-tier water predators that can maintain marine ecology balance and control the food web. As sharks are at the top of the food chain, their overfishing can disrupt the ecosystem chain. The distribution and abundance of fish in waters can be influenced by several factors of oceanographic parameters, including chlorophyll-a and sea surface temperature (SST). The use of satellite imagery for analyzing chlorophyll-a and SST parameters provides significant results in fisheries oceanographic studies. This study aimed to determine the effect of chlorophyll-a and SST parameters on shark catches. The method in this study was divided into 2 stages, namely taking shark fishing area coordinate data and downloading chlorophyll-a as well as SST satellite image data on the NASA Aqua-MODIS website. The results of the of the analysis of chlorophyll-a distribution in the eastern season ranged from 0.08 to 1.23 mg/m3 with an average value of 0.17 mg/m3, where the highest was 1.23 mg/m3 in September and the lowest was 0.08 mg/m3 in August. The SST distribution ranged from 27.65 to 30.29oC with an average of 28.65oC, the highest was 30.29oC in August and the lowest was 27.65oC in September. Based on the results of linear regression analysis, the highest shark catch was influenced by chlorophyll-a, namely *Loxodon macrorhinus* shark, by 72.82%, the highest shark catch type was influenced by SPL, namely *Alopias pelagicus* shark, by 83.12%, and the rest was influenced by other parameters.

Cite this as: Fuadi, A., Rizal, M., & Kusumayadi, D. (2025). Chlorophyll-a and Sea Surface Temperature Analysis Based on Shark Fishing Ground Landed at Fish Landing Base of Ujong Baroh, West Aceh. *Jurnal Ilmiah Perikanan dan Kelautan*, 17(1):152–166. https://doi.org/10.20473/jipk.v17i1.55791

1. Introduction

Aceh is a province located on the western tip of Indonesia or on the tip of Sumatra Island, which is included in the fisheries management area waters (FMA-RI) of 571 of the Malacca Strait and 572 waters of the Indian Ocean (Fuadi *et al*., 2022, 2024). According to Fuadi *et al*. (2018) and (2021), Aceh Province is located at the coordinates of 01°58'37.2"-06°04'33.6" North Latitude and 94°57'57.6"-98°17'13.2" East Longitude, which is surrounded by the ocean and rich in fishery resources, one of which is sharks landed at the Ujong Baroh Fish Landing Base (PPI).

PPI Ujong Baroh is one of the fishing ports well known as the center of the most active fishery activities as well as an important spot for the economy of West Aceh people who work as fishermen (Safriadi, 2018). One of the fishermen's catches landed at PPI Ujong Baroh was sharks, both as the main catch and by catch. This is in line with the research of Oliver *et al*. (2015), Shiffman and Hammerschlag (2016), Boldrocchi *et al*. (2020), Erguden *et al*. (2022), Sitorus *et al*. (2022), and Morgan *et al*. (2022), which stated that shark fisheries in Indonesia have experienced a decline caused by overfishing both as the main catch and by catch. Shark fins are highly valued in international markets for their economic worth (Cardeñosa *et al*., 2020; Houtan *et al*., 2020; Fields *et al*., 2020; and Asbury *et al*., 2021). Besides, there are also some who still buy shark meat for consumption, shark jaws used as antiques or decorations, and shark liver oil used as an alternative treatment (Clarke *et al*., 2007).

According to Dent and Clarke (2015), Hadi *et al*. (2020), and Sitorus *et al*. (2022), one of the countries that catches sharks the most is Indonesia. Indonesia tops the list of countries with the largest shark fishing in the world, although shark fisheries caught by Indonesian fishermen are bycatch caught in long line fishing gear and gill nets, with 28% as the target catch (Emiliya *et al*., 2017). Of course, with these fishing conditions, certain species of sharks will become extinct if not controlled. According to Fuadi *et al*. (2022), one of the fishing ports that lands shark catches and fishermen do not pay attention to the types of sharks that are protected and caught in the waters of South West Aceh (FMA 572 waters) is the Ujong Baroh Fish Landing Base (PPI), West Ace Regency.

According to Malaria *et al*. (2021) and Fuadi *et al*. (2022), shark fisheries, which are predators and mesopredators at the top level of bodies of water, can maintain the balance of marine ecology and control the food web. Sharks play a crucial role at the top of the marine food chain. Overfishing of these species can lead to imbalances in the ecosystem (Graham *et al*., 2010). Minister of Maritime Affairs and Fisheries Regulation No. 5 of 2018 states that there are 4 sprcies of sharks protected in Indonesian waters, namely *Sphyrna lewini*, *Alopias pelagicus*, *Carcharhinus falciformis,* and *Carcharhinus longimanus*. This study underscores the urgent need for international collaboration in shark conservation. By implementing uniform regulations across regions, we can prevent further depletion of shark populations and restore ecological balance (Herndon *et al*., 2010; Dulvy *et al*., 2008; and Techera and Klein, 2011). According to Dulvy *et al*. (2008), Jacques (2010), and Moro *et al*. (2019), although many fishermen have already known and realized that shark populations in the world have begun to decline and have an ecological and socio-economic impact, many of them still carry out shark fishing activities. Shark fishing is estimated to be three times higher than data from the Food and Agriculture Organization of the United Nations (FAO). This is because conservation of shark fisheries is in the absence of legally binding international agreements (Dulvy *et al*., 2008; Jacques, 2010; Techera and Klein, 2011; and Worm *et al*., 2013). So far, the implementation of international action plans for conservation and management of shark fisheries has been carried out voluntarily by national governments, regional agencies, and Regional Fisheries Management Organizations (RFMO), but it is still slow and ineffective in practice (Techera and Klein, 2011; Lack and Sant, 2011).

The distribution and abundance of fish in waters can be influenced by several factors of oceanography parameters, including chlorophyll-a, sea surface temperature, salinity, current weather, and water depth (Tangke *et al*., 2016; Fuadi *et al*., 2018). According to Saifudin *et al*. (2016) and Tangke *et al*. (2016), satellite imagery is a technique that can be applied in the field of fisheries by measuring aquatic oceanographic parameters such as sea surface temperature and chlorophyll-a both temporally and spatially. The use of remote sensing technology through Aqua-MODIS satellite imagery for analyzing oceanographic parameters such as chlorophyll-a distribution and sea surface temperature can provide significant results and prove to be a key role in assessing fish-appropriate oceanographic parameters in the determination of fishing grounds (Tangke 2014; Zainuddin *et al*., 2015). One method that can be applied to determine the preferred habitat of fish is through the analysis of satellite image data and field data support in the form of shark fishing ground coordinates (Fuadi *et al*., 2018). The results of satellite observations are then mapped with Geographic Information System (GIS) techniques, and from fishermen's fishing area data, the fishing area coordinates taken will be connected with oceanographic parameters of sea surface temperature and chlorophyll-a concentration. Further, the relationship of fishing areas with oceanographic parameters will be confirmed in a shark fishing area distribution map to obtain sea surface temperature and chlorophyll-a distribution values. However, research on oceanographic parameters of chlorophyll-a and sea surface temperature has not been carried out on sharks, so information on the influence of chlorophyll-a parameters and sea surface temperature is unknown. One of the parameters that can indicate the presence of fish is chlorophyll-a and sea surface temperature (Fuadi *et al*., 2018).

Based on the description above, this study aimed to determine the effect of chlorophyll-a and sea surface temperature (SST) parameters on shark catches that were landed at PPI Ujong Baroh, West Aceh district. Therefore, the distribution of shark fishing areas can be estimated through satellite image parameters, chlorophyll-a concentration, and SST content to be a consideration for fishermen and the government as a way to reduce fishing activities at a certain location and become a basic reference to be used as a conservation area. The presence of sharks in marine waters is not seen directly but is viewed based on parameters that are thought to affect the presence of sharks in the waters. So by conducting this study, it can be determined that the presence of sharks in marine waters can be influenced by oceanographic parameters, one of which is chlorophyll-a and sea surface temperature (SST).

2. Materials and Methods

2.1 Materials

Tools and materials were used to facilitate the implementation of research in taking data in the field, analyzing the data, and processing the data obtained. The tools and materials used in this study are presented in Table 1.

2.1.1 Ethical approval

This study does not require ethical approval because it does not use experimental animals.

2.1.2 Time and location of research

This research activity was carried out in the eastern season, or for 3 months, from August to October 2022. The timing of the catch was the result of fishermen's recommendations at PPI Ujong Baroh due to the pelagic fishing season. Data collection activities were done in two stages. The first stage was collecting data on the coordinates of the fishing area by following fishermen directly to the sea and collecting the data on shark catches landed at the PPI Ujong Baroh. Then the second stage was downloading satellite image data on chlorophyll-a and sea surface temperature. The location of data collection for shark catches at PPI Ujong Baroh can be seen in Figure 1.

2.2 Methods

2.2.1 Data collection methods

The method of data collection in the field was carried out by surveying and observing fishing units by taking primary data (field data) and secondary data (satellite image data). Primary data collection techniques were carried out by following fishermen's fishing activities to obtain data on shark fishing coordinates, fishing time, and data collection at PPI Ujong Baroh in the form of data on the type of shark catch, length, size, and number of catches (Table 2). The shark fishing fleets that were used as respondents to obtain primary data were five vessels based on recommendations from fish traders, because these vessels often land shark catches at PPI Ujong Baroh.

Secondary data collection was data on chlorophyll-a distribution and monthly sea surface temperature from the satellite imagery on NASA's official Aqua-MODIS (http://oceancolor.gsfc.nasa.gov) website. The selection of Aqua-MODIS level 3 satellite image data was divided into 2 types, namely monthly data from August to October 2023, which were adjusted to the time of capture and shark fishing area in the waters of South West Aceh. Then the selection of chlorophyll-a satellite image data and sea surface temperature (SST) free from cloud cover, and further, the data will be transformed into the form of a map that can describe chlorophyll-a and sea surface temperature in the waters of South West Aceh (Table 2).

2.3 Analysis Data

2.3.1 Shark catch

The catch of sharks landed at the PPI Ujong Baroh was obtained to be grouped based on the time of capture and the species of catch in the waters of South West Aceh. Then the data on grouped shark catch was analyzed to obtain weekly and monthly catch charts (Fuadi *et al*., 2022).

2.3.2 Shark length measurement

There are 3 length measurements in sharks, namely total length (TL), fork length (FL), and standard length (SL) measurements. The measurement of the length of the shark catch landed at PPI Ujong Baroh was done by measuring TL (total length), which was

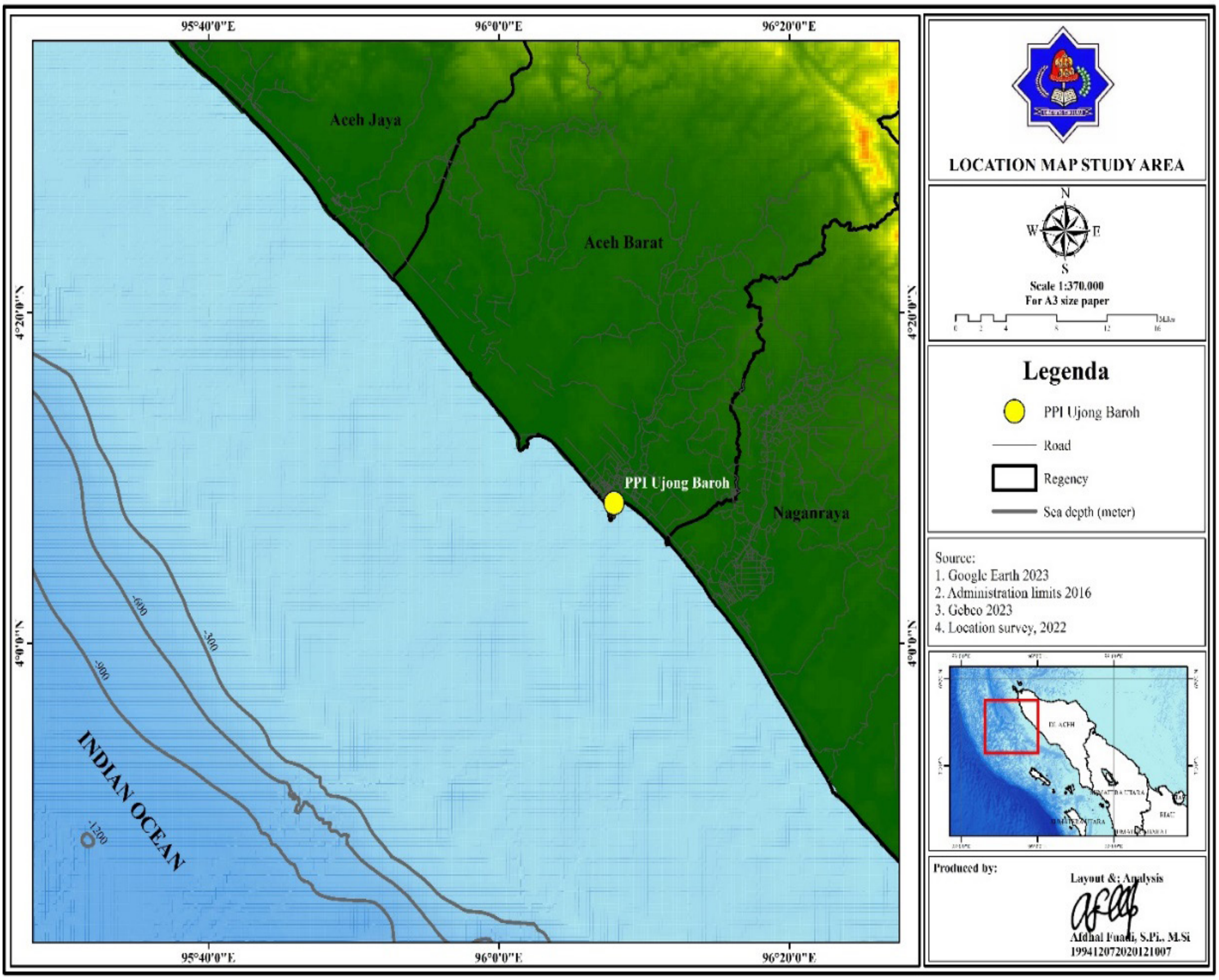


Figure 1. Map of the Ujong Baroh Fish Landing Base (PPI) research location.

Tabel 1. Tools or materials used in research and their usages.

No	Tools/Materials	Uses
1	Global Positioning System Garmin 64s + 8 Gb	To record data on shark fishing ground coordinates in Waters of Aceh Southwest
2	Life jacket	For safety follow the fisherman to the sea
3	Camera	To take documentation of research activities
4	Computer	To analyze the data (Ms. Excel), create maps of chlorophyll-a, sea surface temperature, and shark fishing grounds (ArcGis 10.3).

Table 2. Primary and secondary data collection methods.

Data type	Required data	Data sources
Primary	Coordinate points of shark fishing grounds	Fisherman
	Number of shark catches	PPI Ujong Baroh
	An individual shark catches	PPI Ujong Baroh
	Shark catch size	PPI Ujong Baroh
Secondary	Aqua-MODIS satellite image data of chlorophyll-a and sea surface temperature	NASA Aqua-MODIS (*http://oceancolor.gsfc.nasa.gov*)

measured from the front end of the head to the end of the tail (Fuadi *et al.,* 2022). This measurement is because the sharks that landed at PPI Ujong Baroh have complete body parts. Shark length measurement used a meter with the nearest millimeter. The method of measuring the length of the shark can be seen in Figure 2.

The effect of chlorophyll-a satellite imagery and sea surface temperature on the distribution of shark fishing grounds in the waters of Southwest Aceh was calculated using simple linear regression analysis with the formula Y = a + bX (Walpole, 1995). The coefficient value determination (R^2) with

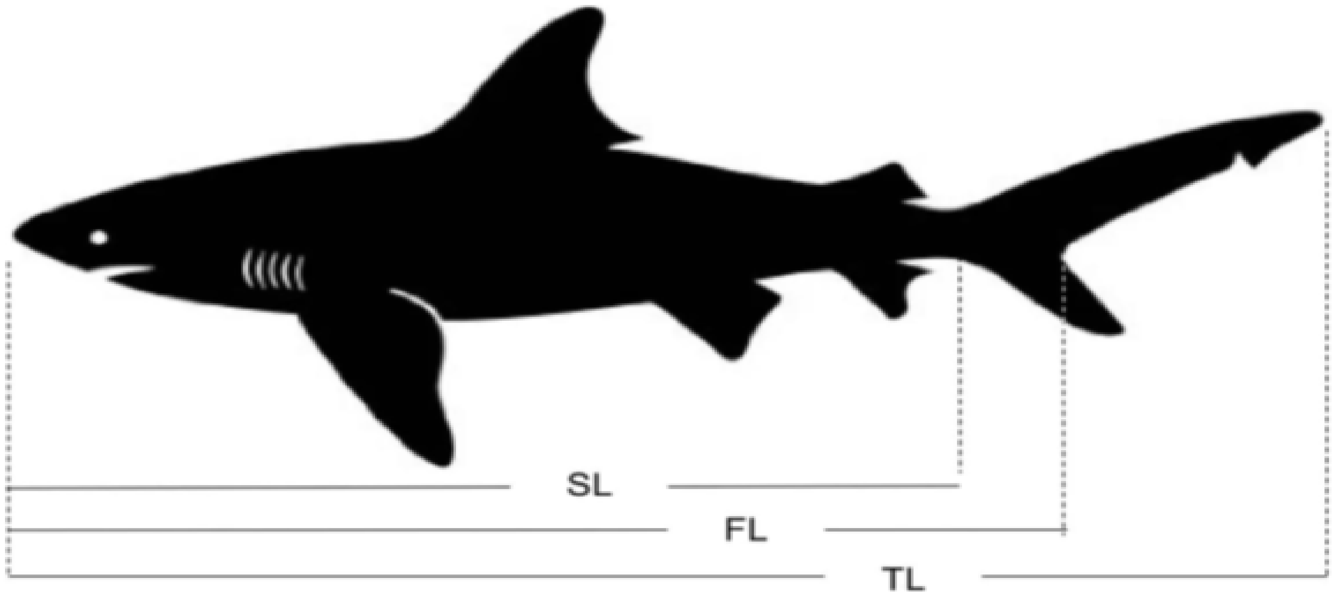


Figure 2. Methods of measuring length in sharks (Shark Survey Handbook & Logbook 2014; Fuadi *et al*., 2022).

2.3.3 SeaDas satellite imagery

Satellite image data of chlorophyll-a distribution and sea surface temperature (SST) in South West Aceh waters were obtained from Aqua-MODIS and analyzed using SeaDAS (Sea Data Analysis System) software, then overlaid with ArcGIS 10.3 software to obtain values and maps of chlorophyll-a distribution and sea surface temperature. Satellite images of chlorophyll-a and SST were downloaded based on shark fishing times obtained from the NASA official Aqua-MODIS website (http://oceancolor.gsfc.nasa.gov).

Satellite imagery of chlorophyll-a and sea surface temperature data available on the NASA official website is freely available, consisting of daily, weekly, monthly, and yearly data (Fuadi *et al*., 2018). The data used in this study was monthly data adjusted to shark fishing activities in the waters of Southwest Aceh landed at PPI Ujong Baroh, Meulaboh regency. The distribution of chlorophyll-a and sea surface temperature were divided into 2 types, namely lunar data, satellite images from August to November 2022, and data from satellite images free from cloud cover.

2.3.4 Effect of chlorophyll-a and sea surface temperature on sharks

a confidence level of 95% was seen for the magnitude of chlorophyll-a values and sea surface temperature contribution to shark catches. So that it can be known that the optimal chlorophyll-a value and sea surface temperature for shark fishing grounds in the waters of Southwest Aceh.

2.4 Chlorophyll-a Distribution Mapping, SST, and Shark Fishing Ground

Mapping of chlorophyll-a satellite imagery and sea surface temperature (SST) was carried out with *ArcGis* 10.3 software, which has been processed and overlaid with SeaDas software to see the value of chlorophyll-a content and SST. Satellite image data for chlorophyll-a and SST were cut based on the distribution of shark fishing grounds in the waters of Southwest Aceh.

Making a map of shark fishing area distribution in the waters of Southwest Aceh landed at the PPI Ujong Baroh also used ArcGis 10.3 software through several stages of the process (Fuadi *et al*., 2022). The stages of the process are: 1) shark fishing coordinate point data is overlayed into Google Earth to obtain information on the distribution of fishing grounds, water depth, and distance between shark fishing grounds; 2) the data is then overlaid into ArcGis to interpolate data on shark fishing coordinates to provide spatial information on the distribution of shark fishing grounds; 3) the last stage is doing a data layout to process coordinate point data into a map of shark fishing ground distribution.

3. Results and Discussion

3.1 Results

3.1.1 Shark catch

We recorded 618 individuals of sharks during the study; the sharks were caught in the southwest waters of Aceh in the eastern season and landed on PPI Ujung Baroh. According to Fuadi *et al.* (2022), the highest fishing season was recorded in September, which was 319, and the lowest catch occurred in October, which was 96 (Figure 3). The type of shark caught were by *Sphyrna lewini, Alopias pelagicus, Carcharhinus falciformis, Loxodon macrorhinus, Carcharhinus sorrah,* and *Chiloscyllium punctatum.*

The shark species that were caught and landed at PPI Ujong Baroh during the study were dominated by *Sphyrna lewini* (hammerhead shark), counted 343 individuals, or 56%, while the lowest species caught was *Alopias superciliosus,* with 14 or 5% caught on gill net fishing gear (Figure 4).

3.1.2 Shark catch length

The length of the shark was measured to the nearest millimeter, starting from the tip of the head to the tip of the shark's tail. According to Fuadi *et al.*

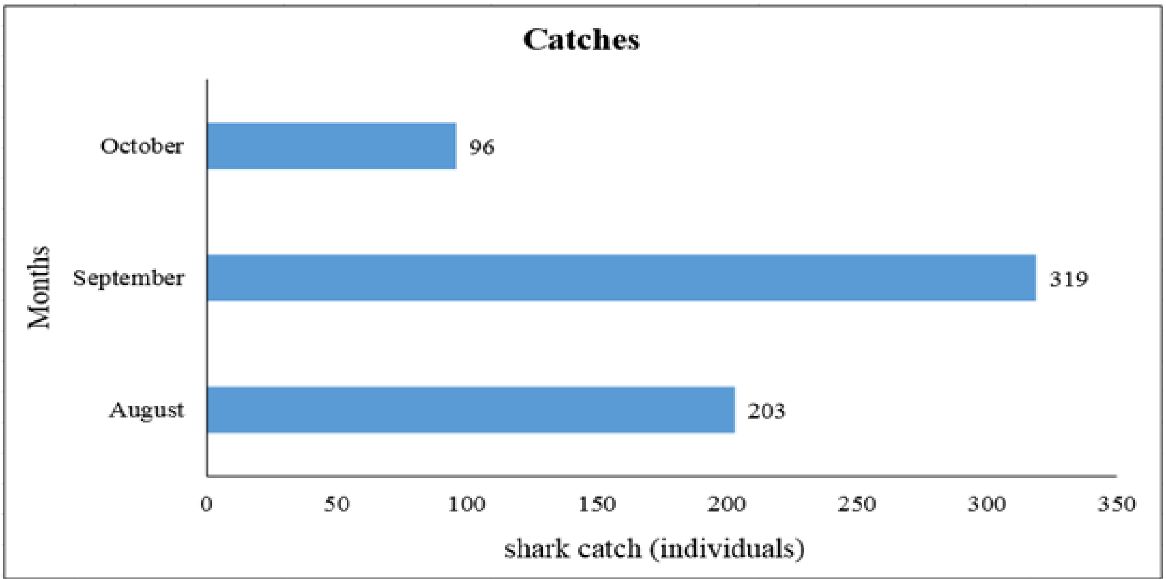


Figure 3. Eastern season shark catch at PPI Ujong Baroh (Fuadi *et al*., 2022).

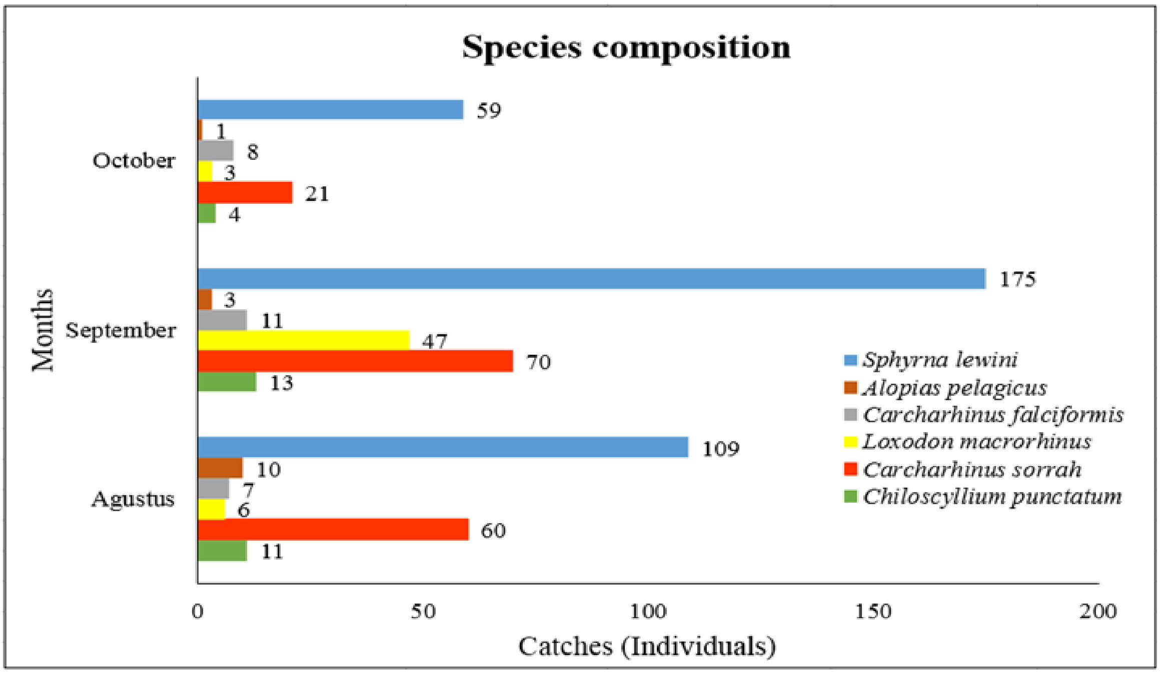


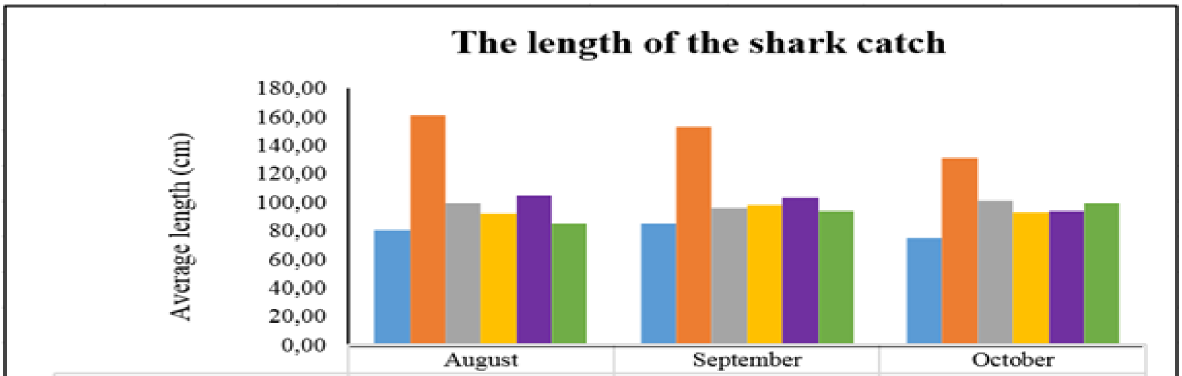
Figure 4. Types of shark catches in the Eastern season at PPI Ujong Baroh (Fuadi *et al*., 2022).

(2022), the average length of sharks caught in the waters of Southwest Aceh and landed at PPI Ujong Baroh was 103.56 cm, which ranged from 58.25 to 186 cm in size (Figure 5). The smallest type of shark caught was *Sphyrna lewini,* with a size of 74.57 cm, and the largest was *Alopias plagicus,* with a size of 160.89 cm.

3.1.3 Chlorophyll-a distribution and sea surface temperature (SST)

Chlorophyll-a

The distribution of chlorophyll-a concentrations was determined with observations of Nasa Aqua-MODIS satellite images in the waters of southwest Aceh based on the time and location of shark fishing during the study in the eastern season (Figure 6, 7, and 8). The distribution of chlorophyll-a during the eastern season study (August to October 2022) varies greatly; the highest chlorophyll-a value occurred in September at 1.23 mg/m3, and the lowest occurred in August at 0,08 mg/m3, with an average chlorophyll-a concentration of 0.17 mg/m3 (Table 3).



	August	September	October
Sphyrna lewini	80,21	84,93	74,57
Alopias pelagicus	160,89	152,75	131,00
Carcharhinus falciformis	99,50	96,00	100,96
Loxodon macrorhinus	92,43	97,93	92,67
Carcharhinus sorrah	104,67	102,99	93,43
Chiloscyllium punctatum	84,80	93,71	99,33

Figure 5. The average length of sharks landed at PPI Ujong Baroh in the Eastern season (Fuadi *et al*., 2022).

The distribution of chlorophyll-a concentrations in Figure 6 shows that chlorophyll-a values in August varied from 0.08 to 0.19 mg/m3, with an average value of 0.10 mg/m3. The highest chlorophyll-a value occurred at fishing ground location 1, and the lowest was found at fishing ground location 15.

Based on Figure 8, the distribution of chlorophyll-a concentrations in October 2022 ranged from 0.09 to 0.82 mg/m^3, with an average of 0.20 mg/m^3. The highest concentration of chlorophyll-a was found in the shark fishing area of location 3, which was 0.82 mg/m^3, and the lowest was found in the fishing area of location 16, which was 0.09 mg/m^3.

Sea surface temperature (SST)

The distribution of sea surface temperature (SST) in the waters of Southwest Aceh in the eastern season (August to October 2022) varied greatly, ranging from 27.65°C to 30.29°C with an average SST of 28.65°C. The highest SST content occurred in August at 30.29°C and the lowest occurred in September at 27.65°C (Figures 9, 10, and 11 and Table 3).

Based on Figure 9, it shows that the sea surface temperature around the location of the shark fishing area in August ranged from 29.44°C to 30.29°C with an average content value of 29.89°C. The sea surface temperature (SST) content in September around shark fishing grounds ranged from 27.65°C to 28.48°C with an average of 28.10°C (Figure 10). The highest value of the distribution of SST was found at location 22, which was 28.48°C, while the lowest temperature content was found at location 23, which was 27.65°C.

The distribution of SST content in the waters of Southwest Aceh in October 2022 ranged from 27.74°C to 28.33°C with an average sea surface temperature of 27.95°C (Figure 11). Sea surface temperatures in October were lower than sea surface temperatures in August and September 2022.

3.1.4 The effect of chlorophyll-a and sea surface temperature on shark catches

Based on the results of the linear regression analysis of the effect of chlorophyll-a on the catch of sharks landed at PPI Ujong Baroh high peling influence, namely the shark *Loxodon macrorhinus*, it can be seen from the value of the coefficient of determination (R^2) obtained, which obtained a value of 0.7289. This value shows that the catch of *Loxodon macrorhinus* sharks is influenced by chlorophyll-a oceanographic parameters by 72.82%, and the remaining 27.18% is influenced by other oceanographic parameters (Table 5 and Figure 12). The type of shark that is slightly influenced by chlorophyll-a parameters is the *Alopias pelagicus* shark, which is 0.68%, or the value of the coefficient of determination (R2) of 0.0068; the rest is influenced by other oceanographic parameters (Table 5 and Figure 12).

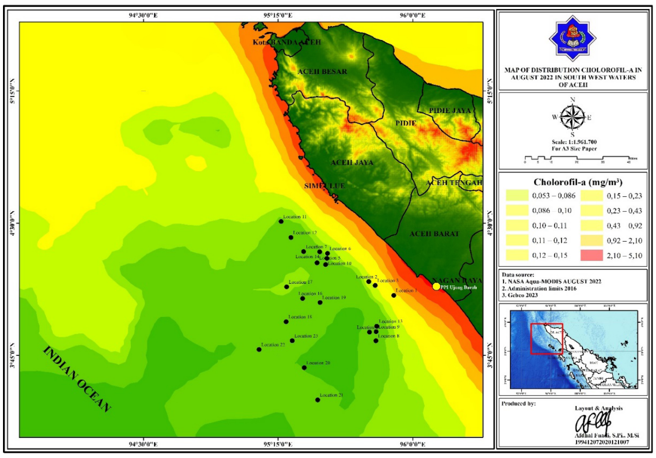


Figure 6. Distribution of chlorophyll-a concentrations in August 2022 in the waters of Southwest Aceh.

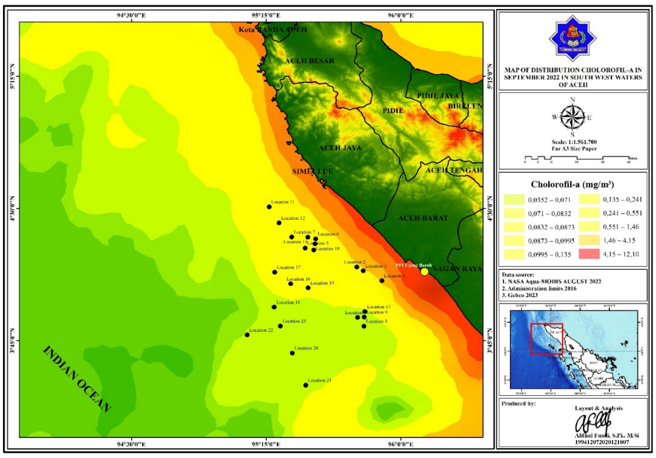


Figure 7. Distribution of chlorophyll-a concentrations in September 2022 in Southwest waters of Aceh.

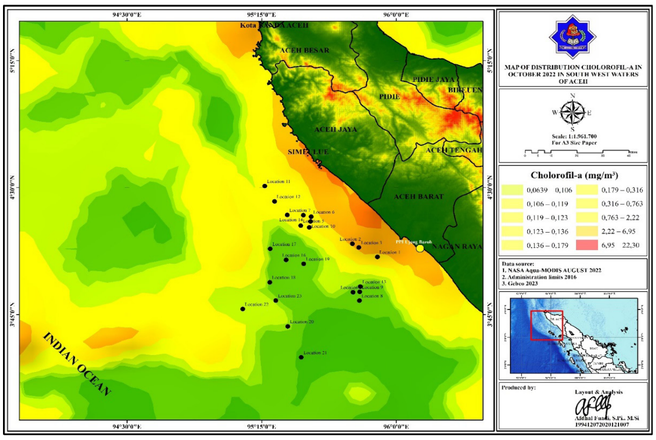


Figure 8. Distribution of chlorophyll-a concentrations in October 2022 in Southwest waters of Aceh.

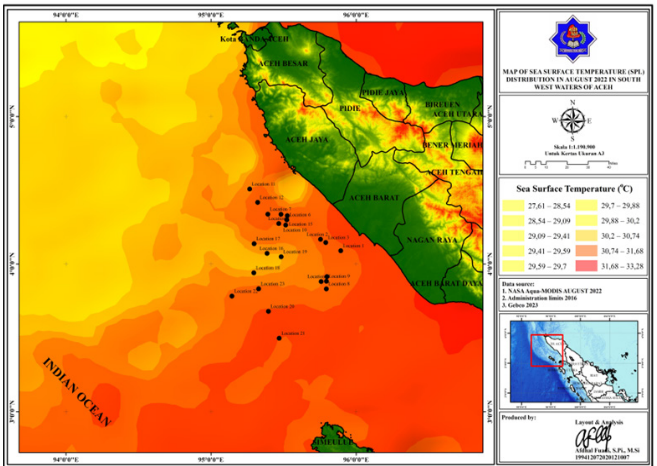


Figure 9. Distribution of SST content in August 2022 in the waters of Southwest Aceh.

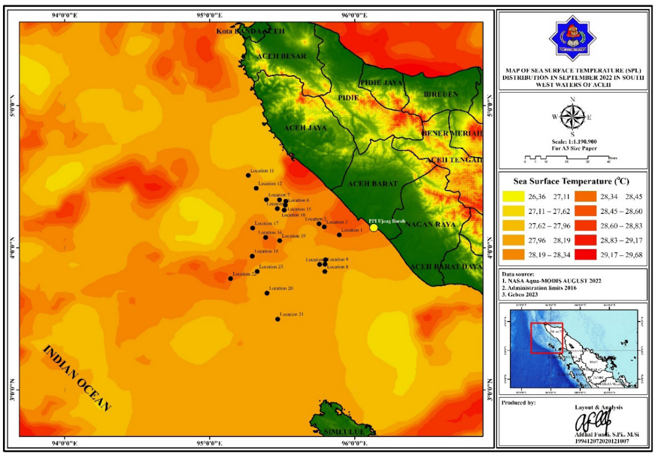


Figure 10. Distribution of SST content in September 2022 in the waters of Southwest Aceh.

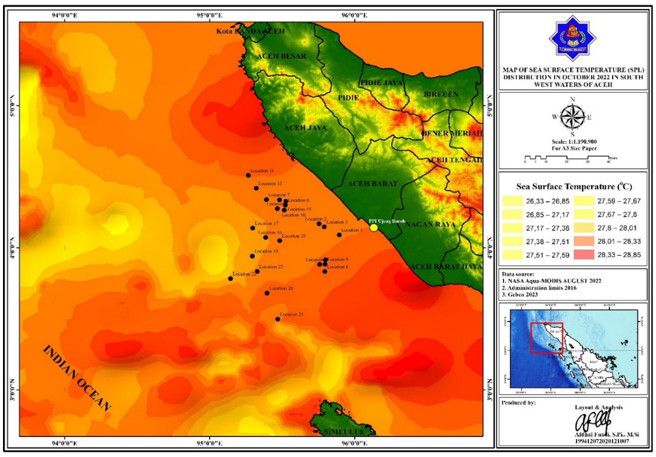


Figure 11. Distribution of SST content in October 2022 in Southwest waters of Aceh.

The effect of the distribution of sea surface temperature (SST) content on shark catches with linear regression analysis has the highest effect, namely the *Alopias pelagicus* shark with a coefficient of determination (R^2) value of 0.8312, or 83.12%, influenced by oceanographic parameters of sea surface temperature (Table 5 and Figure 13). While the catch of sharks least affected by sea surface temperature is the shark *Sphyrna lewini,* which is 0.81%, the rest is influenced by other oceanographic parameters (Table 5 and Figure 13). The average sea surface temperature caught in the waters of Southwest Aceh was predominantly caught at a sea surface temperature of 28.33°C. There is a low correlation value because shark species are the top predators in the food chain in marine waters and fast swimmers. Shark fishery resources, which are predators and mesopredators at the top level of bodies of water, can maintain the balance of marine ecology and control the food web.

3.1.5 Mapping the distribution of shark fishing ground

The distribution of shark fishing areas in the waters of West Aceh landed at the PPI Ujong Baroh, West Aceh regency, in the East season consisted of 23 locations, with the most dominant shark species caught being *Sphyrna lewini* (Figure 14). The shark catch was dominated by gill net fishing gear, and the location of the fishing ground was in a coral area (Fuadi *et al.*, 2022).

Based on Figure 14 shows that the location of shark fishing grounds was at depths ranging from 17 to 1.509 meters, with an average depth of 523 meters. According to Fuadi *et al.* (2022), of 23 shark fishing ground locations landed at PPI Ujong Baroh, there were three zones that caught small-sized sharks that were included in the protected category, namely *Sphyrna lewini* and *Alopias superciliosus*, which were included in the CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna) appendix II category.

Table 3. Distribution of chlorophyll-a concentration from August to October 2022.

No	Months	Chlorophyll-a mg/m³				
		Ranges	Dominant	Max	Min	Average
1	August	0.08-0.19	0.10	0.19	0.08	0.10
2	September	0.10-1.23	0.12	1.23	0.10	0.21
3	October	0.09-0.82	0.12	0.82	0.09	0.20

Table 4. Distribution of sea surface temperature (SST) content from August to October 2022.

No	Months	Sea Surface Temperature (°C)				
		Ranges	Dominant	Max	Min	Average
1	August	29.44-30.29	29.89	30.29	29.44	29.89
2	September	27.65-28.48	27.90	28.48	27.65	28.10
3	October	27.74-28.33	28.01	28.33	27.74	27.95

3.2 Discussion

The sharks that were landed were caught with gill nets. According to Oliver *et al.* (2015), Shiffman and Hammerschlag (2016), and Alaudin *et al.* (2021), the most common type of shark caught in gill net fishing gear is hammerhead sharks caught by fishermen in the West Aceh district, both as the main catch and bycatch.

The number of shark catches was higher when compared to previous studies in the West-East viewing season in 2017, which consisted of 246 individuals consisting of 10 species (Sutio *et al.,* 2018). According to Simeon *et al.* (2020), from the technical report on monitoring the catch of sharks and rays in Aceh in 2022, the most dominant types of catches caught at the Rigaih Aceh Jaya Fish Auction Place (TPI) and the Southwest Aceh Fish Auction Place (TPI) were *Sphyrna lewini,* which was 40%, and the lowest was *Alopidae* type in 18%. The average catch of *Sphyrna lewini* landed at PPI Ujong Baroh was bycatch caught with gill net fishing gear (Alaudin *et al.,* 2021; Fuadi *et al.* 2022). According to Booth *et al.* (2018), there are five types of fishing gear caught by sharks as bycatch: longline (67%), gillnet (50%), trawl (21%), handline (20%), and seine (17%).

The smallest type of shark caught was *Sphyrna lewini,* with a size of 74.57 cm, and the largest was *Alopias plagicus,* with a size of 160.89 cm. According to Clarke *et al.* (2006) and Gallagher and Klimley (2018), shark species were *Sphyrna lewini* placental viviparous with litter sizes of 12–41 and the first size

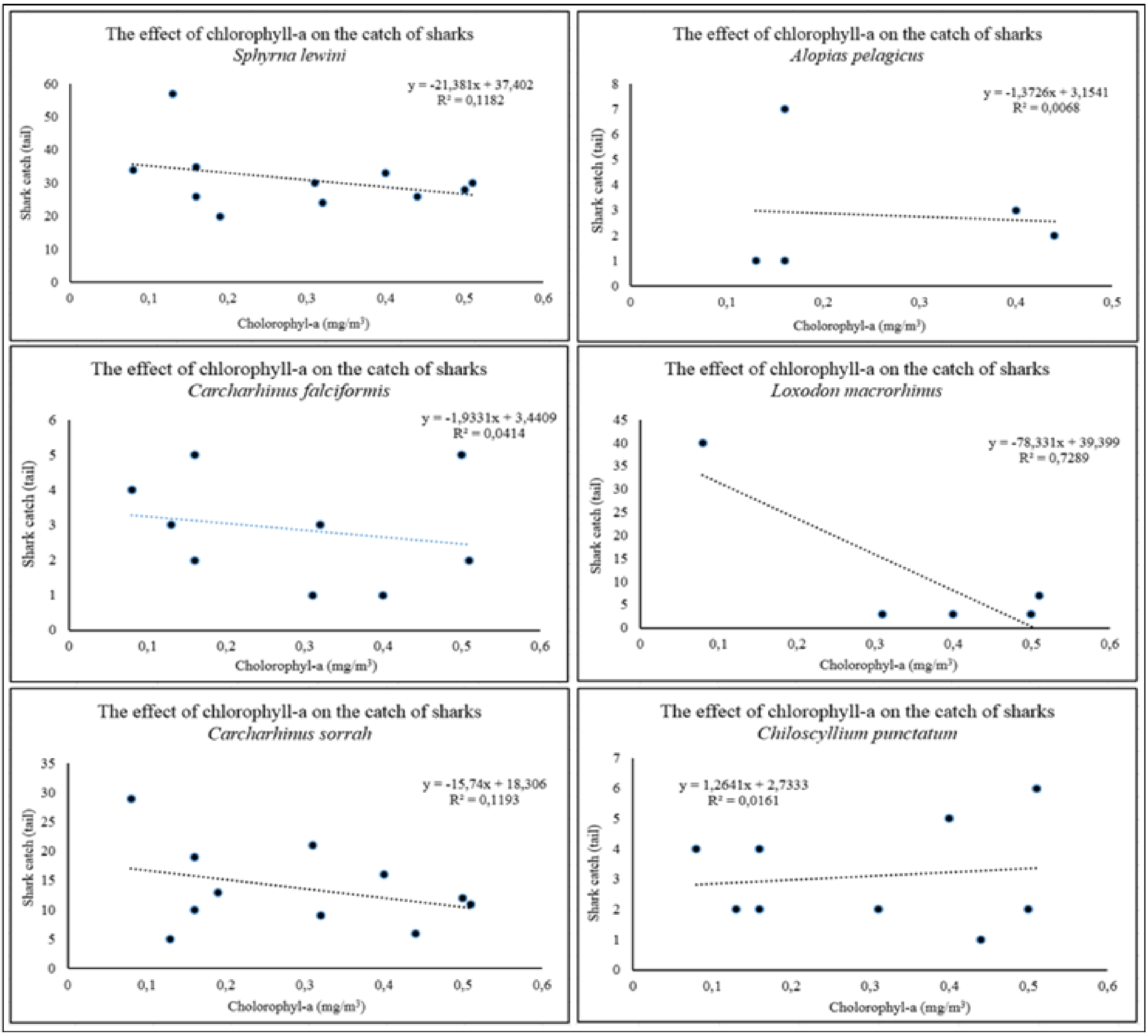


Figure 12. The effect of chlorophyll-a on the catch of sharks landed at PPI Ujong Baroh.

Table 5. The Effect of Chlorophyll-a and Sea Surface Temperature on Shark Catches.

Catches (Individuals)	Value coefficient determination (R2): Klorofil	The Effect of Chlorophyll-a on Shark Catches	Value coefficient determination (R2): SST	The Effect of SST on Shark Catches
Sphyrna lewini	0.1182	11.82%	0.0081	0.81%
Alopias pelagicus	0.0068	0.68%	0.8312	83.12%
Carcharhinus falciformis	0.0414	4.14%	0.0036	0.36%
Loxodon macrorhinus	0.7289	72.89%	0.0279	2.79%
Carcharhinus sorrah	0.1193	11.93%	0.0236	2.36%
Chiloscyllium punctatum	0.0161	1.61%	0.0142	1.42%

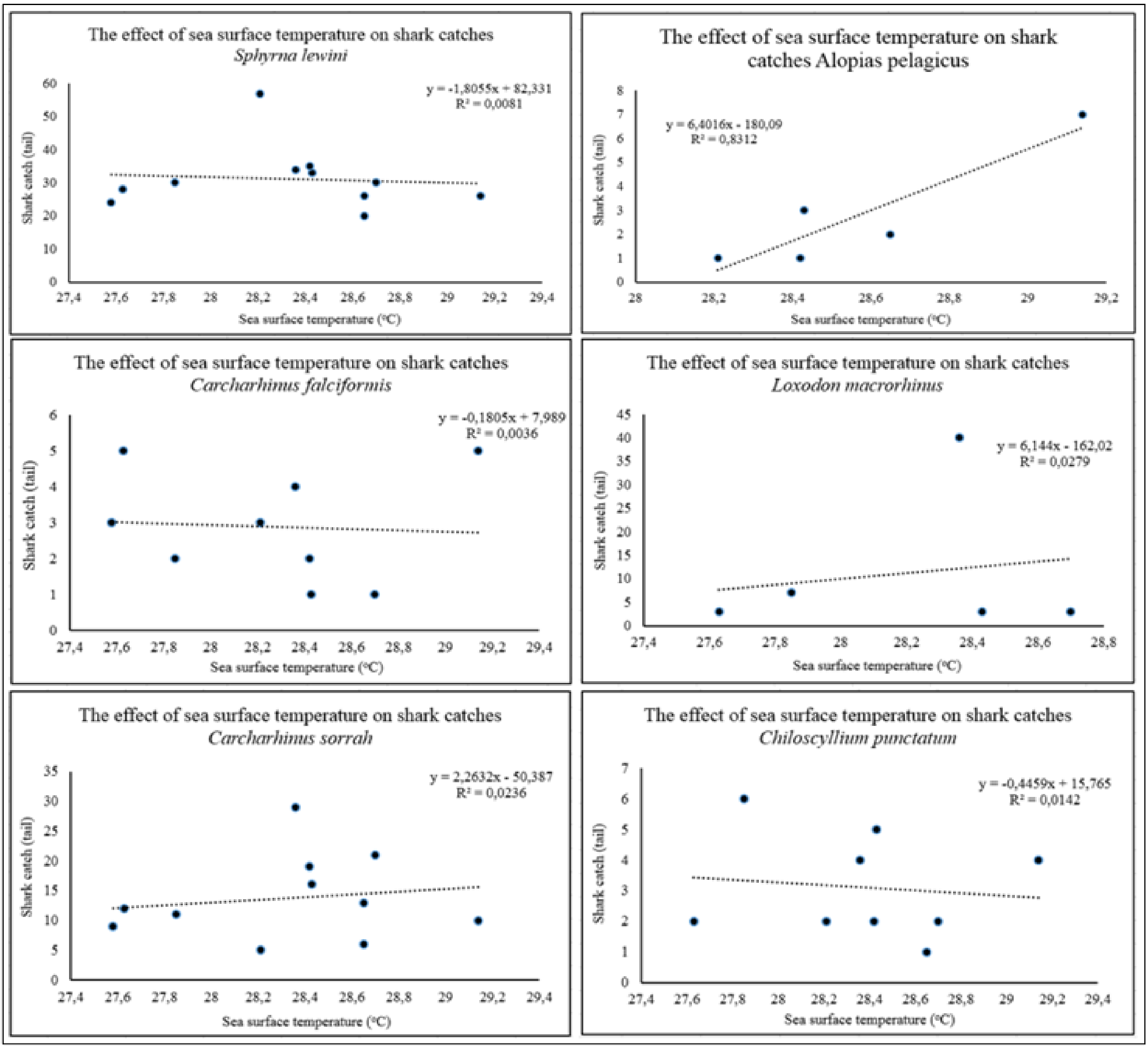


Figure 13. The effect of sea surface temperature on shark catches landed at PPI Ujong Baroh.

at birth is 31–57 cm. This is in line with research by Alaudin *et al.* (2021), which states that the type of *Sphyrna lewini* shark caught by West Aceh fishermen and landed at the Ujong Baroh PPI was still small because the catch was caught with a gill net as bycatch. According to White *et al.* (2012), Fahmi and Dharmadi (2015), Oliver *et al.* (2015), Shiffman and Hammerschlag (2016), and Erguden *et al.* (2022), sharks are caught with gill net fishing gear and have experienced a decline caused by overfishing of sharks.

Geographically, the distribution of chlorophyll-a concentrations in September was higher around the coast, and the lower chlorophyll-a values were offshore (Figure 7). This is in line with Febri (2012) and Fuadi *et al.* (2018), who stated that the value of chlorophyll-a found around the coast is higher because there are several rivers that supply nutrients from land through river water flow to the sea.

According to Febri (2012), Hamka (2012), and Fuadi *et al.* (2016), the distribution of SST content that occurred in the West-East transition season, including warm temperatures ranging from 27.28°C to 32.85°C happened if the sea surface temperature was compared with sea surface temperatures that occurred in the East-West transition season, which ranged from 25.40°C to 30.00°C. The distribution of sea surface temperature content in the East-West transition season in Pidie Jaya waters ranges from 27.28°C to 32.85°C with an average value of 29.25°C.

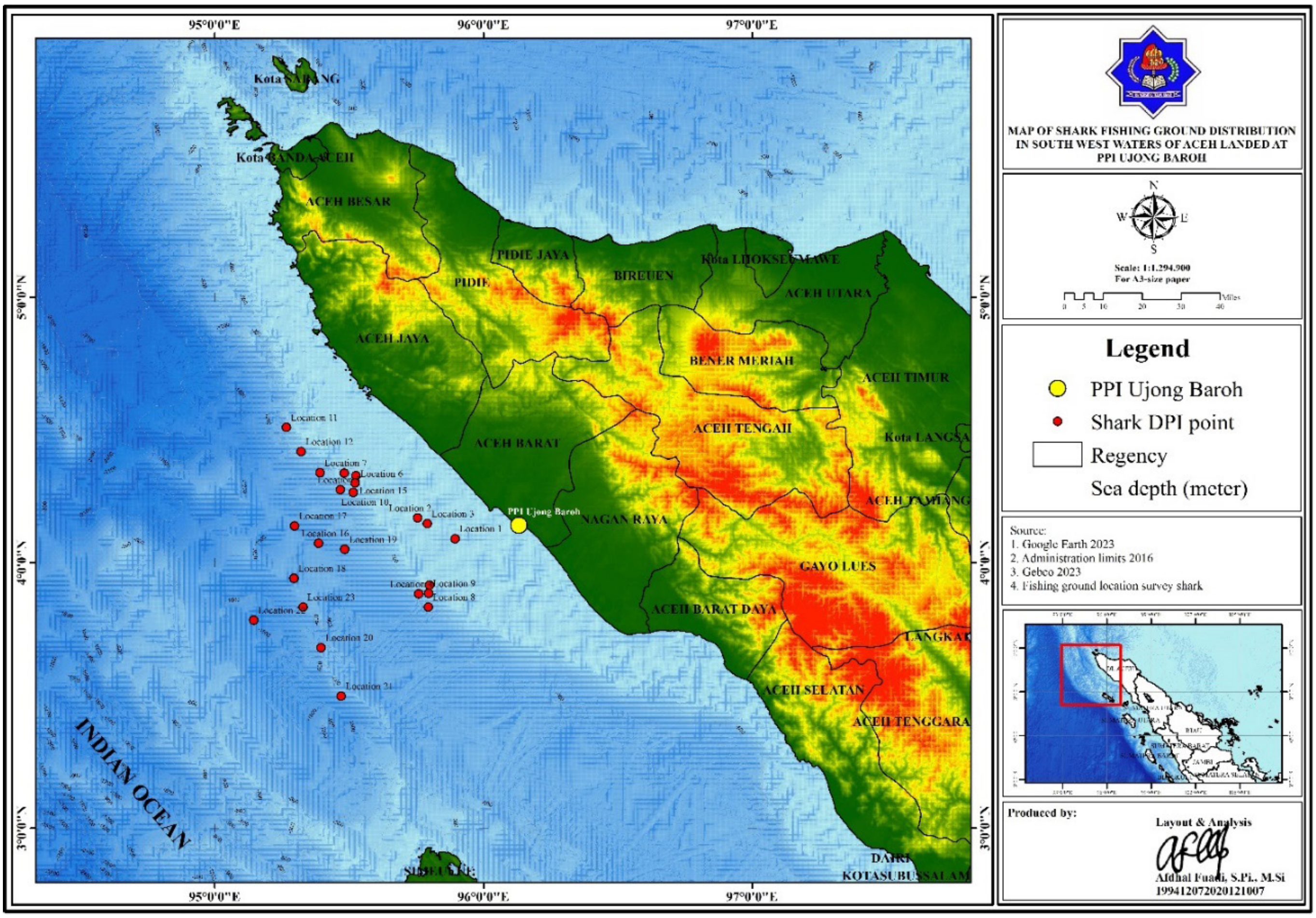


Figure 14. Map of the distribution of shark fishing areas in the Eastern season (August-October 2022) landed at PPI Ujong Baroh (Fuadi *et al*., 2022).

The optimum sea surface temperature for shark fishing is around 28-29°C or in the East-West transition season because at that temperature, there is a peak shark fishing season, and the water temperature tends to be cooler (Khaidir *et al.,* 2015). This condition implied that there could be other oceanographic factors affecting shark fishing grounds, one of which was the parameters of the distribution of water currents and the salinity of the waters (Hamka, 2012).

According to Andrius (2007), there are four main parameters that can affect the migration and distribution of fish in waters: abundance of food, ocean currents, sea surface temperature, and salinity of the waters. The presence of phytoplankton in a body of water begins to be seen from the chlorophyll concentration value >0.20 mg/m3. The presence of phytoplankton helps maintain the food chain and multiply (Fuadi *et al.,* 2018).

Sharks caught in Aceh waters were spread from coastal areas to offshore waters (Simeon *et al.,* 2020; Hutchinson *et al.,* 2023; Nugraha *et al.,* 2023).

According to Fuadi *et al.* (2022), the *Sphyrna lewini* shark species was found in coastal waters and around coral reefs in Aceh Jaya and West Aceh districts, while adult-sized sharks were caught in offshore waters with a water depth of more than 150 meters.

4. Conclusion

The results of satellite image analysis showed that the distribution of chlorophyll-a parameter values in the eastern season ranged from 0.08 to 1.23 mg/m^3, with an average value of 0.17 mg/m^3. The highest value occurred in September at 1.23 mg/m^3, while the lowest was in August at 0.08 mg/m^3. The distribution of SST varied from 27.65°C to 30.29°C with an average value of 28.65°C. The highest distribution of sea surface temperature values was in August with 30.29°C and the lowest was in September with 27.65°C. Based on the results of linear regression analysis, the highest catch of sharks was influenced by chlorophyll-a, namely *Loxodon macrorhinus* sharks, by 72.82%, while the lowest was influenced by chlorophyll-a, namely *Alopias pelagicus* sharks, by

0.68%; the rest were influenced by other parameters. The type of shark catch is most influenced by sea surface temperature (SST), namely the *Alopias pelagicus* shark by 83.12%, while the lowest is influenced by SST, namely the *Sphyrna lewini* shark by 0.81%, and the rest is influenced by other parameters.

Acknowledgement

The first author would like to thank the research and community service institutions (LPPM) of Teuku Umar University for funding this research, through the Assistant Ahli scheme (PAA) in 2022. The authors also thank the Faculty of Fisheries and Marine Science and all reviewers who have provided critics and suggestions to improve the manuscript.

Authors' Contributions

The contribution of each author as follows, Afdhal Fuadi; collected, processed, analysed the data, drafted the manuscript, and critically revised the article. Muhammad Rizal; devised the main conceptual ideas, and editor text. Dimas Kusumayadi; data processing, designed the figures and data collection. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

Declaration of Artificial Intelligence (AI)

The author(s) affirm that no artificial intelligence (AI) tools, services, or technologies were employed in the creation, editing, or refinement of this manuscript. All content presented is the result of the independent intellectual efforts of the author(s), ensuring originality and integrity.

Funding Information

My Research Project was partially or fully sponsored by The Research and Community Service Institutions (LPPM), through the Assistant Ahli scheme (PAA) in with grant number 023/UN59.7/PT.01.03/2021.

References

Alaudin., Jaliadi., Burhanis., & Rizal, M. (2021). Distribution of size and growth of hammerhead sharks (by catch) landed at the Ujong Baroh Meulaboh Fish Landing Base (PPI). *Jurnal Perikanan Tropis*, 8(1):65-77.

Andrius. (2007). Spatial model of information on flying fish fishing areas (*Decapterus* spp.) between the waters of the Makasar Strait and the Java Sea (1100-1200 East Longitude - 2050'-7050' South Latitude). Thesis, Bogor: Postgraduate Program, Bogor Agricultural Institute.

Asbury, T. A., Bennett, R., Price, A. S., Silva, C., Bürgener, M., Klein, J. D., Maduna, S. N., Sidat, N., Fernando, S., & Merwe, A. E. B. (2021). Application of DNA mini-barcoding reveals illegal trade in endangered shark products in southern Africa. *Journal of Marine Science*, 43(4):511-520.

Boldrocchi, G., Monticelli, D., Butti, L, Omar, M., & Bettinetti, R. (2020). First concurrent assessment of elemental-and organic contaminant loads in skin biopsies of whale sharks from Djibouti. *Science of the Total Environment*, 722(6):1-9.

Booth, H., Muttaqin, E., Simeon, B., Ichsan, M., Siregar, U., Yulianto, I., & Kessem, K. (2018). Shark and ray conservation and management in Indonesia: Status and strategic priorities 2018-2023. *Wildlife Conservation Society – Indonesia Program*, 131-201.

Cardeñosa, D., Fields, A. T., Shea, S. K. H., Feldheim, K. A., & Chapman, D. D. (2020). Relative contribution to the shark fin trade of Indo-Pacific and Eastern Pacific pelagic thresher sharks. *Animal Conservation,* 24(3):367-372.

Clarke, S. C., McAllister, M. K., Milner-Gulland, E. J., Kirkwood, G. P., Michielsens, C. G. J., Agnew, D. J., Pikitch, E. K., Nakano, H. & Shivji, M. S. (2006). Global estimates of shark catches using trade records from commercial markets. *Ecology Letters,* 9(10):1115-1126.

Clarke, S. C., Milner-Gulland, E. J., & Bjorndal, T. (2007). Social, economic, and regulatory drivers of the shark fin trade. *Journal Marine Resource Economics,* 22(3):305-327.

Dent, F., & Clarke, S. (2015). State of the global market for shark products. FAO Fisheries and Aquaculture Technical Paper, 590. 187 pp.

Dulvy, N. K., Baum, J. K., Clarke, S., Compagno, L. J. V., Cortés, E., Domingo, A., Fordham, S., Fowler, S., Francis, M. P., Gibson, C., Martínez, J., Musick, J. A., Soldo, A., Stevens, J., & Valenti, S. (2008). You can swim but you can't hide: The global status and conservation of oceanic pelagic sharks and rays. Aquatic Conservation: *Journal Marine and Freshwater Ecosystems,* 18(5):459-482.

Emiliya, Pratomo, A., & Putra, R. D. (2017). Identification of the type shark fishermen catch on Bintan Island Riau Islands Province. Research Report. Tanjung Pinang, Riau Islands: Faculty of Marine Sciences and Fisheries, Raja Ali Haji Maritime University.

Erguden, D., Kabasakal, H., & Ayas, D. (2022). Fisheries by catch and conservation priorities of young sharks (Chondrichthyes: Elasmobranchii) in the Eastern Mediterranean. *Journal Zoology in the Middle East,* 68(2):135-144.

Fahmi., & Dharmadi. (2015). Pelagic shark fisheries of Indonesia's Eastern Indian Ocean fisheries management region. *African Journal of Marine Science,* 37(2):259-265.

Febri, S. P. (2012). Evaluation of flying fish (*Decapterus* Spp.) fishing areas based on indicators of catch composition, sea surface temperature and chlorophyll-a.Thesis, Bogor: Bogor Agricultural Institute.

Fields, A. T., Fischer, G. A., Shea, S. K. H., Zhang, H., Feldheim, K. A., & Chapman, D. D. (2020). DNA Zip-coding: Identifying the source population supplying the international trade of a critically endangered coastal shark. *Animal Conservation,* 23(6):670-678.

Fuadi, A., Musman, M., & Miswar, E. (2016). Validation of potential small pelagic fishing areas using purse seine with satellite imagery in Pidie Jaya waters. *Jurnal Imiah Mahasiswa Kelautan dan Perikanan Unsyiah,* 1(2):195-202.

Fuadi, A., Wiryawan, B., & Mustaruddin. (2018). Estimation of flying fishing areas using satellite imagery in Aceh waters around Pidie Jaya. *Jurnal Teknologi Perikanan dan Kelautan,* 9(2):149-161.

Fuadi, A., Rizal, M., & Akbardiansyah. (2022). Zoning mapping of protected shark fishing areas landed at the Ujong Baroh Fish Landing Base (PPI), West Aceh. *Jurnal Penelitian Perikanan Indonesia,* 28(4):199-208.

Fuadi, A., Arif, M., Dianshar, R., Kusumayadi, D., & Oktavinanda, G. (2024). Mapping the Distribution of Stingray Fishing Ground in the South West Waters of Aceh During the East Season. *Journal of Aquatic, Coastal, and Fisheries Sciences,* 13(3):385-390.

Gallagher, A. J., & Klimley, A. P. (2018). The biology and conservation status of the large hammerhead shark complex: The great, scalloped, and smooth hammerheads. *Reviews in Fish Biology and Fisheries,* 28(4):777-794.

Graham, N. A., Spalding, M. D., & Sheppard, C. R. C. (2010). Reef shark declines in remote atolls highlight the need for multi-faceted conservation action. *Journal Aquatic Conservation: Marine and Freshwater Ecosystems,* 20(4):543-548.

Hadi, S., Andayani, N., Muttaqin, E., Simeon, B. M., Ichsan, M., Subhan, B., & Madduppa, H. (2020). Genetic connectivity of the scalloped hammerhead shark *Sphyrna lewini* across Indonesia and the Western Indian Ocean. *Journal PLoS One,* 15(10):1-14.

Hamka, E. (2012). Mapping potential fishing areas for flying fish (*Decapterus* spp.) in the Banda Sea. Thesis. Bogor: Bogor Agricultural Institute.

Herndon, A., Gallucci, V. F., DeMaster, D., & Burke, W. (2010). The case for an international commission for the conservation and management of sharks (Iccms). *Journal Marine Policy,* 34(6):1239-1248.

Houtan, K. S. V., Gagné, T. O., Reygondeau, G., Tanaka, K. R., Palumbi, S. R., & Jorgensen, S. J. (2020). Coastal sharks supply the global shark fin trade. *Biology Letters,* 16(10):1-4.

Hutchinson, M., Scott, M., Bauer, R., Anderson, J., Coffey, D. M., Holland, K., Meyer, C., O'Sullivan, J., & Royer, M. (2023). Habitat use and movement patterns of adult male and juvenile scalloped hammerhead sharks *Sphyrna lewini* throughout the Hawaiian archipelago. *Endangered Special Research,* 52(3):41-64.

Jacques, P. J. (2010). The social oceanography of top oceanic predators and the decline of sharks: A call for a new field. *Journal Progress in Oceanography,* 86(1-2):192-203.

Khaidir, A., Sari, T. E. Y., & Bustari. (2015). The influence of sea surface temperature on catches of skipjack tuna (*Katsuwonus pelamis*) at Lampulo Harbor, Banda Aceh. *Jurnal Online Mahasiwa Universitas Riau,* 2(2):1-12.

Lack, M., & Sant, G. (2011). The future of sharks: a review of action and inaction. Traffic report. Cambridge: Traffic International and the Pew Environment Group.

Malaria, D., Battaglia, P., Consoli, P., Arcadi, E., Longo, F., Stipa, M. G., Pagano, L., Greco, S., Andaloro, F., & Romeo, T. (2021). When opportunistic predators interact with swordfish harpoon fishing activities: shark depredation over catches in the Strait of Messina (central Mediterranean Sea). *The European Zoological Journal,* 88(1):226-236.

Morgan, A., Mendes, M., Tingley, G., Brian S. W., & Sousa, P. (2022). Have fishery improvement projects (FIPs) adequately addressed key needs to monitor and mitigate fishery impacts on endangered, threatened, and protected (ETP) species? A review, with recommendations to the supply chain. *Marine Biology Research,* 18(4):173-186.

Moro, S., Lasinio, J. G., Block, B., Micheli, F., De Leo, G., Serena, F., Bottaro, M., Scacco, U., & Ferretti, F. (2019). Abundance and distribution of the white shark in the Mediterranean Sea. *Fish and Fisheries,* 21(2):338-349.

Nugraha, B., Samusamu, A. S., Puspasari, R., Oktaviani, D., Rachmawati, R., Rachmawati, P. F., Sulaeman, P. S., Hartati, S. T., & Wiadnyana, N. N. (2023). Biological aspects, exploitation rates, and spawning potential ratio of scalloped hammerhead shark (*Sphyrna lewini* Griffith & Smith, 1834) in Lampung Bay waters, Indonesia. *IOP Conf. Series: Earth and Environmental Science,* 1148(38):1-9.

Oliver, S., Braccini, M., Newman, S. J., & Harvey, E. S. (2015). Global patterns in the by catch of sharks and rays. *Journal Marine Policy,* 54(2):86-97.

Safruddin., Dewi, Y. K., Hidayat, R., & Umar, M. T. (2018). Study of oceanographic conditions in large pelagic fishing areas using pole and line in the waters of Bone Bay. *Proceedings of the National Marine and Fisheries Symposium,*1(2):48-58.

Sauni, S. W. (2023). Analysis of the level of utilization of class D fishing port facilities (case study at PPI Ujong Baroh, West Aceh Regency. Thesis, Meulaboh: Fisheries Study Program. Faculty of Fisheries and Marine Science. Teuku Umar University.

Shiffman, D. S., & Hammerschlag1, N. (2016). Shark conservation and management policy: a review and primer for non-specialists. *Journal Animal Conservation,* 19(5):401-412.

Simeon, B. M., Fajri, I., Ula, S., Muttaqin, E., Ichsan, M., Dharmadi., Damora, A., & Sarong, M. A. (2020). Technical report on monitoring catches of sharks and rays in Aceh Province. Wildlife Conservation Society-Indonesian Program, 1-57.

Sitorus, Y. D. P., Julyantoro, P. G. S., & Dewi, A. P. W. K. (2022). Identification of dominant shark fins landed at The Port of Benoa, Bali based on CO1 Gene. *Journal of Marine and Aquatic Sciences,* 8(2):221-229.

Sutio, S., Ulfah, M., & Rizwan, R. (2018). Identification of sharks caught in West Aceh Waters and their conservation status. *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah,* 3(3):118-126.

Tangke, U. (2014). Population parameters and level of exploitation of mackerel (*Euthynnus affinis*) in the waters of Morotai Island. *Agrikan: Jurnal Ilmiah Agribisnis dan Perikanan,* 7(1):74–81.

Tangke, U., Karuwal, J. W. C., Mallawa, A., & Zainuddin, M. (2016). Analysis of the relationship between sea surface temperature, salinity and currents with tuna catches in the waters of the western part of Halmahera Island. *Jurnal Iptek: Pemanfaatan Sumberdaya Perikanan,* 3(5):368-382.

Techera, E. J., & Klein, N. (2011). Fragmented governance: Reconciling legal strategies for shark conservation and management. *Journal Marine Policy,* 35(1):73-78.

Walpole, R. E. (1995). Introduction to statistics. Translated by Bambang Sumantri. Jakarta: PT. Gramedia Pustaka Utama.

White, W. T., Dichmont, C., Purwanto., Nurhakim, S., Dharmadi., West, R. J., Buckworth, R., Sadiyah, L., Faizah, R., Sulaiman, P. S., & Sumiono, B. (2012). Tanjung Luar (East Lombok) longline shark fishery (p.53). Australia: Australian National Centre for Ocean Resources and Security (Ancors).

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C. A., Chapman, D., Heithaus, M. R., Kessel, S. T., & Gruber, S. H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. *Journal Marine Policy,* 40(3):194-204.

Zainuddin, M., Safruddin., Farhum, S. A., Nelwan, A., Selamat, M. B., Hidayat, S., & Sudirman. (2015). Characteristics of potential skipjack fishing areas in Bone Bay-Flores Sea based on satellite data on sea surface temperature and chlorophyll-a in the January-June 2014 period. *Jurnal Iptek: Pemanfaatan Sumberdaya Perikanan,* 2(3):228-237.