Estimation of Yellowfinn Tuna (Thunnus albacares) Fishing Ground Based on Oceanographic Parameters in Fisheries Management Area 573, Indonesia

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Abstract: Yellowfin tuna (Thunnus albacares) is a group of large pelagic fish, one of whose habitat is in the Indonesia Fisheries Management Area (IFMA) 573. Estimation of Thunnus albacares can be done through Indonesian Weather Information for Shipping (Ina-WIS) which is a satellite image-based product from the Indonesian Agency for Meteorogical. Climatological, and Geophysics (IAMCG). The purpose of this study was to analyze the oceanographic distribution used for estimating Fishing Areas (FG) of Thunnus albacares. The research method is descriptive quantitative with oceanographic parameters used include Sea Surface Temperature (SST), chlorophyll-a concentration, and currents. Oceanographic parameter data used were taken from Ina-WIS and Aqua-MODIS data. Satellite observations were made at coordinates 110°-113° EL and 8°-9° SL as the dominant area of Thunnus albacares habitat in the eastern part of southern Java Island, one of which is Sendang Biru waters. The research obtained is based on the condition of oceanographic parameters in Sendang Biru waters can be used as FG of Thunnus albacares. Not all waters with good oceanographic parameters are followed by an increase in catches. Not all waters with good oceanographic parameters are followed by increased catches. There is a time lag for the target fish to gather in waters with good oceanographic parameters. SST conditions and chlorophyll-a concentrations in April ranged from 28.72 - 29.65 °C and 0.15 - 0.5 mg/m³ (high category). In that month, the catch of Thunnus albacares weighing >10 kg was 591 kg (<1 ton). Thus, it can be said that the occurrence of FG does not always coincide with the increasing condition of oceanographic parameters of a water body.

Keywords: FG, IFMA 573, Ina-WIS, Oceanographic, Thunnus albacares

I. INTRODUCTION

Indonesia is an archipelago with a larger water area than the land area. This causes Indonesia to be rich in fisheries potential, especially capture fisheries (Bramana et al., 2020). To regulate the management of the fisheries sector, Indonesia through MInister of Marine Affairs and Fisheries Regulation Number 18 of 2014 has divided water into 11 sectors of the Indonesian Fisheries Management Area (IFMA), including IFMA 572 and 573 (KKP, 2020). IFMA 573 covers the Indian Ocean south of Java to Nusa Tenggara, including the Sawu Sea, and the western Timor Sea (PERMEN KP, 2014). The strategic location of IFMA 573 makes the existing fisheries potential very large, especially from the large pelagic fish group (IOTC, 2021) such as yellowfin tuna (Thunnus albacares) (Agustina et al. 2019 and Fadhilah et al. 2022), bigeye tuna (Thunnus obesus) (Istnaeni et al. 2023), skipjack (Katsuwonus pelamis) (Arrate et al. 2021), and mackerel tuna (Euthynnus affinis) (Kusdiantoro et al. 2019).

The migration pattern of a fish species is very important to study and know in order to determine which waters are potential fishing grounds. In general, fish migrate for two reasons, namely foraging and reproduction (Simbolon, 2019). Fish move from one body of water to another to find food, and find mates in order to reproduce. Thunnus albacares as part of the large pelagic fish group, not only migrates to tropical waters such as Indonesia but also includes subtropical regions such as Australia (Hampton, 2010). In eastern Indonesian waters, Thunnus albacares spreads in the Banda Sea, Halmahera, Maluku, Sulawesi, northern Pacific Ocean waters, Flores Sea, Makassar Strait, and Bone Bay (Haruna et al. 2018; Safruddin et al., 2019), then moves to the east of southern Java Island. Large pelagic migration patterns in IFMA 713 were detected in January-February (Seloi et al. 2019), while in IFMA 573 and 572 were detected or caught in May-June (Safruddin et al., 2020). In addition to migration patterns, the distribution of Thunnus albacares can also be influenced by the condition of oceanographic parameters (Simbolon, 2011; Baharuddin et al. 2022) such as Sea Surface Temperature (SST) conditions and chlorophyll-a distribution in a body of water (Zainuddin et al. 2017 and Nursan et al. 2022).

Thunnus albacares is a fish of high economic value both domestically and abroad. Indonesia as a member country of the Indian Ocean Tuna Commission (IOTC) is one of the largest tuna producers in the Indian Ocean (IOTC, 2018). The high local and international demand makes fishermen compete in catching. In Indonesia, fishermen use purse seine gear (Kunarso et al. 2005; Nasution, 2017), longline (Sari et al. 2020), huhate (pole and line), handline (Kantun et al. 2014) and tonda fishing rod (Khikmawati et al. 2019) to catch Thunnus albacares considering the nature of the fish swimming in the water column that is not too deep ranging from 0-250 m (Nurdin, 2017). Thunnus albacares with a swimming speed of 80km / hour is often found schooling together with bigeye tuna (Thunnus obesus) due to the similarity of swimming layers compared to other types of tuna such as bluefin tuna (Thunnus maccoyii) (Rahmawati et al. 2013). Oceanographic parameters play an important role in the process of forming Fishing Ground (FG) in a body of water, which is a factor in fish abundance by influencing fish behavior in foraging, spawning, and survival. Oceanographic parameters vary widely such as the distribution of SST, chlorophyll-a concentration, currents, salinity, etc. Oceanographic conditions can be used as indicators to determine whether a body of water is classified as fertile or infertile (Nurdin et al. 2018), where these conditions can lead to other phenomena such as thermal fronts and upwelling. Information related to oceanographic parameters such as SST distribution and chlorophyll-a concentration can be obtained using satellite imagery, one of which is the Aqua-MODIS satellite. This satellite is commonly used in the field of fisheries (Anugrah et al. 2023). because it has high-quality resolution thanks to the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor (Wulandari et al. 2019) so that the satellite image data produced is more accurate than other satellites. In addition to Aqua-MODIS, the Indonesian Agency for Meteorogical. Climatological, and Geophysics (IAMCG) through Ina-WIS also provides information related to oceanographic parameters such as currents, waves and wind. Ina-WIS or Indonesian Weather Information of Shipping is able to present data related to impact-based weather forecasts so that it not only supports fishing activities in terms of determining potential waters but also the safety of fishermen (Prasetyo et al. 2022).

FG of Thunnus albacares is highly dependent on oceanographic factors in the surrounding waters (Zainuddin et al. 2013) and stock abundance in nature. A body of water can be said to be a FG if it has oceanographic conditions that match the preferences of the target fish. Thunnus albacares is a cold-blooded fish (poikilothermic), where its body temperature always adjusts to the temperature of the surrounding waters (Hartoko et al. 2013), so it is important to know the amount of water temperature that supports its life activities. Thunnus albacares is generally found at depths below 500 m (Brill et al. 2005) with temperatures around 20-26°C (Cai et al. 2020). In addition to temperature, another factor that affects the abundance of tuna in a body of water is the concentration of chlorophyll-a, which determines the waters can be used as a feeding ground. Chlorophyll-a contained in phytoplankton as the first primary producer is important for the survival of small fish which are the food of large pelagics such as tuna. This study aims to determine FG in parts of IFMA 573 by analyzing the distribution of oceanographic parameters. Information related to FG is very important, especially for fishermen as the main actors in the fishing business. In addition, this research is also expected to be able to perfect previous studies and can be used as a reference for future research. The use of Ina-WIS IAMCG in determining FG can be used as another alternative to the commonly used Aqua-MODIS satellite image data.

II. LITERATURE REVIEW

A. Productivity of water based on chlorophyll-a concentration.

The productivity of aquatic environments is highly dependent on the concentration of chlorophyll-a, which is the main pigment in phytoplankton. Phytoplanktons are autotrophic organisms that serve as the foundation of the marine food chain, as they produce food for other organisms as a result of their photosynthesis (Garini et al. 2021). An increase in chlorophyll concentration in a body of water generally indicates a higher abundance of phytoplankton. With the high concentration of chlorophyll-a, it can become a fishing ground for small fish, which in turn become food for yellowfin tuna. Based on the levels of chlorophyll-a concentration by Hatta (2010), chlorophyll-a based on its concentration is divided into 3 (three) categories, namely high, medium, low, with consecutive values <0.07 mg/m^3; 0.07-0.14 mg/m^3; and >0.14 mg/m^3.

B. The relationship between oceanographic parameters and fishing grounds.

Oceanographic parameters significantly influence the presence of fishing grounds. Sea Surface Temperature (SST), currents, and chlorophyll-a concentration are three of the many oceanographic parameters that influence fishing areas. The oceanographic parameters used in this study have been adjusted to align with the research subject, namely yellowfin tuna. Yellowfin tuna live and migrate to water areas with temperatures that match their preferences.

Additionally, the distribution of yellowfin tuna can also be influenced by the presence of food sources (chlorophyll-a) carried by ocean currents. Areas with nutrient-rich currents tend to have abundant fish populations, which then have the potential to become fishing grounds (Harahap et al. 2019; Marpaung et al. 2022). Pailin et al (2019) in their research explain that the concentration of chlorophyll-a in a body of water does not directly influence the increase in fish schools in that water; there is a time lag between these events.

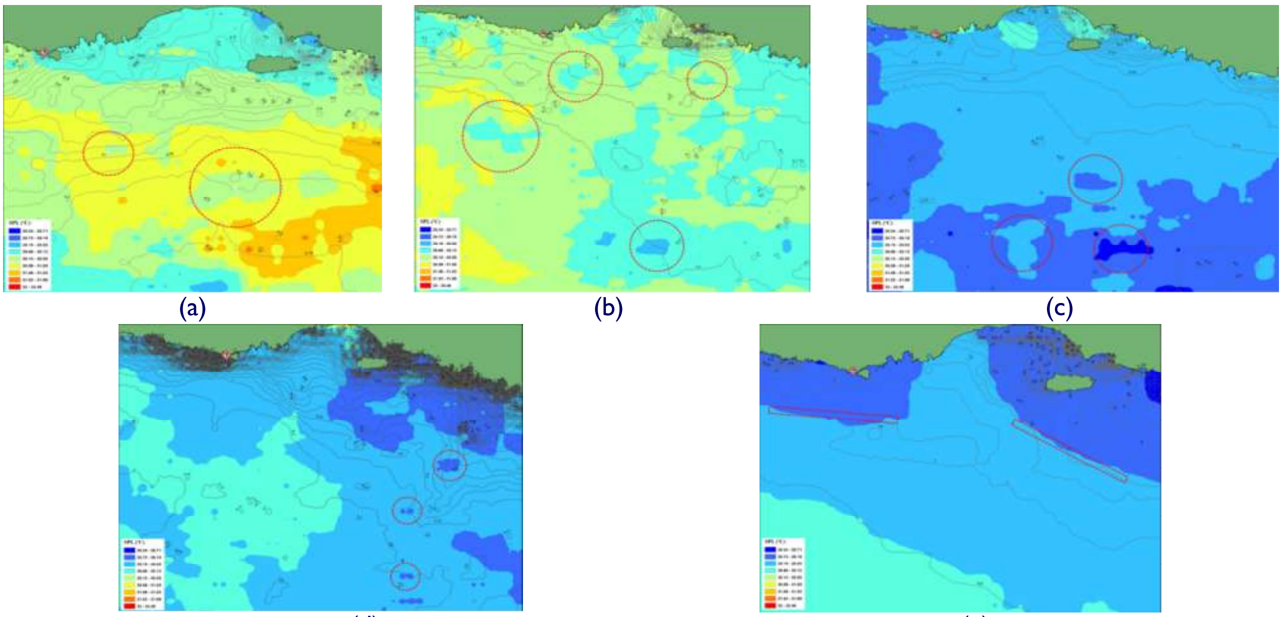
III. METHODOLOGY

This research was conducted in Sendang Biru waters in March-May 2024 using descriptive quantitative methods. Quantitative method with a descriptive approach aims to describe and analyze numerical data obtained from research in a systematic and objective way. This approach is used to explain the characteristics of existing events or phenomena without making generalizations from existing data. Sendang Biru waters are used as the location of satellite observation, which is a representation of part of IFMA 573, which is located at 110-113° EL and 8-9° SL. In addition, Sendang Biru is the location where *Thunnus albacares* is caught, which is more dominant than other waters included in IFMA 573. The data used in this study consisted of secondary data, including image data of SST and chlorophyll-a concentration, and currents with the period January-May 2024. SST image data and chlorophyll-a concentration were obtained from the Aqua-MODIS Level 3 satellite and current data were obtained through Ina-WIS IAMCG. The data obtained is then processed with the aim of correcting and modifying so that it can be presented and identified. The identification results can then be used to determine the FG of *Thunnus albacares* based on oceanographic parameter analysis.

IV. RESULT AND DISCUSSION

A. Distribution of STT and Chlorophyll-a

An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it. Sea Surface Temperature (SST) is a unit that expresses the amount of heat present above the surface of sea water. SST has a direct influence on fish distribution and abundance in a body of water. Thunnus albacares has a poikilothermic or cold-blooded nature. This requires fish to adapt to the temperature of the surrounding waters. If the waters have a higher temperature than the temperature profile that can be tolerated, then Thunnus albacares will migrate to waters with lower temperatures or in accordance with the desired temperature profile (Fauziah et al., 2020). Chlorophyll-a is one type of chlorophyll that can be found in all types of phytoplankton. Chlorophyll-a is an important parameter that affects the fertility of a body of water.



(a) (b) (c)

(d) (e)

Figure 1. Distribution of SST and chlorophyll-a January-May 2024 in Sendang Biru Waters.
Note: Red Circle = Thermal Front.

As shown as Fig.1 , the values of SST and chlorophyll-a can be seen. The concentration of chlorophyll-a in the open water has a smaller value than the coastal waters. This is because coastal waters get nutrient supply from land. This statement is reinforced by Sihombing et al. (2013), horizontally more chlorophyll-a content is found in waters closer to the coast, because of the unlimited supply from the mainland. This supports phytoplankton to carry out photosynthetic activities. SST has an inversely proportional relationship with depth, where the magnitude of SST will decrease as the depth of a body of water increases. SST can also have an influence on the occurrence of the thermal front phenomenon. This phenomenon can be used as an indicator that a body of water can be said to be a potential FG or not. The thermal front phenomenon is characterized by a lower temperature than the temperature of the surrounding waters which forms a gradient ranging from 0.5-1°C.

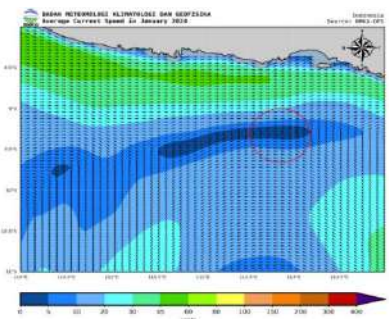
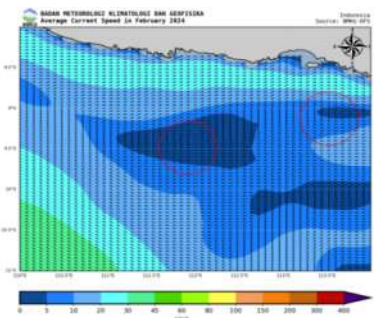
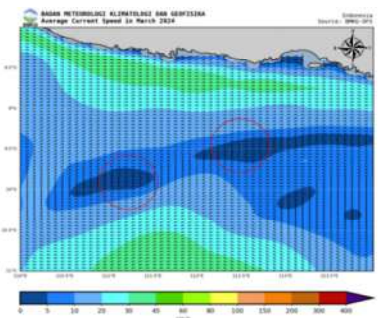
Panggabean et al. (2018) in their research argue that the thermal front is characterized by the meeting of two high-temperature water masses with low-temperature water masses, which have a clearly visible temperature gradient. SST and chlorophyll-a have different values every month (Table 1).

Table 1- Distribution of SST and chlorophyll-a January-May 2024

Bulan	**Parameter Oseanografi**	
	Klorofil-a (mg/m³)	**SPL (°C)**
Januari	0,15 - 0,35	29,66 - 31-99
Februari	0,25	29,66 - 30,58
Maret	0,15 - 0,4	28,24 - 29,62
April	0,1 - 1,2	28,72 - 29,651
Mei	0,5 - 4,6	28,00 - 29,55

B. Distribution of Current Direction and Velocity

Current or sea current is the movement of a mass of water from one place to another caused by force acting on the mass of water. One of the forces that can cause currents is wind. The movement of the current begins with the difference in the intensity of solar radiation at sea level which then causes a difference in air pressure from one place to another so that air can move from high pressure areas to low pressure areas (Aziz, 2006). Currents play an important role in the dynamics of the distribution of other oceanographic parameters such as SPL and chlorophyll-a. In addition, currents can also affect the behavior of fish migration and spawning.

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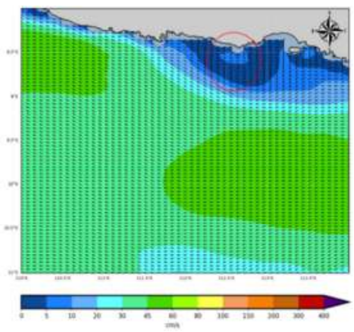

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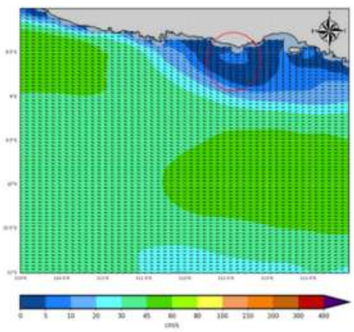

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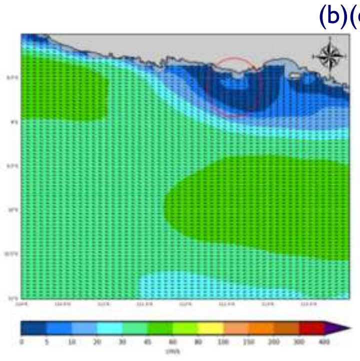
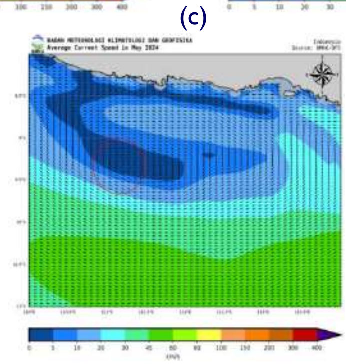

(d)(e) Figure 2. Distribution of Current Direction and Velocity Januari-Mei 2024 in Sendang Biru Waters

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Note: Red Circle = Upwelling.

The currents have different directions and speeds each month (Fig. 2). Cyclonic rotating currents can be used as one indicator of determining DPI from the upwelling phenomenon that occurs. This is also reinforced by Zhao et al. (2009) that water areas crossed by tropical cyclonic currents allow vertical movement of water masses rich in nutrients to the surface layer to form upwelling. The upwelling phenomenon is an event where there is a movement of water masses from the lower water column that carries nutrients to fill the void at the surface.

Upwelling is closely related to chlorophyll-a concentration. Chlorophyll-a concentrations can be used to predict where fish gather because chlorophyll-a acts as the first food chain producer in the ocean ecosystem (Gaol et al., 2018).

C. Distribution of Thunnus albacares Caught in IFMA 573

The distribution of Thunnus albacares in the ocean can be influenced by the abundance of fish caused by its migration pattern and seasonality. The migratory pattern of Thunnus albacares is influenced by oceanographic parameters mainly for foraging and spawning. Migration patterns can be divided into vertical and horizontal patterns. Vertical migration patterns are caused by variations in SST. If the water temperature conditions are anomalous, the fish will migrate to the waters with the desired depth. The fishing season of Thunnus albacares reported by Mugi et al. (2018) occurred in January-November, with the peak period in May-June and the lean period at the beginning of the West Season in December.

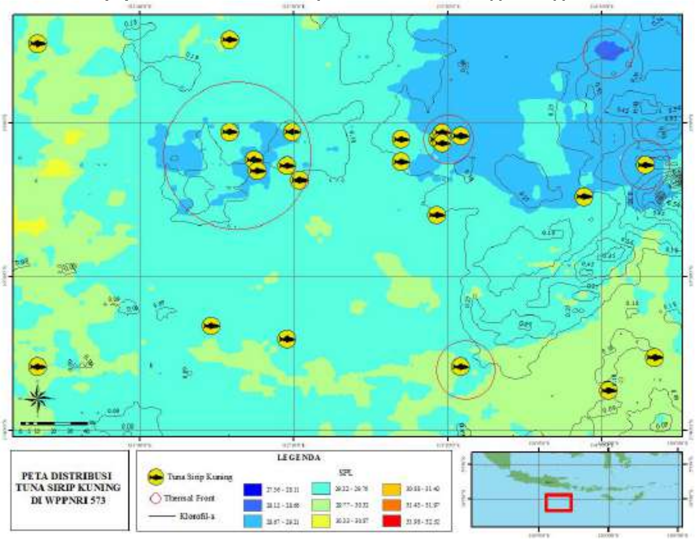

Figure 3. Distribution of Thunnus albacares Caught in IFMA 573 (Southern of Java Island)

Based on Fig. 3, the distribution of Thunnus albacares in the waters of IFMA 573 can be seen. Thunnus albacares has a temporally wide migration pattern because it is a fish with good swimming ability. The spatial distribution of Thunnus albacares can be seen from its longitude and latitude position. Thunnus albacares landed at PPP Pondokdadap, Malang were caught in the range of 8° - 9° EL, and 111° - 113° SL. This is in accordance with Wujdi et al. (2015), that the spatial distribution of Thunnus albacares using fishing gear is in the South of East Java to the Southern part of West Nusa Tenggara with coordinates of 8° - 13° EL and 110° - 120° SL

DISCUSSION

The condition of oceanographic parameters in a body of water is the main factor that influences the process of FG formation. In addition, oceanographic factors can also affect the behavior of fish in finding food, spawning, and also surviving predator attacks. Thunnus albacares migrate vertically by swimming at depths ranging from 0-250 m above sea level. Swimming layer of this fish is in the mixed layer to the top of the thermocline with a temperature range of 27-30°C. Sendang Biru waters as a representation of IFMA 573 waters have a SST between 28.72-30.12°C, and the temperature decreases with increasing depth. The temperature can be said to be in accordance with the preferences of Thunnus albacares temperature profile reported in Kantun et al. (2014) that Thunnus albacares was found below the mixed layer and above the thermocline at 18-31°C with a depth of more than 100m. Chlorophyll-a as the first food chain constituent of *Thunnus albacares* has an important role to collect fish in a water area. Sendang Biru waters have a high concentration of chlorophyll-a category (Hatta, 2010) so that it can be a food supply in the form of phytoplankton. The existence of phytoplankton as the first primary producer is what will later bring abundance in a water area, especially planktivore fish. Furthermore, planktivore fish that have gathered can be used as FG for carnivore group fish. This is related to the trophic level of food which is then related to the food commonly eaten (food habit) and eating habits in fish (feeding habit). Information related to food habit and feeding habit can be used to determine fish gathering areas or DPI. Currents affect the distribution of SST and chlorophyll-a, both of which influence the migration and spawning behavior of fish. Furthermore, the migratory and spawning behavior of fish influences the success rate of new recruitment and fish abundance. Oceanographic parameters have direct and indirect relationships to *Thunnus albacares*'s FG. SST and chlorophyll-a concentration have a direct effect on the formation of FG, while currents have an indirect effect. SST and chlorophyll-a concentration contribute directly to fish abundance and fish presence in a body of water. Furthermore, currents contribute to the distribution of SST and chlorophyll-a concentration. This is in line with the research of Ekayana et al. (2017), the distribution of fish in a water area is not only influenced by one factor of oceanographic parameters. It is possible that the distribution of tuna species in one place is dominantly influenced by SST and chlorophyll-a concentration, while other areas can also be influenced by wind, wave, and current conditions.

V. CONCLUSIONS

Based on oceanographic parameters, Sendang Biru waters can be used as a FG for Thunnus albacares. The best SST conditions and chlorophyll-a concentrations occur in April, ranging between 28.72 - 29.65 °C and 0.15 - 0.5 mg/m³ (high category). In that month, the catch of Thunnus albacares weighing >10 kg was 591 kg (<1 ton).

Thus, it can be said that the emergence of FG does not always coincide with improving oceanographic parameter conditions of a body of water, and not all waters with good oceanographic parameters are followed by an increase in catches. There is a pause for the target fish to gather in waters with good oceanographic parameters. This naturally occurs in all types of fish, including carnivore fish such as Thunnus albacares, to prey on other fish that are below the food chain.

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