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Research Article

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Fishing season estimation for tuna troll line fishing fleet at Palabuhanratu Nusantara Fishing Port, Sukabumi, Indonesia

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ABSTRACT

Indonesia covers over 15% of global tuna production. This has placed Indonesia as the top tuna-producing country in the world. Troll line is one of the fishing fleets that targets tuna as main catch, operates in many areas in Indonesia, including those bases at Palabuhanratu Nusantara Fishing Port in Sukabumi. Fishermen complained about uncertain changes of the fishing season in recent years. This causes fishermen unable to determine the right time for fishing. Some trolling fishermen suffer losses and even bankruptcy. This study tried to estimate fishing season for trolling fleets based on three main catch commodities: skipjack tuna, yellowfin tuna, and bigeye tuna. Data on catches and fishing trips are collected monthly from 2018 to 2022 from the Sukabumi Regency Central Capture Fisheries Statistics Agency. Data was processed using a catch-per-unit effort approach followed by a fishing season index analysis. Results show that the three main catch commodities have similar fishing season patterns. Peak fishing season is from the beginning of the east season in June to the middle of the second transition season in October. Productivity of the three commodities reached its lowest point in the lean season in January and February, in the middle and end of the west season.

Keywords: catch composition, fishing season, productivity, tuna.

ABSTRAK

Produksi tuna Indonesia mencapai 15% dari total produksi tuna dunia. Hal ini menjadikan Indonesia sebagai negara penghasil tuna terbesar di dunia. Pancing tonda yang merupakan salah satu armada penangkapan ikan yang menargetkan tuna sebagai hasil tangkapan utama, beroperasi di berbagai wilayah Indonesia, termasuk di PPN Palabuhanratu, Sukabumi. Nelayan mengeluhkan perubahan musim penangkapan yang tidak menentu dalam beberapa tahun terakhir. Hal ini menyebabkan nelayan tidak dapat menentukan waktu yang tepat untuk melakukan operasi penangkapan. Beberapa nelayan pancing tonda mengalami kerugian bahkan kebangkrutan. Penelitian ini mencoba mengestimasi musim penangkapan untuk armada pancing tonda berdasarkan tiga komoditas tangkapan utama yaitu cakalang, tuna sirip kuning, dan tuna mata besar. Data hasil tangkapan dan jumlah trip penangkapan dikumpulkan setiap bulan sejak tahun 2018 hingga 2022 dari Badan Pusat Statistik Perikanan Tangkap Kabupaten Sukabumi. Data diolah dengan pendekatan hasil tangkapan per satuan upaya tangkap yang dilanjutkan dengan analisis indeks musim penangkapan. Hasil penelitian menunjukkan bahwa ketiga komoditas tangkapan utama tersebut memiliki pola musim penangkapan yang hampir sama. Musim puncak penangkapan terjadi pada awal musim timur di bulan Juni hingga pertengahan musim peralihan kedua di bulan Oktober. Produktivitas ketiga komoditas tersebut mencapai titik terendah pada musim paceklik di bulan Januari dan Februari, di pertengahan dan akhir musim barat.

Kata kunci: komposisi, musim penangkapan, produktivitas, tuna.

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1. Introduction

Indonesia's tuna production is a potential food resource recognized worldwide. The average increase in Indonesian tuna production in 2017-2021 is 12% yearly. In 2021, Indonesia's tuna production will reach 343,393 tons. This value puts Indonesia at the top of the world tuna producer ranking. This value even far exceeds several other competing tuna-producing countries. The value of Indonesian tuna production is twice as high as that of Japanese tuna production, ranked 2nd as the world's tuna supplier. The value of Japanese tuna production was recorded at 137,685 tons in 2021 (MMAF, 2021).

Indonesia's tuna production is stated to decline by 16% in 2022 compared to the previous year. However, Indonesia remains firmly established as the number 1 producer of tuna commodities and controls 15% of the world's total tuna supply (MMAF, 2022). The Ministry of Fisheries and Marine Affairs of the Republic of Indonesia (2022) recorded that Indonesia's tuna production in 2022 was 301,799 tons with a monetization value of IDR 10.77 trillion. World market demand for tuna commodities is also very promising in several countries, such as the United States, Spain, Italy, France, Germany, Canada, the Netherlands, and several other countries (FAO, 2023). The total domestic tuna absorption is also quite promising. It is recorded that the total absorption of tuna, skipjack, and cob products in Indonesia in 2022 is 1.5 million tonnes and is the main commodity in the seafood group that is in demand (MMAF, 2022).

Five tuna species are often found in Indonesian waters, including bigeye, yellowfin, skipjack, albacore, and southern bluefin tuna (Muawanah et al., 2021). Generally, tuna in Indonesia is caught from direct fishing in sea waters (Sunoko & Huang, 2014). Fishermen in Indonesia operate several types of tuna fishing gear, such as troll line, tuna longline, pole and line, purse seine, gill net, and several other types of fishing gear (Proctor et al., 2019).

The troll line is a fishing fleet that targets sizeable pelagic fish and fast swimmers, such as tuna, as its main catch (Annida et al., 2021). Troll lines are quite common in various fishing ports in Indonesia, including the Palabuhanratu Nusan-tara Fishing Port. Until the end of 2022, troll lines always occupy >20.8% of the total active fishing fleet at the Palabuhanratu Nusantara Fishing Port (CSA, 2022). However, the Sukabumi Regency Maritime and Fisheries Service noted a decreasing trend in the troll line fishing fleet operating at the Palabuhanratu Nusantara Fishing Port in the last ten years. Several fishermen complained that there were irregular changes in the fishing season, resulting in mistaken decisions about the time of fishing operation. This caused significant losses for several units of the trolling fleet. This condition indicates the need for research on evaluating and estimating fishing seasons to avoid mistakes in determining appropriate fishing time decisions (MFS, 2022).

Research on fishing season estimates was widely conducted in Indonesia for several fish commodities caught by specific fishing fleets (Fadhilah & Dewinta, 2021; Ginting et al., 2022; Hasugian et al., 2023; Imron et al., 2022; Rahmah et al., 2022; Ridwan et al., 2022). Research on fishing season estimates for trolling fishing fleets based on a simple approach of catch value per unit effort was executed by Wahju et al., (2013) through monthly data series for 2007-2011 collected by Fitria (2012). Nurdin et al., (2015) continued their study of special fishing season estimates for yellowfin tuna from troll line fleets through monthly data series for 2008-2014. Based on research that was finished previously, we are trying to carry out the latest evaluation of the fishing season for several main fish commodities caught from the trolling fleet. We focus on three main spceies of catches in the tuna commodity: bigeye, skipjack, and yellowfin. It is hoped that the results of this research can become the latest reference for determining the fishing season for the trolling fleet at the Palabuhanratu Nusantara Fishing Port.

2. Materials and methods

This research was conducted at the Palabuhanratu Nusantara Fishing Port, Sukabumi, Indonesia. The object of the study was the trolling fishing fleet that fished in the area of 105°30’52”-106°50’57” East Longitude and 6°59’58”-8°22’55” South Latitude of the Indian Ocean. The focus of the study was the catch of three commodities that were the main catch targets. The three commodities in question were bigeye tuna, skipjack tuna, and yellowfin tuna. Data on catch series and fishing trips were collected monthly from 2018 to 2022. Data on the number of catches and fishing trips were obtained from the Central Agency for Capture Fisheries Statistics, Palabuhanratu Archipelago Fisheries Port, Sukabumi, Indonesia. Both data were used in productivity analysis through the catch per unit effort approach, catch composition analysis, and fishing season estimation for the three main fish commodities caught.

2.1. Catch Productivity

Sampling was was conducted at three The catch productivity of the troll line fishing fleet for the three main catch commodities was analyzed using a catch per unit effort approach, using a formulation based on Gulland (1983).

$$CPUE_i = \frac{Catch_i}{Effort_i}$$

Where $CPUE_i$: number of catches per unit effort at time-i (Kg/trip); $Catch_i$: number of catches at time-i (Kg); and $Effort_i$: the number of fishing attempts in this case is the number of fishing trips in the period..

2.2. Catch Composition

The productivity value of the catch for each commodity was used to calculate the main catch's composition value. The composition of the catch was analyzed to determine the proportion of each commodity caught at a particular time. The composition of the catch is calculated using a formula referring to Krebs (2014).

$$Catch\ composition_i = \frac{B_i}{B} x100\%$$

The catch composition value was presented in percentage units, where B_i is the number of catches of species-i, and B is the total number of main catches. Both have weight units (Kg).

2.3. Fishing Season Index

The estimated fishing season was analyzed using the fishing season index approach based on the monthly catch productivity data series for five years from 2018 to 2022. This monthly data series has then calculated using moving average values, referring to Imron et al., (2022). There are at least six main steps in analyzing the fishing season index using a moving average value calculation approach.

1). Arrange a data series of $CPUE_i$ from January 2018 until December 2022.

$$n_i = CPUE_i$$

Where is the monthly series value of catch per unit effort in sequence-i and i is the monthly data series sequence: 1, 2, 3, …., 60.

2). Arrange moving average CPUE for every 12 months (MA)

$$MA_i = \frac{1}{12}\left(\sum_{i=i-6}^{i+5} CPUE\right)$$

Where MA_i: moving average 12 month sequence-I; CPUEi: CPUE sequence-I; and i: 6, 7, …, n-5.

3). Arrange moving average centered CPUE (MAC)

$$MAC_i = \frac{1}{2}\left(\sum_{i=i}^{i=1} MA_i\right)$$

Where MAC_i: moving average centered CPUE sequence-I; MA_i: moving average 12 months sequence-i; and i: 7, 8, ..., n-5.

4). Arrange Month Average Ratio (MAR)

$$MAR_i = \frac{CPUE_i}{MAC_i}$$

Where MAR_i: month average ratio-I; $CPUE_i$: CPUE sequence-I; and i: 6, 7, ..., n-5.

5). Arrange the average value in a matrix of size ixj for each month of each year. Then, calculate the monthly ratio average value and the overall average total value.

a. The average ratio for sequence month-i ($ARSM_i$)

$$ARSM_i = \frac{1}{n}\left(\sum_{j=1}^{n} ARSM_{ij}\right)$$

Where $ARSM_i$: average ratio for sequence month-I; $ARSM_{ij}$: average ratio for sequence month i x j; i: 1, 2, ..., 12; j: 1, 2, 3, ..., n.

b. Total of month average ratio (TMAR)

$$TMAR = \sum_{i=1}^{12} ARSM_i$$

Where TMAR: total month average ratio; $ARMS_i$: average ratio for sequence month-i; i: 1, 2, ..., 12.

c. Calculate the correction factor

Ideally, the TMAR value is 1200. However, there are often slight differences due to several factors which cause the TMAR value not to be exactly 1200. Therefore, the TMAR value needs to be corrected into a correction factor (CF) value with the formula:

$$CF = \frac{1200}{TMAR}$$

6). Calculate the fishing season index

After the correction factor (CF) value and average monthly ratio value ($ARSM_i$) are obtained, then calculate the fishing season index value using the formula:

$$FSI_i = ARSM_i \ x \ CF$$

Where FSI_i : fishing seasonal index sequence-i; $ARSM_i$: average ratio for month sequence-i; i : 1, 2, ..., 12. The FSI value can be used to recommend suitable fishing times for certain caught commodities in a fishing fleet. Referring to Zulkarnain et al., (2012), an FSI value >100% indicates the peak fishing season. FSI values between 50-100% indicate a normal fishing season. An FSI value <50% suggests a lean season that is not recommended for fishing activities.

3. Results and Discussion

3.1. Results

3.1.1. Catch Productivity

The productivity of the three fish commodities caught from the trolling fleet is presented in annual and monthly catch per unit effort calculations. Based on annual productivity values, there are different trends for the three main catch commodities (Figure 1). Skipjack tuna has a fluctuating pattern and trend that tends to increase, especially in the last two years. The productivity of skipjack tuna catches was highest in 2022 (421.3 Kg/trip) and lowest in 2018 (164.7 Kg/trip). Yellowfin tuna fluctuates, with the highest value in 2020 (296.1 Kg/trip) and the lowest in 2021 (178.9 Kg/trip). The bigeye tuna commodity has a pattern that tends to decline in the last three years. The productivity of bigeye tuna catches had the highest value in 2019 (47.6 Kg/trip) and its lowest point in 2022 (28.3 Kg/trip).

The monthly average values for the productivity of the main catch for the three commodities have almost the same pattern. In general, the productivity value of catches for the three main catch commodities reached its highest point in July and August and was at its lowest in January (Figure 2). Skipjack tuna has

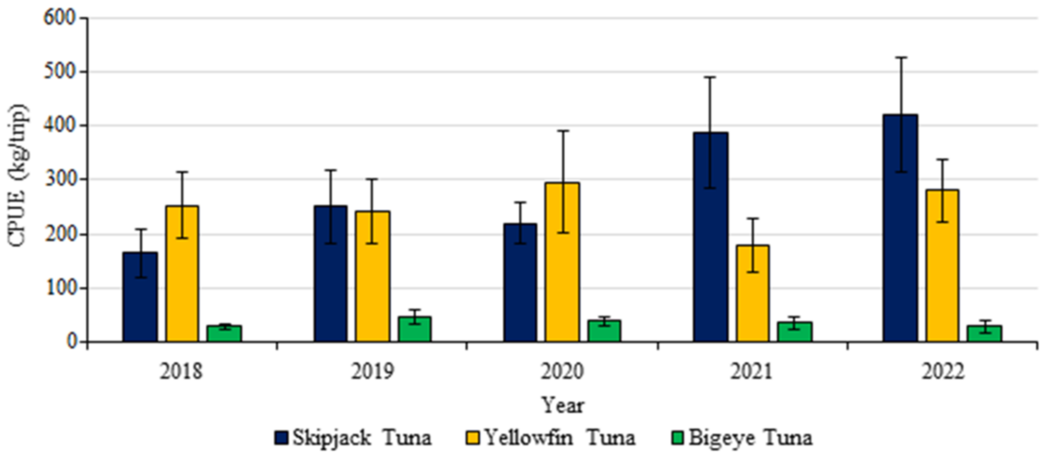

Figure 1. Productivity of the main catch of the troll line fishing fleet in 2018-2022.

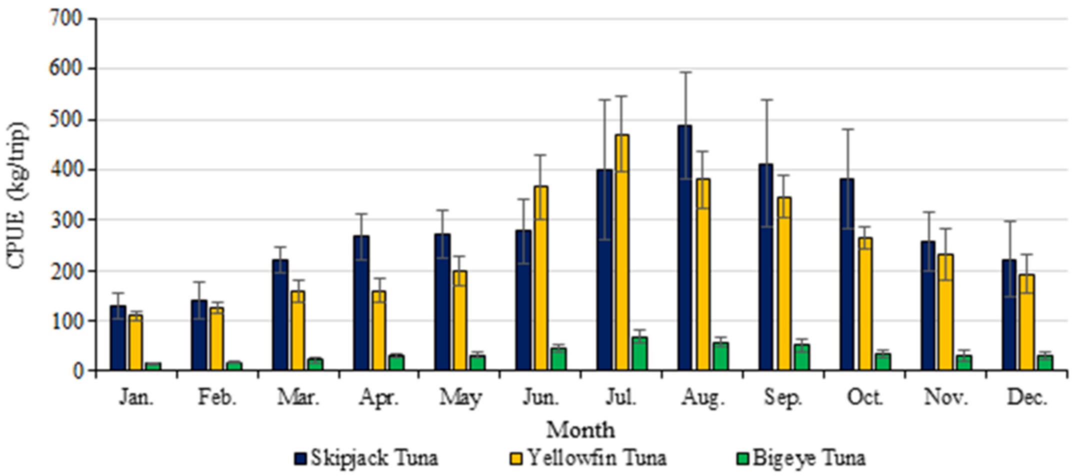

Figure 2. Average monthly main catch productivity of the troll line fishing fleet

the highest productivity value in August (488.1 Kg/trip) and the lowest in January (127.4 Kg/trip). The yellowfin tuna commodity has the highest peak productivity value of catches in July (470.7 Kg/trip) and the lowest in January (109.4 Kg/trip). A similar pattern also occurred in the bigeye tuna commodity, with the highest catch productivity value in July (68.2 Kg/trip) and the lowest in January (14.3 Kg/trip).

3.1.2. Catch Composition

The composition of the main catch is also presented annually and monthly. In calculating the composition of the main catch on an annual basis, skipjack tuna dominates, followed by yellowfin tuna (Figure 3). The proportion of catch for bigeye tuna was always the lowest every year. The annual average composition for each main catch commodity were skipjack tuna (52.1%), yellowfin tuna (41.5%), and bigeye tuna (6.4%).

Based on monthly calculations, the composition of the main catch has a picture structure that is not very different from the annual presentation. The proportion of the main catch was still dominated by skipjack tuna (50.9%), followed by yellowfin tuna (42.9%). Meanwhile, bigeye tuna still has a lower catch proportion with an average composition of 6.2% (Figure 4).

3.1.3. Fishing Season Index

The fishing season index calculation results show almost the same distribution pattern in the three fish commodities (Figure 5). The peak fishing season is from the beginning of the east season in June to the middle of the second transition season in October. The lean season for the three commodities were in January and February, which are included in the middle and end of the west season (Table 1).

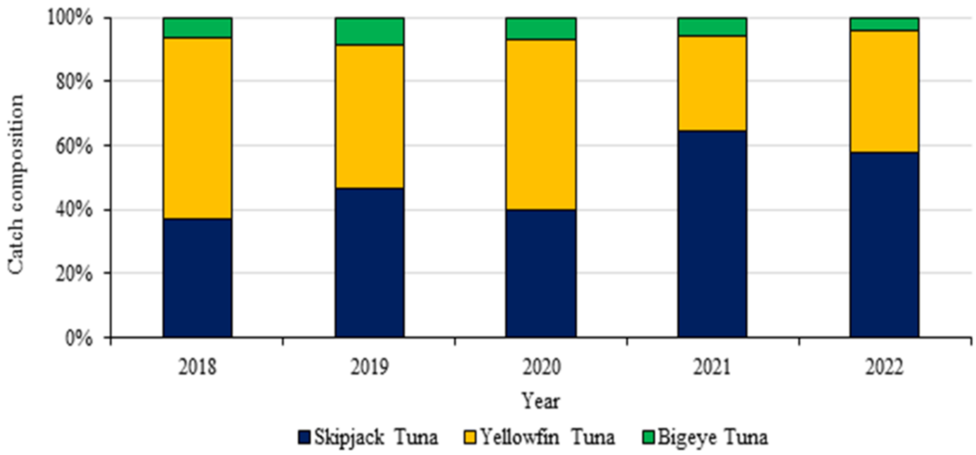

Figure 3. Composition of the main catch of the troll line fishing fleet in 2018-2022.

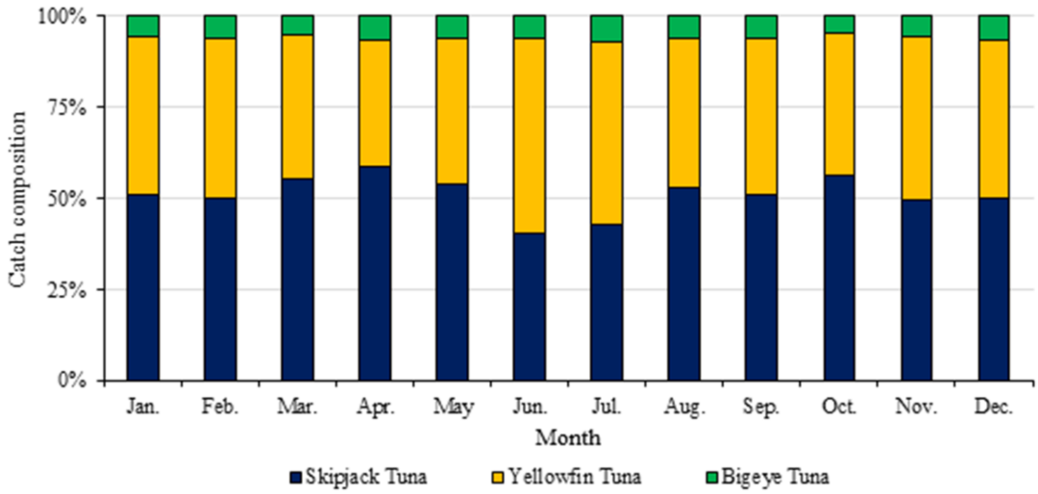

Figure 4. Average monthly composition of the main catch of the troll line fishing fleet

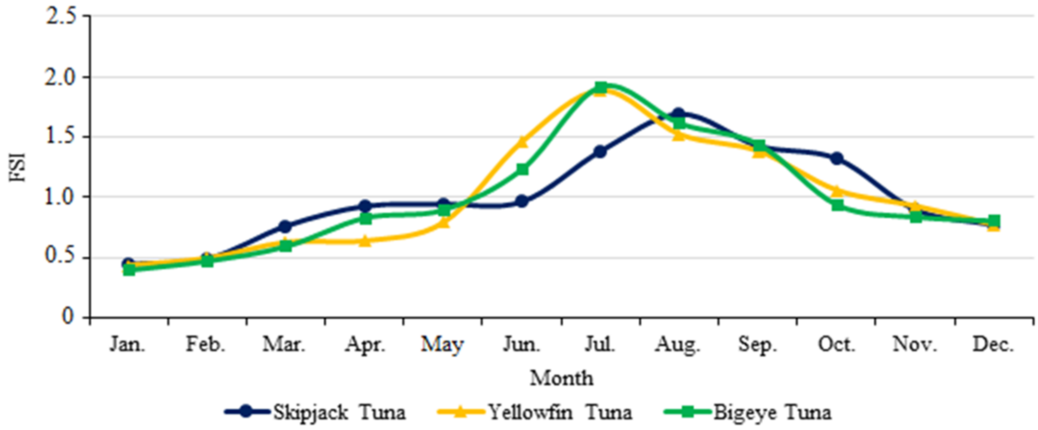

Figure 5. Fishing season index of the main catches of the troll line fishing fleet.

Table 1. Fishing season index and the relationship between seasons in Indonesia

Month	FSI (%)			Seasons in Indonesia (Wahju *et al.*, 2012)
	Skipjack Tuna	Yellowfin Tuna	Bigeye Tuna	
Jan.	44.18	43.76	40.17	West / rainy season
Feb.	48.70	49.64	47.60	West / rainy season
Mar.	76.06	62.80	59.81	Transition season I
Apr.	92.44	63.97	83.34	Transition season I
Mei	94.03	79.28	89.93	Transition season I
Jun.	96.31	146.31	123.66	East / dry season
Jul.	138.52	188.34	191.58	East / dry season
Aug.	169.19	152.00	161.22	East / dry season
Sep.	142.58	138.23	144.00	Transition season II
Oct.	131.89	105.78	93.96	Transition season II
Nov.	89.28	92.74	83.90	Transition season II
Dec.	76.81	77.15	80.81	West / rainy season

Note :
- (red) Lean fishing season
- (yellow) Normal fishing season
- (blue) Peak fishing season

3.2. Discussions

Troll lines are one of the fishing fleets often found in various fishing ports in Indonesia, such as at the Palabuhanratu Nusantara Fishing Port, Sukabumi (Annida et al., 2021). Trolling line are widely known as one of the fishing fleets that target sizeable pelagic fish with fast swimming abilities, like tuna groups (Rahmat & Ilhamdi, 2015). Apriliani et al., (2021) stated that 82% of the trolling fleet's catch came from tuna, which was the main catch. There are at least three species classified as the main catch: skipjack tuna, yellowfin tuna, and bigeye tuna (Apriliani et al., 2021).

We found that skipjack tuna has the highest proportion of the three main tuna commodities, followed by yellowfin tuna. Bigeye tuna has the smallest composition at each measurement time, both monthly and annually. Skipjack tuna is a fishery commodity often found in wide waters and has the highest distribution in tropical waters, such as in the waters south of Java, Indonesia (Suhermat et al., 2022). This fish is also reported to spawn throughout the year around equatorial waters but is seasonal in waters far from the equator (Venegas et al., 2019). Yellowfin tuna is a highly migratory fish species with a wide distribution in tropical and subtropical waters except Mediterranean ones (Pecoraro et al., 2017). This fish is susceptible to low oxygen, so it is more commonly found in surface areas and rarely below 250 meters under the sea (Holland et al., 1990; Sharp & Dizon, 1977). Yellowfin tuna are known to spawn in groups yearly, but the peak of spawning is in summer (Itano, 2001). This fish prefers warm water areas, so spawning is mainly carried out in equatorial waters such as Indonesia (Pillai & Satheeshkumar, 2012). Bigeye tuna is known to have a wide distribution in three oceans: the Indian, Pacific, and Atlantic (Sumadhiharga, 2009). Sugama (2008) reported that the Indian Ocean is an area that's a concentration of distribution and the main spawning area for this species. In other research, we also found that these three commodities were obtained as catches from the tuna longline fleet (Annida et al., 2023) and boat seine (Annida et al., 2024), which also landed fish at the Palabuhanratu Nusantara Fishing Port.

As one of the tuna fishing fleets, Troll Lines has contributed a lot of tuna products to domestic and export markets (Muawanah et al., 2021). Yuliyanah et al., (2020) stated that some of the tuna and other large pelagic fish commodities caught by the troll line fleet were exported to countries such as Japan, the United States, and several European Union countries. This condition reflects the high opportunities for capture fisheries business from the trolling fleet operating around the Palabuhanratu Nusantara Fishing Port. However, we found several facts in the field where several trolling fishermen deplore uncertain changes in the fishing season that caused errors in determining when to go to the fishing ground of the troll line armada. This is known to have caused severe impacts, such as losses and even insolvency.

Estimating the fishing season for a fishing fleet can be done using the catch per unit effort approach for several main catch commodities obtained (Ridwan et al., 2022). In the study of sustainable capture fisheries, the catch per unit effort is also known as catch productivity (Dollu & Muksin, 2019). Catch productivity is a measure that describes the amount of catch that a fishing fleet can obtain in a particular unit of effort (Mulazzani et al., 2015). The productivity of catches is often used to compare several fishing fleets to assess their effectiveness in catching a specific fish commodity (Annida et al., 2023, 2024). However, it is known that the productivity of catches can differ in particular fishing time units. In other words, the productivity of catches is not only influenced by the fishing effectiveness of a fishing fleet. Still, it is also influenced by the availability of fish resources in waters in certain seasons (Rahim & Hastuti, 2023). This is the scientific basis for the catch productivity approach of a fishing fleet, which can be used to estimate the fishing season.

We found that the monthly average value of the productivity of the three main caught fish commodities has almost the same pattern. The productivity value of catches generally reaches its highest point in July and August and the lowest in January. In line with this, the estimated fishing season value calculation also illustrates that the peak fishing season conditions for the three main catch commodities are at the beginning of the east season in June to the middle of the 2nd transition season in October. Pramuwardani et al., (2018) stated that the east season in Indonesia is marked by the blowing of the east monsoon wind, which moves from the Australian region to the Asian region. Under these conditions, Australia experiences winter, and Asia experiences summer. The east monsoon winds that move from the Australian region pass through narrow gaps and several deserts, such as Gibson, Great Australia, and Victoria, causing little rainfall in Indonesia. Therefore, Indonesia will experience a warm season or dry season (Wheeler et al., 2007). In connection with the biological characteristics of the three main catch commodities of the troll line fleet, which prefer warm water areas, the eastern monsoon conditions cause this fish to be frequently found in Indonesian waters to find food and spawn. This causes the peak fishing season for the three main catch commodities in the east season (ISSF, 2022).

The lean season for catches occurs in the middle and end of the west season in January and February. As opposed to the east season, the west season is characterized by the movement of the west monsoon winds, which move from the Asian region (winter) to the Australian region (warm season). It is known that the wind blows over large areas such as the waters of Natuna and the Indian Ocean. Therefore, the west monsoon winds bring high rainfall, causing the rainy season in Indonesia and reducing the average water temperature (Rosyidah et al., 2022). The lower average water temperature causes the concentration of the three main catch commodities to move away from Indonesian waters. This causes the lean season to occur, especially in the west season. Also, rain and storm conditions in sea waters often happen during the west season (Lee, 2015). This impacts fishermen's low level of safety at sea and the high risk of work accidents in fishing operations (Lukum et al., 2023).

The fishing season conditions of the troll line fleet that we obtained have experienced a slight shift from the results of previous research. Wahju et al., (2013) presented the results of fishing season estimates using data series of catch results from trolling fishing fleets at the Palabuhanratu Nusantara Fisheries Harbor from 2007-2011 with the peak season occurring in June-September and the lean season occurring in December-February. Meanwhile, in other research, (Nurdin et al., 2015) estimated the fishing season for the troll line fleet at the Palabuhanratu Nusantara Fishing Harbor using catch series data from 2008 to 2014, with the peak season being May-August. No months can be considered lean season (FSI>50%). This shift in the fishing season may occur due to global climate change, which causes fluctuations in the average water temperature that are often erratic (Barange et al., 2018)

4. Conclusion

Based on the analysis of the seasonal index of the three main catch commodities obtained from the fishing area 105°30’52”-106°50’57” East Longitude and 6°59’58”-8°22’55” South Latitude of the Indian Ocean, the peak fishing season for the trolling fleet occurs at the beginning of the east season in June to the middle of the second transition season in October. The productivity of the three main catches reaches its lowest point in the lean season in the middle to the end of the west season in January and February.

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