Production and fishing season of tuna landed at the Bitung Ocean Fishing Port (PPS)

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Abstract. Monthly fluctuations in tuna catches are closely related to the presence of fish or to the fishing season. Information about the tuna fishing season is important for improving the efficiency and effectiveness of tuna fishing carried out by fishermen in Bitung. Fishermen generally perform tuna fishing operations in the waters of the Molucca Sea (FMA 715) and Celebes Sea (FMA 716) and land at the Bitung Ocean Fishing Port (PPS). This study aimed to describe the dynamics of catches and fishing efforts of tuna based on PPS Bitung and determine the fishing season. The data used were sourced from PPS Bitung fisheries statistics for the 2018-2022 period. Data analysis uses catch per unit effort (CPUE) analysis and moving average method. The results of the study showed that the CPUE value of tuna in the waters of the Molucca Sea (FMA 715) and Celebes Sea (FMA 716) experienced slight fluctuations, but there was a difference in the trend of CPUE between the Molucca Sea, which tended to start decreasing, while in the Celebes Sea it tended to increase. The CPUE value of tuna in the Molucca Sea was 1.99 ton per trip in 2018 to 2.01 ton per trip in 2022. Furthermore, the value of CPUE in the Celebes Sea was 1.64 ton per trip in 2018 to 2.53 ton per trip in 2022. The tuna fishing season can occur every month and throughout the year in the Molucca and Celebes seas.
Key Words: CPUE, tuna fishing season, moving average model, PPS Bitung, FMA 715 & 716.

Introduction. The Bitung Ocean Fishing Port (PPS) is a type A fishing port that has adequate facilities to support capture fishery activities in Bitung City and is the center of tuna fishery activities in North Sulawesi, even in the Eastern Indonesian Region (Firdaus 2018). The strategic location is between the Fisheries Management Area (FMA), namely the waters of the Molucca Sea (FMA 715), and the waters of the Celebes Sea (FMA 716). Based on the Regulation of the Minister of Maritime Affairs and Fisheries Number 18 of 2014 (The Government of the Republic of Indonesia 2018), FMA 715 covers the waters of Tomini Bay, Molucca Sea, Halmahera Sea, Seram Sea, and Berau Bay, whereas FMA 716 includes the Celebes Sea and the North of Halmahera Island. According to the KKP (2024), the Molucca Sea is one of the waters that produces the most tuna fish commodities in Indonesia, apart from the waters of the Makassar Strait (FMA 713) and Flores Sea (FMA 714). PPS Bitung is a landing place for tuna caught by Bitung fishermen and from outside Bitung caught around the waters of the Molucca Sea and the Celebes Sea). The types of landed tuna are yellow fin, big eye, and albacore, but the most dominant type of yellow fin is followed by big eye and albacore. Yellow fin and big eye types are among the leading commodities in the Samudera Bitung Fisheries Port, with sustainable potential and utilization rates of 15,251 ton or 86% and 111 ton or 69%, respectively (Kusumaningrum et al 2021).

Tuna landed at the Samudera Bitung Fisheries Port is the result of fishermen using fishing units with handlines and longline fishing gear. The tuna handline fishing unit is the most dominant compared to the longline fishing unit, with each size for the handline ranging from 1-10 gross tons (GT), which is classified as small-scale fishermen, and the size of 11 GT to 64 GT which is a large-scale business; the average longline fishing unit size is 27-73 GT (PPS Bitung 2023). In general, Bitung fishermen carry out tuna fishing operations in the waters of the Molucca Sea using handline fishing gear (Dalegi et al 2020; Kusumaningrum et al 2021), while the longline tuna fishing unit operates in the northern part of the Pacific Ocean waters (Widodo et al 2011).

Tuna production sourced from FMA 715 and 716 for the last five years (2018-2022) experienced slight fluctuations. For FMA 715, it ranged from 5,771 to 7,275 tons year^{-1}, whereas in the Sulawesi Sea, it ranged from 1,388 to 2,261 tons year^{-1} (PPS Bitung 2023). Fluctuations in tuna production in both FMAs also occurred on a monthly basis. Setiawan et al (2016) and Tuyu et al (2023) stated that the distribution of tuna in the Molucca Sea and the Celebes Sea experienced peak values only in certain months or interpreted as the tuna fishing season. The distribution and abundance of tuna fish resources in water are influenced by environmental conditions (Akia et al 2021). These conditions can cause fluctuations in tuna catches; for this reason, it is necessary to conduct studies related to the right time or month for fishermen to carry out more effective and efficient tuna fishing operations and obtain maximum catches, especially to increase tuna production sourced from the Celebes Sea. This study aimed to describe the production of tuna landed at PPS Bitung and determine the pattern of tuna fishing seasons in the Molucca and Celebes seas.

Material and Method

Description of the study sites. Bitung Ocean Fishing Port (PPS) is located in the area of Aertembaga Satu Village, Aertembaga District, Bitung City, and its geographical location is located at 010 26' 42" N and 1250 12' 24" E (Figure 1). PPS Bitung is a type A fishing port that is the center of tuna capture fishery activities in North Sulawesi Province. The location of the port is strategic because it is located between fisheries management areas 715 and 716. PPS Bitung has infrastructure to support port management, namely: docks, ice factories, clean water, and fish auction sites. In addition, PPS Bitung is a place for buying and selling transactions and a starting point for the distribution of tuna to the domestic and export markets. The types of fish landed are dominated by large and small pelagic fish, namely: skipjack fish (*Katsuwonus pelamis*), tuna fish (*Thunnus*), cod fish (*Euthynnus affinis*), and kite fish (*Decapterus*).

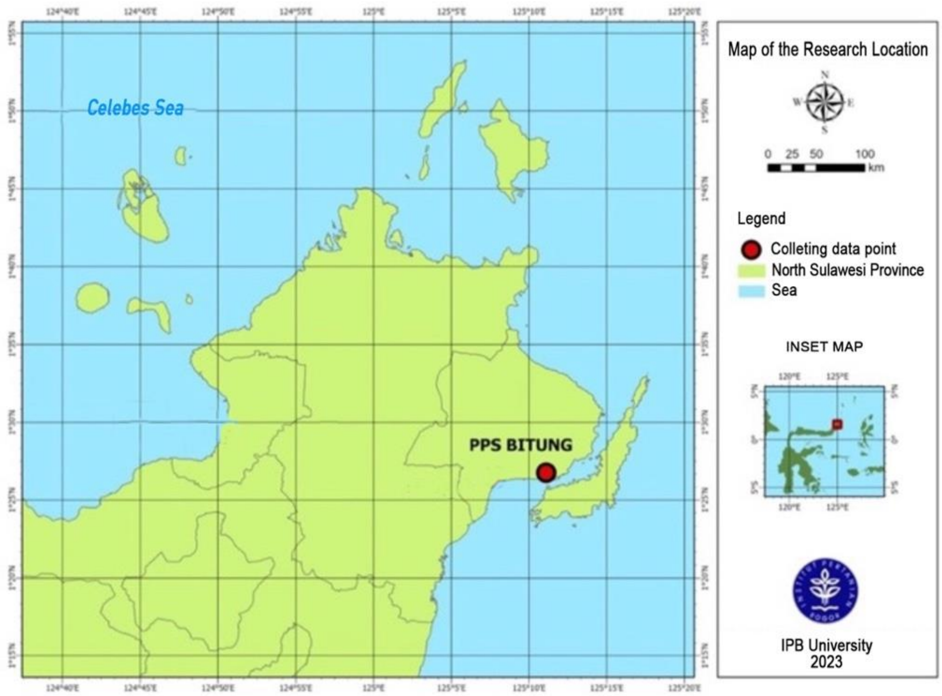

Figure 1. Research location map.

Data collection. The collection of research data was carried out in January-March 2023 at the Port of Samudera Bitung. This study focuses on tuna fishing vessel units operating in Fisheries Management Area 715. The data collected in this study are secondary data obtained from the Samudera Bitung Fisheries Port during a five-year period (2018-2022), including catch data and fishing efforts. In addition, we used data sourced from literature studies related to the research objectives.

Data analysis. Data analysis was carried out by calculating the catch per unit effort (CPUE) and fishing season index (FSI) using the moving average method. The formula used to calculate CPUE refers to Gulland (1982) and Nurani et al (2021), while calculating FSI refers to Dajan (1983) and Wiyono et al (2006).

1. Analysis of catch per unit effort. Catch and effort data are presented in the form of a table, and the CPUE value is calculated by dividing the total catch by the total number of catch attempts in a 5 year period (2018-2022).

$$CPUE = Catch/Effort$$

Where:
CPUE - catch per fishing attempt (ton trip^{-1});
Catch - catch (ton);
Effort - attempted capture (trip).

2. Standardization of fishing efforts. There are two fishing tools used to catch tuna, handline and longline, so one of them is used as a standard and the other fishing gear is standardized for fishing gear. Standardization is required because each fishing gear has different capabilities. Standardization was performed using the following formulas:

a) Fishing power index calculation

$$FPI = CPUE_{dst}/CPUE_{st}$$

Where:
FPI - fishing power index;
CPUEdst - CPUE of fishing gear to be standardized (ton trip^{-1});
CPUEst - CPUE of standard fishing gear (ton trip^{-1}).

b) Standard effort calculations

$$Fs = FPI \times Fdst$$

Where:
Fs - Efforts to capture standardized results (trips);
Fdst - Efforts to capture results to be standardized (trip).

c) CPUE analysis

$$CPUEs = Catch/Effort$$

Where:
CPUEs - catch per standardized gear of the ith fishing effort (ton trip^{-1});
Catch - catch in the ith month (ton);
Effort - efforts (trips) to catch standardized results in the ith month.

3. Fishing season index

a) The CPUEs over the five years period (2018-2022) was computed:

$$CPUEs= \sum_{i=1}^{n} CPUEsi$$

Where:
i - 1,2,3,…,n;
n - number of months.

b) The moving average of CPUE over 12 months (RG). The process of calculating the moving average begins by summing up the CPUE series for 12 months, consisting of six months before the i^{th} month, the i^{th} month itself, and five months after the i^{th} month. Next, the CPUE series that has been summed is divided by 12 to calculate the average.

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

Where:
RG_i - the moving average over 12 months related to the i^{th} month;
$CPUE_i$ - CPUE of the i^{th} month (starting from the 7^{th} month);
i - 7,8,9...., n-5 (calculated moving average from the 7^{th} to 55^{th} month);
i-6 - 6 months before the i^{th} month;
i+5 - 5 months after the i^{th} month.

c) The moving average of the centered CPUE (RGP). This stage calculates the sum of all RGi values collected from the first month to the i^{th} month, then divides the number by 2 for get an RGPi value.

$$RGPi = \frac{1}{2}\left(\sum_{i=1}^{i=1} RGi\right)$$

Where:
RGP_i - i-th centered CPUE moving average;
RG_i - 12-month moving average of the i^{th} order;
i = 7,8,9,....., n-5.

d) Average ration every month (Rb). To obtain the monthly average ratio value, the monthly CPUE value was divided by the RGP value in the same month.

$$Rbi = \frac{CPUEi}{RGPi}$$

Where:
Rbi - average ration of the i^{th} month;
$CPUE_i$ - CPUE of the i^{th} month;
RGP_i - -i^{th} month-centered CPUE moving average.

e) Build the monthly average ratio values' matrix (with the size i x j), starting from January 2018 to December 2022; count the total value of average ration in every month, and then calculate the overall total average ratio and the catching season pattern.

f) Calculate the sum of the monthly average ratio (RRB_i)

$$JRRBi = \sum_{i=1}^{12} RRBi$$

Where:
JRRbi - total monthly average ratio;
RBBi - average Rbij for month order-i;
i - 1, 2, 3, ..., 12.

g) Fishing season index. Ideally, the sum of the JRBB monthly average ratios is equal to 1200; however, owing to many factors, the JRBB value is not always equal to 1200. Therefore, the value of the monthly average ratio must be corrected by a correction value called the Correction Factor (CF).

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

Where:
CF - correction factor value;
JRBB - total monthly average ratio.

The fishing season index (FSI) can be calculated using the formula

$$FSI_i = RBB_i \text{ x } FK$$

Where:
FSI_i - fishing season index month-i;
RRB_i - average ration for a month-i;
FK - correction factor value;
i - 1,2,3....,12.

Results

Distribution of tuna fishing areas. In general, tuna fishing units that land tuna catches at the Samudera Bitung Fisheries Port carry out fishing operations in the waters of the Molucca Sea (FMA 715) and Celebes Sea (FMA 716). Figure 2 shows that the fishing operation area in the Molucca Sea is around the waters of Batang Dua Island, which is the area of Ternate City, North Maluku Province, where there are many rumpons or pontoons, as the gathering zone of tuna fishing boats from Bitung.

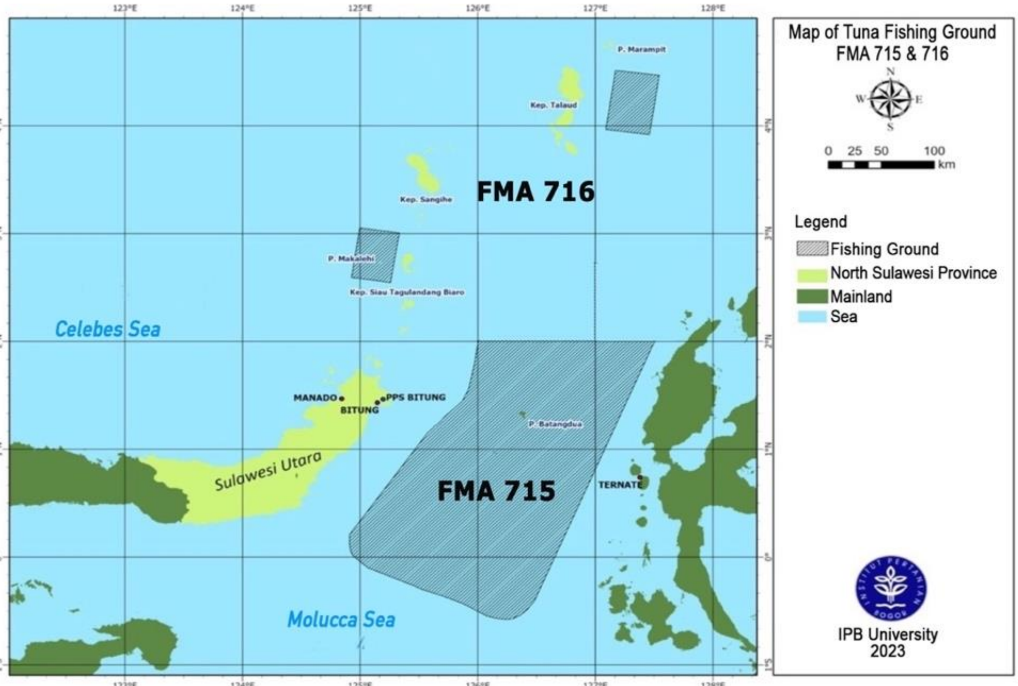

Figure 2. Tuna fishing areas at FMA 715 and 716.

Tuna fishing vessels with handline fishing gear operate a lot in these waters, while there are very few boats with longline fishing gear. Furthermore, the waters of the Celebes Sea, located in the southern part of Talaud Islands Regency, are the waters around Marampit

Island, which is a deep sea and the outermost island in North Sulawesi and borders the Philippines. These waters are the main locations for longline boat fishing operations, so the number of longline boats is higher than in the waters of the Molucca Sea (Table 1). Another location is around the waters of Makalehi Island, Siau Islands Regency, and Tagulandang Biaro (Sitaro), these waters are also scattered by several ramps and pontoons. To make it easier for fishing boat units to go to fishing areas, fishermen and boat captains mark location points using GPS devices and navigation applications available on mobile phones.

Table 1

Number of tuna fishing units based at PPS Bitung for the 2018-2022 period

Year	*Fishing Management Area (FMA)*			
	715 (Molucca Sea)		*716 (Celebes Sea)*	
	Handline (Unit)	*Longline (Unit)*	*Handline (Unit)*	*Longline (Unit)*
2018	482	7	215	10
2019	559	1	193	22
2020	620	4	154	20
2021	554	2	101	19
2022	541	4	113	19

Tuna fish production in PPS Bitung. In general, Bitung fishermen catch tuna in the Molucca Sea and Celebes Sea, which are part of the waters of FMA 715 and 716, respectively. Table 2 shows the number of monthly catches of tuna sourced from the FMA 715 and FMA 716 waters landed at the Bitung PPS.

Table 2

Tuna catches at FMA 715 and 716 for the 2018-2022 period

Month	*Catch (Ton)*									
	2018		*2019*		*2020*		*2021*		*2022*	
	FMA 715	*FMA 716*	*FMA 715*	*FMA 716*	*FMA 715*	*FMA 716*	*FMA 715*	*FMA 716*	*FMA 715*	*FMA 716*
January	395.18	107.19	413.20	165.83	555.18	162.34	364.74	110.53	304.81	103.27
February	321.92	140.01	335.54	124.44	488.03	98.78	344.40	86.65	382.72	137.06
March	473.44	177.53	650.04	239.32	562.73	136.03	420.98	123.14	571.13	108.04
April	635.13	201.91	568.54	147.59	504.94	159.49	328.67	100.81	625.24	114.36
Machine	718.22	225.26	759.00	226.09	499.40	94.75	373.70	118.29	686.02	189.47
June	361.32	143.72	457.00	114.31	452.82	125.31	499.18	117.05	599.08	145.73
July	289.31	144.16	525.38	204.90	598.07	139.85	528.93	94.81	420.85	136.95
August	545.66	177.56	285.00	79.61	347.32	86.62	523.86	111.67	448.30	100.18
September	436.32	130.27	448.35	150.51	369.70	105.98	726.76	200.17	579.06	45.83
October	661.77	265.26	706.83	198.25	704.51	174.44	679.53	108.67	644.21	88.83
November	782.13	258.61	852.59	246.42	846.23	247.25	554.23	120.50	982.17	62.42
December	850.88	290.23	829.56	224.13	660.35	138.44	426.12	101.05	1,031.52	156.27
Total	6,471.27	2,261.71	6,831.03	2,121.40	6,589.26	1,669.29	5,771.12	1,393.33	7,275.10	1,388.40

The monthly production of tuna in FMA 715 ranged from 285-1,032 tons month^{-1}, while in FMA 716 from 79.61-290.23 tons month^{-1}. The total tuna production in FMA 715 in the last five years has fluctuated slightly, in contrast to the condition in FMA 716, which continues to experience a decline in production. Total tuna production in FMA 715 in 2019 increased compared to 2018, from 6,471.27 ton to 6,831.03 ton, an increase of 6%. In 2020, there was a decrease in production compared to 2019 to 6,589.26 ton, a decrease of 4%. The decline in tuna production continued to occur in 2021 to 5,771.12 ton, a decrease of 12% compared to 2020. However, in 2022, there was a significant increase in tuna production of 7,275.10 ton or an increase of 26%. Then, tuna production in FMA 716 in 2019 decreased compared to 2018, from 2,261.71 ton to 2,121.40 ton or decreased by 6%, then in the last three years (2020-2022) it continued to decrease to 1,669.29 tons, 1,393.33 ton, and 1,388.40 ton, respectively, or decreased by 21, 17, and 0.4%, respectively.

Tuna fishing efforts at Bitung PPS. Table 3 explains the tuna fishing efforts in the trip unit at FMA 715 and 716. Tuna fishing effort at FMA 715 show an increase in the 2018-2022 period. In 2018, 3,783 trips were performed, which increased to 4, 581 trips or 21% in 2019. In 2020, the effort decreased to 4,285 trips, or 6% compared to 2019. In 2021, the effort decreased again to 4,049 trips, or 6% compared to 2020. However, in 2022, the effort increased again compared to 2021, although the increase was not remarkable, namely 4,202 trips or 4%. The increase in tuna fishing effort in FMA 715 averages only 3% per year. In contrast to the attempts at FMA 715, the attempts at FMA 716decreased over the last five years. In 2018, there were 1,439 trips, and in 2019, there was an increase, although not much, of 1,474 trips, or only 2%. In 2020, effort decreased to 1,037 trips, or by 30% compared to 2019. In 2021 and 2022, the decrease in effort will continue to occur in the year compared to the previous year, namely, 836 and 568 trips or 19 and 32%, respectively. Meanwhile, the decline in tuna fishing efforts in FMA 716 was quite large, with an average of 20% $year^{-1}$.

Table 3

Tuna fishing efforts in FMA 715 and 716 period 2018-2022

Month	*Attempts (Trip)*									
	2018		*2019*		*2020*		*2021*		*2022*	
	FMA 715	*FMA 716*	*FMA 715*	*FMA 716*	*FMA 715*	*FMA 716*	*FMA 715*	*FMA 716*	*FMA 715*	*FMA 716*
January	241	89	238	90	300	81	277	67	224	38
February	232	97	240	95	330	73	274	62	292	53
March	292	129	418	152	412	80	330	79	368	54
April	325	117	380	125	345	91	272	64	376	66
Machine	360	129	510	181	348	75	240	58	319	66
June	275	111	350	103	305	76	361	69	365	78
July	226	106	388	131	364	97	353	64	283	56
August	272	105	190	75	270	75	305	62	292	41
September	243	83	287	101	292	76	406	83	324	28
October	385	145	513	148	436	104	446	76	388	27
November	472	158	528	142	458	123	402	76	489	24
December	460	170	539	131	425	86	383	76	482	37
Total	3,783	1,439	4,581	1,474	4,285	1,037	4,049	836	4,202	568

Catch per Unit Effort (CPUE). The calculation of CPUE in this study began by dividing the tuna catch (ton) by tuna fishing efforts (trip) using handline and longline fishing gear in the Molucca Sea (FMA 715) and Celebes Sea (FMA 716), respectively, based on data from to 2018-2022. The calculation results showed that the highest CPUE values for FMA 715 and 716 were determined for longline fishing gear. This means that longline fishing gear is most effective for catching tuna in FMA 715 and 716. The difference in CPUE values also shows that each fishing gear has different capabilities, so the standardization of fishing gear is carried out using the calculation of fishing power index (FPI) values. The result of the FPI value of tuna fishing with standard fishing gear is longline because it has the largest CPUE value. However, based on the CPUE value of each fishing gear, which is only slightly different, it can be concluded that handline and longline fishing gear have almost the same ability to catch tuna. The determination of CPUE values and standardization of tuna fishing gear are presented in Table 4.

The CPUE values of tuna in FMA 715 for the last five years (2018-2022) are 1.99 ton per trip, 1.73 ton per trip, 1.54 ton per trip, 1.65 ton per trip, and 2.01 ton per trip, respectively (Table 5). Furthermore, the CPUE trend in FMA 715 over the past five years tended to decline slightly (Figure 3). In 2018, the value of CPUE was 1.99 ton per trip. The value of the CPUE then decreased in 2019 to 1.73 ton per trip. In 2020, the CPUE value decreased again to 1.54 ton per trip. Then, in 2021 and 2022, the CPUE value increased again compared to the previous year to 1.65 ton per trip and 2.01 ton per trip, respectively. Based on the calculation of CPUE, the lowest CPUE value in 2020 was 1.54 ton per trip, while the highest CPUE value in 2022 was 2.01 ton per trip.

Table 4

CPUE tuna fishing gear and standardized fishing gear

Fishing gear	*Fishing Management Area 715 (Molucca Sea)*				*Fishing Management Area 716 (Celebes Sea)*			
	Catch total	*Effort total*	*CPUE total*	*FPI*	*Catch total*	*Effort total*	*CPUE total*	*FPI*
Handline	32,804.16	20,827	1.58	0.86	7,710.22	4,699	1.64	0.96
Longline	133.62	73	1.83	1	1,123.90	655	1.72	1

The condition is different in FMA 716, where the CPUE trend for the period 2018-2022 shows a significant upward trend (Figure 4). Table 5 shows the CPUE values of 1.64 ton per trip, 1.50 ton per trip, 1.67 ton per trip, 1.73 ton per trip, and 2.53 ton per trip, respectively. In 2018, the value of CPUE was 1.64 ton per trip. The value of the CPUE decreased to 1.50 ton per trip in 2019. Furthermore, in 2020 and 2021 the CPUE value increased by 1.67 ton per trip and 1.73 ton per trip, respectively, compared to the previous year. The increase in the value of CPUE continued in 2022, even increasing significantly to 2.53 ton per trip. The lowest CPUE value was in 2019, which was 1.50 ton per trip, while the highest CPUE value in 2022 was 2.53 ton per trip.

Table 5

Calculation of total production, standard effort, standard CPUE

Year	*Fishing Management Area 715*			*Fishing Management Area 716*		
	Total catch	*Effort standard*	*CPUE (ton trip^{-1})*	*Total catch*	*Effort standard*	*CPUE (ton trip^{-1})*
2018	6,471.27	3,257	1.99	2,262.71	1,378	1.64
2019	6,831.03	3,942	1.73	2,121.40	1,417	1.50
2020	6,589.26	4,285	1.54	1,669.29	999	1.67
2021	5,771.12	3,487	1.65	1,393.33	807	1.73
2022	7,275.10	3,619	2.01	1,388.40	548	2.53

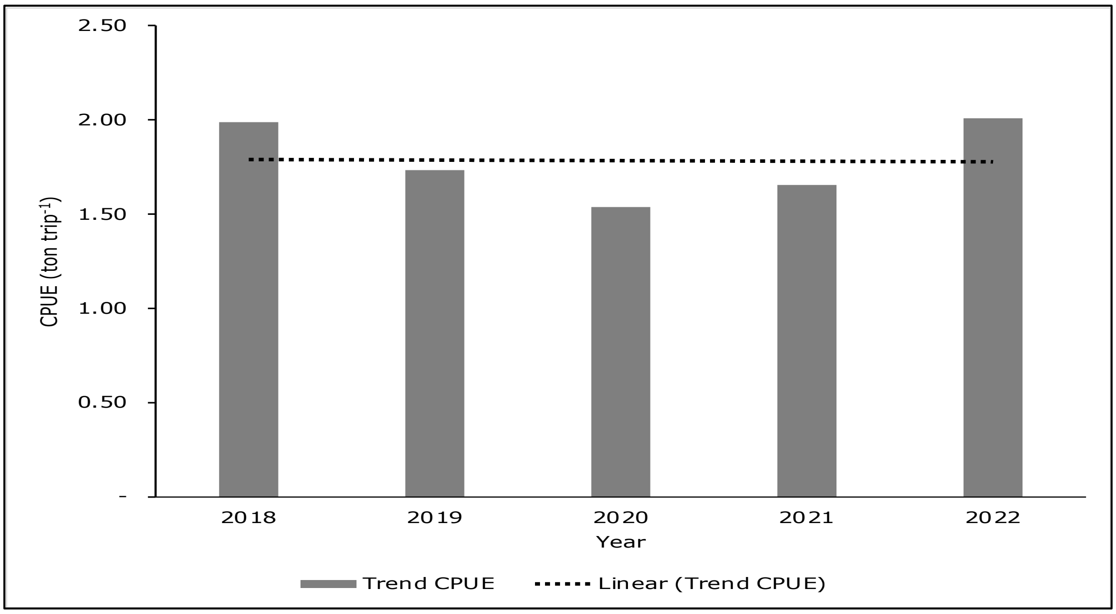

Figure 3. Tuna CPUE in FMA 715 in 2018-2022.

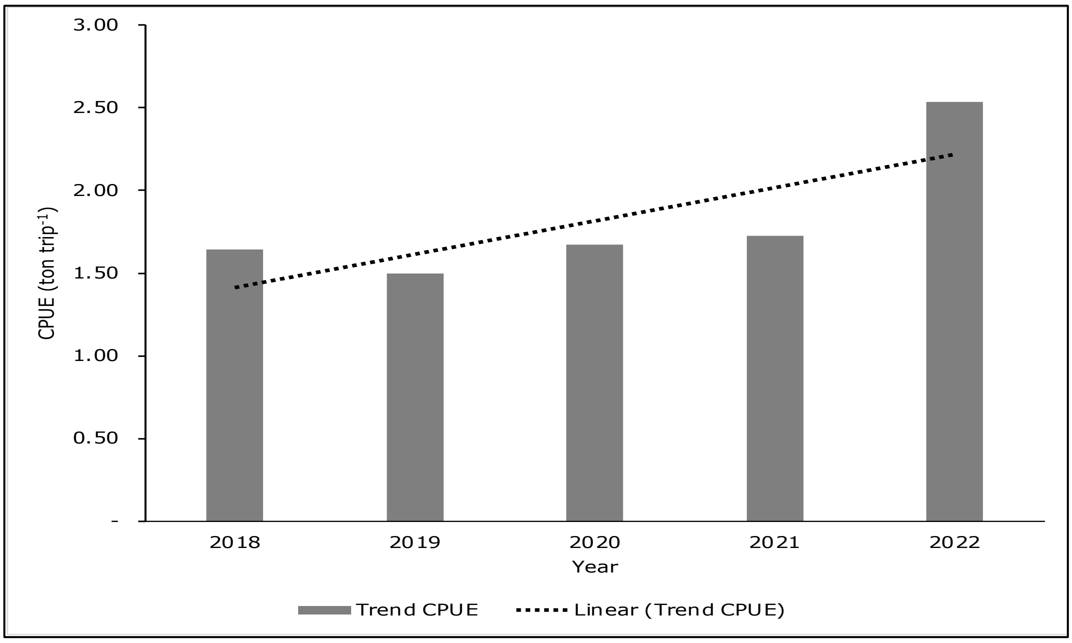

Figure 4. Tuna CPUE in FMA 716 of 2018-2022.

Tuna fishing season. The results of interviews with tuna fishermen who are based and landed their catches at the Bitung PPS show that fishing operations are carried out throughout the year in the waters of the Molucca Sea and the Celebes Sea, but the highest tuna catch is obtained from November to May compared to other months. This shows that the fishing season is at the end of the second season, which is November, and enters the western season in December-February, then in the first season, March-May. In November, fishermen begin to face undulating water conditions, and from December to January, the waves become higher, followed by strong winds. However, some large handline and longline fishing units still carry out fishing operations by adjusting to the weather conditions in the waters at that time, which are still tolerable, while small fishing units do not go to sea. In addition to weather conditions affecting the catch of tuna fishermen, there are other factors, namely, the obstacle of ship damage and difficulty in obtaining fuel oil (BBM). Damages often concern the hatch where the fish are stored, which can have leaks, and engine damage, and take a long time to repair, which delays the sea trips. Then, the problem of scarcity of government-subsidized fuel for ships under 30 gross tons (gt), where the size of the ship uses the most subsidized fuel and has to queue up to get fuel.

This study shows the results of an analysis based on monthly production data for the last five years (2018-2022) around the waters of the Molucca Sea (FMA 715) and the Celebes Sea (FMA 716). The analysed data on the tuna catches using handline and longline fishing gear, showed that these were dominated by yellowfin species and a small number of bigeye and albacore. Figure 5 shows that the chart of the tuna fishing season index (IMP) does not fluctuate too much or tends to be almost evenly distributed so that every month has good periods for tuna fishing. This can be seen from the fluctuation in the IMP value in FMA 715, which is not so large, at approximately 89-109% on average. In Table 4, it can be seen that the IMP values are quite high or more than 100% in January, May, August, September, October, November, and December, with IMP values of 102%, 109%, 106%, 105%, 103%, 107%, and 100%, respectively. The IMP values below 100% occur in July, namely 89%, 95%, 95%, 95%, and 95% in February, March, April, June, and July, respectively. Furthermore, the results of the tuna fishing season in the waters of the Celebes Sea (FMA 716) are shown in Figure 5. Seasonal fluctuations are not too high in the lunar period, similar to the conditions that occur in the Molucca Sea; the average value of the FMA 716 IMP ranges from 88-122%. An IMP value above 100% was found in January, March, May, September, and November, namely 122%, 101%, 103%, 105%, and 108%, respectively. Furthermore, IMP values below 100% were found in February, April, June, July, August, October, and December, namely 96%, 92%, 90%, 93%, 88%, 97%, and 98%, respectively (Table 4).

Tuna fishing season does not fluctuate excessively in the waters of the Molucca Sea and the Celebes Sea. It influences the activities of handline and longline fishing units that routinely carry out fishing operations throughout the year, and each operation gets a fairly large and even abundant tuna catch. Tuna production, sourced from fishing operations in Molucca Sea waters, ranges from 285-1,032 tons month^{-1}, while catches sourced from Celebes Sea waters range from to 80-290 tons month^{-1} (Table 2).

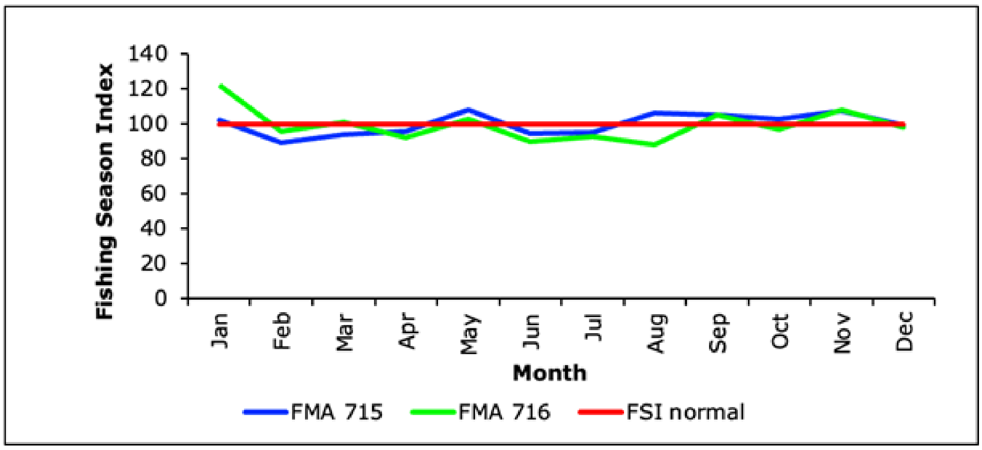

Figure 5. Chart of fishing season index for 2018-2022.

Table 4

Tuna fishing season index in 2018-2022

Month	*Season index (%)*	
	FMA 715	*FMA 716*
January	102	122
February	89	96
March	95	101
April	95	92
May	109	103
June	95	90
July	95	93
August	106	88
September	105	105
October	103	97
November	107	108
December	100	98

Discussion. Table 2 shows that the production of tuna landed at PPS Bitung is sourced from waters around the Molucca Sea (FMA 715) and Celebes Sea (FMA 716). Tuna production at FMA 715 in a period of two years, namely 2020 and 2021, has decreased; even in 2021, there was a decrease in production by 12% compared to 2020, which only decreased by around 4%, but in 2022, production began to increase quite a lot by 26%. Different conditions occurred for tuna production in FMA 716, which has continuously decreased from 2019 to 2022, so that the total production decline reached 44.40%. When compared to tuna production every year or total production for the 5-year period (2018-2022), the tuna catch in FMA 715 is much greater than the catch in FMA 716, because tuna fishing units operate more in the waters of the Molucca Sea than in the waters of the Celebes Sea. Thus, fishing unit produces more tuna than longlines. Handline fishing gear dominates the tuna fishing unit based at PPS Bitung, with the main operating area located in the waters of the Molucca Sea (Darondo et al 2014; Kowaas et al 2023). In contrast, tuna fishermen in the waters of South Java (FMA 573) use longlines as their primary fishing tool to catch tuna (Nurani et al 2018).

The decline in tuna production in FMA 715 in 2020 and 2021 is likely caused by a decrease in fishing efforts, while the increase in production in 2022 is correlated with an increase in fishing efforts. The decrease in fishing efforts at FMA 716 also caused tuna production to decline from 2019 to 2022: a drastic decrease in fishing efforts occurred over the period 2020-2022. This shows that the catch effort or the number of days of fishing operations greatly affect the increase and decrease in tuna production, even though handline and longline tuna fishing units based at PPS Bitung are numerous. The increase in production encourages the intensification of the fishing efforts. In addition, based on the results of interviews with fishermen and boat captains, it is known that the reduction in operating days is due to difficulties in obtaining fuel oil, particularly government subsidies. revious research conducted by Pontoh et al (2019) stated that the shortage of fuel had a negative impact on the productivity of the tuna handline fishing unit at PPS Bitung. The same situation also occurred in the longline tuna fishing unit at PPS Cilacap (Lestari et al 2017). On the other hand, the decline in tuna production was also influenced by the implementation of government policies due to Covid-19 from 2020 to 2021, which limited human activities, resulting in a reduction in the number of operation days and fishing units. Most fishermen admit that it is difficult to obtain permission from the local government to go to sea. Some boat owners temporarily halted fishing operations due to a lack of demand for fish and the price of tuna, which dropped drastically to half the normal price. Several studies in other countries and regions in Indonesia report on the impact of Covid-19 on the tuna fisheries sector: in Portugal, tuna production fell from 85 tons to 47 tons or by 44% (Seixas et al 2024); in Spain, industrial demand and local consumers declined so that there was a decrease in the selling price of tuna and other types of fish (Gonzalez et al 2022). In Indonesia, Atmajaya et al (2021) reported that, at the Pondokdadap Beach Fisheries Port in Malang, the demand for tuna fish fell by up to 30% and the selling price fell by up to 50%. Furthermore, Sari et al (2020) revealed that at the Morotai Island Integrated Marine and Fisheries Center, the price of tuna dropped drastically and tuna exports stopped. In the Talaud Islands Regency, adjacent to Bitung, there is also a decrease in prices and a lack of demand for tuna, which has an impact on high operational costs, so that fishermen and boat owners lose money (Naung et al 2021).

The results of the study show that a comparison of the trend of tuna CPUE in the waters of 715 (Molucca Sea) and 716 (Celebes Sea) in the last five years tends to show a slight decrease in the waters of the Molucca Sea, while in the waters of the Celebes Sea, the trend of CPUE has increased significantly. The CPUE trend in the waters of the Molucca Sea is a sign that efforts in tuna fishing operations are beginning to be excessive. According to Yang & Zhou (2024), the decrease in CPUE indicates a decrease in the number of tuna populations in the waters due to uncontrolled exploitation of tuna resources or overfishing. The calculation of CPUE is important for determining the condition of fish stock availability in water at a certain time (Heidrich et al 2023). In addition, Sofiati & Alwi (2019) added that the more fishing attempts (trips), the lower the tuna production. This is because tuna fish resources will tend to decrease if fishing continues to increase. Limiting fishing efforts is one of the optimal strategies in sustainable tuna fisheries management (Hoshino et al 2024). The decrease in fishing efforts has had a positive effect on the increase in tuna CPUE in the waters of the Celebes Sea, because it provides an opportunity for the recovery of tuna fish resources. Lestari et al (2017) stated that every decrease in the number of trips can increase CPUE, so it shows a strong relationship between the value of CPUE and the trip of fishing operations. This is in line with the research conducted by Marinding et al (2023) at PPS Bitung, for the 2018-2022 period, on tuna handline fishermen, which found that the fluctuation of the CPUE value in that period was influenced by the efforts' fluctuations, namely the days and the number of fishing vessels in operation. That happened in 2021, when the decrease in the CPUE value was influenced by very high efforts in 2019, which had an impact on the decrease in catch. However, in 2022, the CPUE value has increased, indicating the recovery of tuna resources due to reduced efforts in 2021.

Tuna fishing units operating around the Molucca Sea waters show symptoms of excess fishing efforts over a period of five years (2018-2022). This was marked by a decrease in CPUE of fishing units that catch yellowfin, big-eye, and albacore tuna in the waters of the Molucca Sea. In contrast, the waters of the Celebes Seashow an increase in the value of CPUE, so it can be stated that tuna fish resources in these waters can still be increased. Marinding et al (2023) stated that the average utilization rate of tuna fish resources at PPS Bitung in 2018-2022 was 94% and the average catch effort was 102.98%. This shows that the utilization rate is close to over-exploitation regarding the sustainable yield potential, while fishing efforts are categorized as over-exploitation from the optimal effort perspective. Different results reported by the WCPFC (Western and Central Pacific Fisheries Commission) in 2023, which mention the presence of yellowfin tuna, big-eye tuna, and albacore in the waters of the Pacific Ocean, show that tuna stocks have not been overfished.

In this study, an analysis was carried out on the fishing season in the waters of the Molucca Sea (FMA 715) and Celebes Sea (FMA 716). The fishing season was used to determine the right month to carry out tuna fishing operations so that the maximum number of tuna catches could be obtained. Tuna fishing operations around the waters of the Molucca Sea and Celebes Sea are conducted throughout the year by handline and longline fishermen. The results of the average value of the tuna fishing season index (IMP) in the waters of the Molucca Sea and the Celebes Sea are 89-109% and 88-122%, respectively, which shows that there is no high fluctuation, so it can be concluded that the tuna fishing season occurs every month and every year. This is because the tuna fish resources in the two waters are always there, so fishing efforts are carried out continuously, and the tuna caught and landed is quite abundant. This is assumed to happen because the environmental conditions of the waters supply a lot of nutrients, so that the waters become fertile and rich in food for tuna when migrating. The results of a study by Akia et al (2021) showed that the peak of the tuna fishing season coincided with the occurrence of upwelling, which made the waters rich in nutrients. The upwelling process brings most of the small fish to the surface of the waters, making it easier for tuna to get food (Battaglia et al 2022). Tuna abundance is also influenced by oceanographic parameters, including sea surface temperature, chlorophyll concentration, salinity, and dissolved oxygen (Ma'mun et al 2018; Wiryawan et al 2020; Li et al 2024), and is also influenced by climate (Lin et al 2023).

Meanwhile, the tuna fishing season index stability is influenced by the high frequency of tuna fishing operations conducted by large handlines and longline vessels. Thus, even though the water weather conditions are bad still tolerated for going to sea, the catch can be quite large or even maximum. This condition is due to the operating pattern that has been applied by Bitung fishermen: handline fishermen who collaborate with rumpon guards often obtain information related to the existence of tuna gangs. The effectiveness of the operation of the handline fishing unit based at PPS Bitung is highly dependent on the existence of the rumpon as a fishing aid or Fish Aggregating Device (FAD), localization point for fishing areas and mooring place for vessels. The results of the research by Dalegi et al (2020) stated that the use of rumpons in the Molucca Sea has an impact on the existence of tuna fish that are always available. For longline fishermen, the routine of fishing operations is greatly helped by information sourced from fishing vessels that are first in the waters and temporarily carry out tuna fishing operations. The tuna longline fishing unit does not carry out fishing operations around the rumpon area because it interferes with the fishing activities of handline fishermen and can damage fishing gear.

The results of the average value of tuna PMI in the Molucca Sea and the Celebes Sea, which are 89-109% and 88-122%, respectively, show that the fishing season occurs every month. The results of this study show a difference from previous research, which stated that only certain months are the tuna fishing season, namely October to January and March to May for fishermen at the Belang Minahasa Southeast Fisheries Port (PP), with the highest IMP value in January (Suprianto et al 2017). Furthermore, according to Dalegi et al (2020), March to May, July, November and December are the best months for tuna fishing vessels based at PPS Bitung to carry out fishing operations, while Tuju et al (2023) stated that the tuna fishing season in the Celebes Sea is from March to May. Previous research is not much different from the results of interviews with fishermen at PPS Bitung, which stated that the fishing season in the waters of the Molucca Sea and the Celebes Sea occurs at the end of the 2nd season, which is November, and enters the western season in December-February, then in the 1st season, which is March-May. On the other hand, in some Indonesian fisheries management areas, tuna fishing operations are also carried out almost year-round, although only in certain months it is possible to obtain a considerable amount of catch. According to Nurani et al (2016), the tuna fishing season around the waters of the Indian Ocean in the southern part of Java (FMA 573) is divided into several areas, including the south of East Java in May-September and the peak in June, the south of Yogyakarta from April to October and the peak in July, the south of East Nusa Tenggara in May-June and October-November, and the peak in November. In the waters of the Indian Ocean in the western part of Sumatra (FMA 572), from which tuna catches are landed at PPS Bungus, Padang City, the fishing season occurs in March, April, May, and October (Nugroho et al 2018).

This study shows that tuna fish resources in the waters of the Molucca Sea (FMA 715) and Celebes Sea (FMA 716) are available every month and throughout the year so that fishermen can carry out tuna fishing operations at any time. However, it is necessary to control fishing efforts that are carried out continuously in the Molucca Sea, because there are indications of overfishing based on the trend in CPUE values that tend to begin to decline. In the Celebes Sea, the CPUE value tends to show an upward trend, so it is still possible to increase fishing efforts and tuna production.

Conclusions. The results of the study showed that the CPUE value of tuna in the waters of the Molucca Sea (FMA 715) and the Celebes Sea (FMA 716) both experienced slight fluctuations, but there was a difference in the trend of CPUE between the Molucca Sea, which tended to start decreasing, and the Celebes Sea, where it tended to increase. The CPUE value of tuna in the Molucca Sea increased from 1.99 ton per trip in 2018 to 2.01 ton per trip in 2022, while the value of CPUE in the Celebes Sea increased from 1.64 ton per trip in 2018 to 2.53 ton per trip in 2022. The tuna fishing season in the Molucca and Celebes seas can occur every month throughout the year.

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