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Analysis of Catch Per Unit Effort (CPUE) and Maximum Sustainable Yield (MSY) of Skipjack Tuna (*Katsuwonus pelamis*) Landed at the Kendari Oceanic Fisheries Port

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ABSTRACT
Skipjack tuna (*Katsuwonus pelamis*) is one of the major pelagic fish species landed at the Kendari Oceanic Fisheries Port (PPS Kendari). This study aims to analyze the Catch Per Unit Effort (CPUE) and Maximum Sustainable Yield (MSY) of skipjack tuna landed at PPS Kendari. The research was conducted from November to December 2023 at PPS Kendari. The data used in this study were secondary data collected from PPS Kendari covering the period 2016–2022, including skipjack tuna landings, types of fishing gears used, and catch volumes for each fishing gear. The surplus production model of Schaefer was applied as the analytical method. Fishing gears used to catch skipjack tuna landed at PPS Kendari included gillnets, hand lines, pole and line, purse seines, boat lift nets, carrier vessels, and other gears. Pole and line was selected as the standard fishing gear. The results showed that the CPUE of skipjack tuna landed at PPS Kendari fluctuated during the study period. The highest CPUE was recorded in 2020, reaching 3,670 kg/trip, while the lowest CPUE occurred in 2018 at 1,578 kg/trip. Based on the MSY analysis, the optimum fishing effort was estimated at 2,126 trips/year, with an optimum catch of 6,130,516 kg/year. The utilization level of skipjack tuna resources at PPS Kendari has not yet reached an overfishing condition. Therefore, it can be concluded that the current fishing effort has not exceeded the sustainable stock limit in the Banda Sea waters. Consequently, fishing effort may be increased to achieve maximum yields, provided that it remains within the calculated MSY limits.

Keywords: CPUE, MSY, PPS Kendari, Skipjack Tuna

INTRODUCTION

The Banda Sea is one of the major fishing grounds with economically important marine resources and has long been targeted by fishing fleets ranging from small-scale to large-scale operations (Waileruny 2014). Fish stocks in the Banda Sea consist of a wide variety of fish species, mollusks, and shellfish. The Banda Sea waters, particularly in the eastern part of Southeast Sulawesi, are located within the Fisheries Management Area of the Republic of Indonesia (WPPNRI) 714 and represent a highly potential fishing ground, especially for skipjack tuna (*Katsuwonus pelamis*) (Picaulima 2022).

Skipjack tuna is one of the dominant species landed at the Kendari Oceanic Fisheries Port (PPS Kendari), which is recognized as one of the most active ports in fish production in the region (Nurmayana 2022). As a large pelagic fishery resource, skipjack tuna (*Katsuwonus pelamis*) is a high-value export commodity in the eastern waters of Indonesia (Diningrum 2019). Since the early 1970s, skipjack tuna fishing activities in eastern Indonesian waters have generated significant economic impacts and have been widely utilized by local communities for fresh sales and consumption after processing (Sipahutar 2019). Several types of fishing gears are operated at PPS Kendari to target skipjack tuna, including gillnets, hand lines, pole and line, purse seines, and boat lift nets, with vessel sizes ranging from 10 to 30 GT.

Catch Per Unit Effort (CPUE) is a simple approach used to estimate the status of fish biomass in marine waters by comparing catch production with the fishing effort exerted (Nur 2011). Changes in fisheries production within a particular area can be observed through variations in fishing effort and catch results. According to Marinding (2023), the values generated from CPUE analysis reflect the availability of fish stocks at fishing grounds and indicate the potential for additional production.

Maximum Sustainable Yield (MSY) refers to the maximum amount of fish stock that can be

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harvested continuously using existing fishing potential without compromising stock sustainability. Understanding the sustainable yield potential is essential to ensure that the level of resource utilization does not exceed sustainable limits, thereby maintaining the long-term conservation of fish resources (Taher *et al*. 2020).

This research study aims to analyze the CPUE, MSY, and the utilization level of skipjack tuna resources. Analysis of catch per unit effort (CPUE) and maximum sustainable yield (MSY) of Skipjack Tuna (Katsuwonus pelamis) Landed. The expected outcome of this research is to provide estimates of CPUE, MSY, and utilization levels of skipjack tuna fisheries in the Banda Sea waters, Kendari Oceanic Fisheries Port.

Time and Location of Research

The study was conducted from November to December 2023 at the Kendari Oceanic Fisheries Port (PPS Kendari). The data used in this research were secondary data obtained from PPS Kendari covering the period 2016–2022. The dataset included skipjack tuna landings, types of fishing gears used, and catch volumes for each fishing gear.

Fishing activities were carried out within the Fisheries Management Area of the Republic of Indonesia (WPPNRI) 714, namely the Banda Sea, located approximately between 07°26.160′ S and 05°23.280′ S. Sampling was conducted at PPS Kendari, located in Puday Village, Abeli District, Kendari, Southeast Sulawesi, Indonesia.

MATERIAL AND METHOD

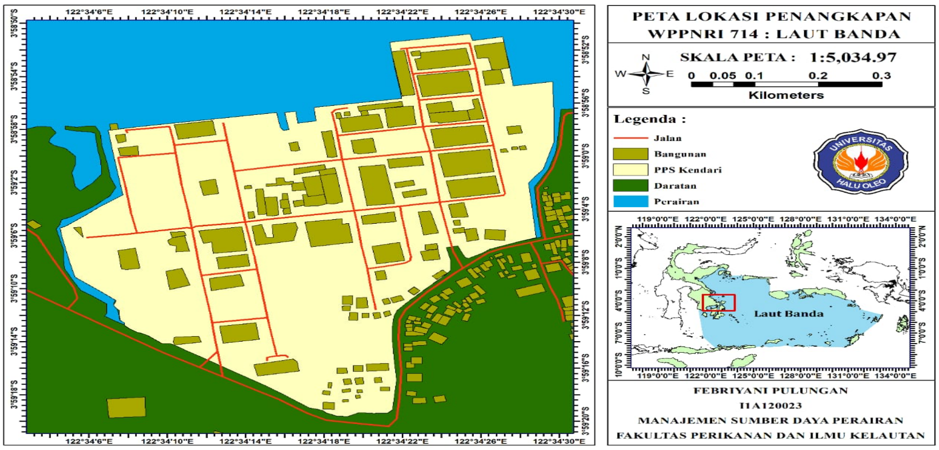

Figure 1. Map of the study area and skipjack tuna fishing grounds in the Banda Sea, WPPNRI 714

Data Collection

Data collection was carried out at the Kendari Oceanic Fisheries Port. The data source consisted of logbooks collected over a seven-year period (2016–2022). The data collection stage involved obtaining raw research data. The data extraction process began with the selection of fish species relevant to the study. Information extracted from the logbooks included date, vessel name, vessel gross tonnage (GT), type and number of fishing gears, and total catch (kg). The catch data were then organized annually by fishing gear type, followed by calculation of total catch per gear. All logbooks had been verified by the harbormaster officers at PPS Kendari.

Data Selection

The data selection process was based on logbook records. These logbooks serve as daily written reports by vessel captains regarding fishing activities. The logbooks function as official statements by captains documenting fishing operations and fishery resource catches to be landed at the Kendari Oceanic Fisheries Port. The data extraction procedure began with the selection of fish species in accordance with the research objectives.

Data Analysis

Effort Standardization

Fishing effort standardization was conducted by calculating the Fishing Power Index (FPI). The FPI value for the standard fishing gear was set to 1, while the FPI values for other fishing gears were calculated by dividing the CPUE of each respective fishing gear by the CPUE of the standard fishing gear. The fishing capacity index was used to identify the most efficient (standard) fishing gear based on the equations proposed by Sparre and Venema (1999):

$$\mathrm{FPI} = \mathrm{CPUEr}/\mathrm{CPUEs}$$

$$Effort\ Std = FPI\ x\ E$$

Where FP is Fishing Power Index, CPUEr is Catch per unit effort of non-standard fishing gear (kg/trip), CPUEs is Catch per unit effort of the standard fishing gear (kg/trip), E Std is Fishing effort standardization, E is Fishing effort (trip).

Catch Per Unit Effort (CPUE)

After effort standardization, Catch Per Unit Effort (CPUE) was calculated following Sparre and Venema (1999) as follows:

$$\text{CPUE} = \frac{Catch(\text{c})}{Effort(\text{f})}$$

Where CPUE is Catch per unit effort of skipjack tuna in year t (kg/trip), Catch*t* is Skipjack tuna catch in year *t* (kg), Effort*t is* Skipjack tuna fishing effort in year *t* (trip).

Maximmum Sustainable Yield (MSY)

The potential yield of skipjack tuna was estimated by analyzing catch and fishing effort data. According to Sparre and Venema (1999), the relationship between catch and fishing effort can be modeled using the Schaefer surplus production model. The data analysis procedures were as follows:

Plotting fishing effort (f) as a function of CPUE (C/f) and estimating the intercept (a) and slope (b) using linear regression.

Estimating the Maximum Sustainable Yield (CMSY) and optimum fishing effort (EMSY) based on the linear regression equation:

$$\text{y} = \text{a} - \text{bx}$$

where:
y : dependent variable (CPUE, kg/trip)
x : independent variable (fishing effort, trip)
a and b : regression parameters

The regression parameters a and b were calculated using the following formulas:

$$a = \Sigma \frac{Xi}{n} - \Sigma \frac{Yi}{n}$$

$$b = \frac{n.\Sigma\left((xi)\ (yi)\right) - (\sum Yi)}{n.\sum(xi^2) - (\sum xi)^2}$$

where:
a : intercept (constant)
b : slope
xi : fishing effort in period *i*
yi : CPUE in period *i*

Estimation of optimal catch and fishing effort using the Schaefer model, the relationships were defined as follows:

The CPUE model equation: $\text{CPUE} = \text{a} - \text{b(f)}$

The relationship between catch (C) and effort (f): $\text{C} = \text{af} - \text{b(f)}^2$

where:
CPUE : Catch per unit fishing effort (kg/trip)
a : intercept
b : regression coefficient
f : fishing effort (trip) in period *i*

If the slope parameter (b or d) is negative, an increase in fishing effort will result in a decrease in catch per unit effort. Conversely, if the slope parameter is positive, it is not possible to estimate optimal stock size or fishing effort, and only indicates that increasing fishing effort will continue to increase total catch (Sparre and Venema, 1999).

RESULT AND DISCUSSION

Results

Effort Standardization

Effort standardization was conducted by determining a standard value. Fishing gears used in skipjack tuna fisheries included gillnets, hand lines, pole and line, purse seines, carrier vessels, boat lift nets, and other gears. The highest catch was recorded in 2017 using purse seine gear, amounting to 3,903,042 kg/year, while the lowest catch occurred in 2020 using gillnet gear, with a total catch of 300 kg/year.

Table 1. Catch and fishing effort of skipjack tuna by fishing gear (2016–2022)

Years	Fishing Gear							
	Gillnet		Hand Line		Pole and Line		Purse Seine	
	C	E	C	E	C	E	C	E
2016	1.680	1	198.629	197	346.586	145	2.566.303	1924
2017			349.906	493	310.948	168	3.903.042	2878
2018			237.681	381	337.791	214	3.716.817	3794
2019			284.134	426	187.116	52	3.117.038	2866
2020	300	1	238.547	354	278.942	76	2.938.814	2017
2021	330	2	113.568	236	217.226	75	2.000.992	1479

Years	Fishing Gear					
	Boat Lift Net		Carrier Vessel		Others	
	C	E	C	E	C	E
2016			1.319.202	334	176.544	114
2017			1.818.046	435	172.831	113
2018	2.840	2	2.145.489	484		
2019			1.189.214	297		
2020			1.077.413	229		
2021			669.215	217		
2022			345.698	92		

Source: Data analysis results, 2023
C = Catch (kg), E = Fishing effort (trip)

Table 2. Productivity of skipjack tuna fishing gears

Years	Productivity						
	GL	HL	PL	PS	BP	PG	Others
2016	1680	1008	2390	1334		3950	1549
2017		710	1851	1356		4179	1529
2018		624	1578	980	1420	4433	
2019		667	3598	1088		4004	
2020	300	674	3670	1457		4705	
2021	165	481	2896	1353		3084	
2022		574	3166	1572		3758	

Source: Data analysis results, 2023
GL = Gillnet, HL = Hand line, PL = Pole and line, PS = Purse seine, BP = Boat lift net, PG = Carrier vessel, Others = Unidentified fishing gears

The productivity values of each fishing gear indicate that pole and line exhibited the highest productivity among the gears analyzed. After obtaining the productivity values for each type of skipjack tuna fishing gear, effort standardization was subsequently performed by selecting the most productive gear as the standard fishing gear.

These fishing gears exhibit different capabilities in capturing skipjack tuna; therefore, the calculation of the Fishing Power Index (FPI) was required. Based on the productivity values presented in Table 2, pole and line demonstrated consistently higher productivity compared to other fishing gears. The results of the Fishing Power Index and fishing effort calculations (Table 3) indicate that pole and line was selected as the standard fishing gear. The FPI value for pole and line was equal to 1 for each year, as this gear consistently showed the highest fishing effort and productivity. Consequently, pole and line was designated as the standard fishing gear for skipjack tuna fisheries, as presented in Table 3.

Table 3. Fishing Power Index (FPI) values of skipjack tuna fishing gears

Years	FPI						
	Gillnet	Hand Line	Pole and Line	Purse Seine	Boat Lift Net	Carrier Vessel	Others
2016	0,703	0,422	1	0,558		1,652	0,648
2017		0,383	1	0,733		2,258	0,826
2018		0,395	1	0,621	0,900	2,808	
2019		0,185	1	0,302		1,113	
2020	0,082	0,184	1	0,397		1,282	
2021	0,057	0,166	1	0,467		1,065	
2022		0,181	1	0,497		1,187	

Source: Data analysis results, 2023

The FPI values were subsequently used to calculate standardized fishing effort. Based on the analysis, the highest standardized effort for skipjack tuna occurred in 2018 using purse seine gear, reaching approximately 2,355 kg/trip.

In contrast, the result of the lowest standardized effort was recorded in 2020 using gillnet gear, with a value of approximately 0.08 kg/trip. The standardized effort values are presented in Table 4.

Table 4. Standardized fishing effort of skipjack tuna

Years	Effort Standard						
	Gillnet	**Hand Line**	**Pole and Line**	**Purse Seine**	**Boat Lift Net**	**Carrier Vessel**	**Others**
2016	0,70	83	145	1074		552	74
2017		189	168	2109		982	93
2018		151	214	2355	1,80	1359	
2019		79	52	866		330	
2020	0,08	65	76	801		294	
2021	0,11	39	75	691		231	
2022		38	104	994		109	

Source: Data analysis results, 2023

Table 5. CPUE calculation of skipjack tuna (2016-2022)

No	Years	Total Catch (kg)	Fishing Effort (trip)	Number of Vessels	CPUE (Kg/trip)
1	2016	4.608.944	1928	445	2390
2	2017	6.554.773	3541	506	1851
3	2018	6.440.618	4080	470	1578
4	2019	4.777.502	1328	434	3598
5	2020	4.534.016	1235	349	3670
6	2021	3.001.331	1036	272	2896
7	2022	3.943.695	1245	277	3166
	Total	**33.860.879**	**14395**	**2753**	**19151**
	Average	**4.837.268**	**2056**	**393**	**2736**

Source: Data analysis results, 2023

Catch Per Unit Effort (CPUE)

Based on data collected during the period 2016-2022, the average CPUE over seven years was 2,736 kg/trip. The highest CPUE value was observed in 2020, reaching 3,670 kg/trip, while the lowest CPUE occurred in 2018 at 1,578 kg/trip. The linear regression analysis between fishing effort and CPUE produced the equation Y = 46.6787 − 232.44x, where the intercept value (a) was 46.6787 and the regression coefficient (b) was −232.44. This equation indicates that each additional unit of fishing effort results in a decrease of approximately 232.44 kg/trip in CPUE. When fishing effort approaches zero, the potential availability of skipjack tuna stock in the environment is estimated to be 46.6787 kg/trip.

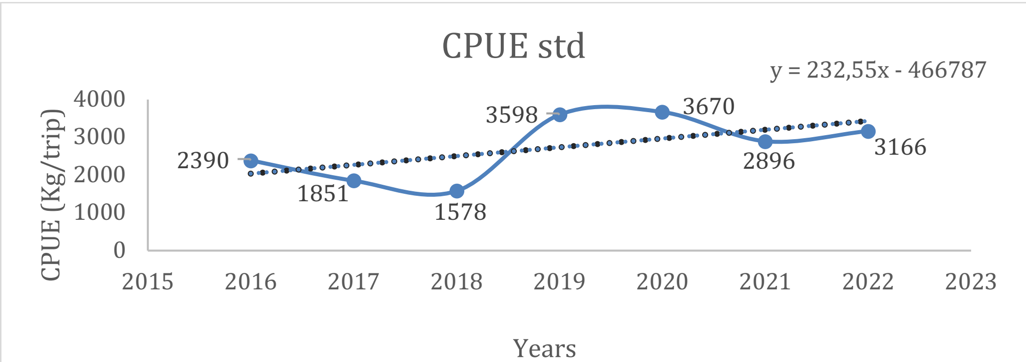

Figure 2. Temporal trend of Catch Per Unit Effort (CPUE) of skipjack tuna (*Katsuwonus pelamis*)

Maximmum Sustainable Yield (MSY)

Based on skipjack tuna production data over the most recent seven-year period (2016–2022), the Maximum Sustainable Yield (MSY) was estimated using the Schaefer surplus production model. This analysis allowed the determination of both MSY and the optimum fishing effort for skipjack tuna landed at the Kendari Oceanic Fisheries Port (PPS Kendari). According to the Schaefer model, the maximum sustainable fishing effort (F_{MSY}) was estimated at 2.126 trips/year, while the maximum sustainable yield (C_{MSY}) was calculated at 6.130.516 kg/year. These results are illustrated in Figure 3. Based on skipjack tuna production data over the last seven years (2016–2022), the Fox model was applied to estimate the Maximum Sustainable Yield (MSY). The results indicated a maximum sustainable catch (C_{MSY}) of 6.460.769 kg/year and an optimum fishing effort (F_{MSY}) of 4.020 trips/year. These results are illustrated in the following figure.

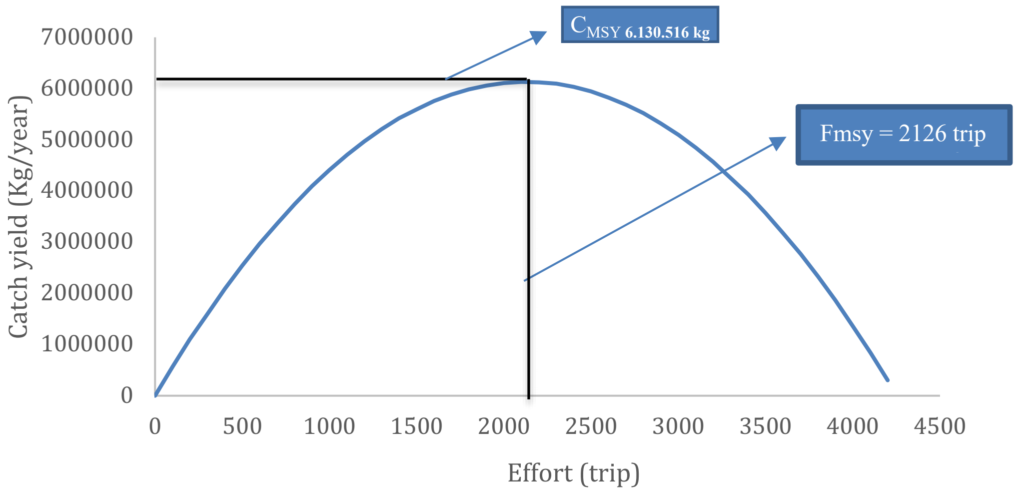

Figure 3. MSY curve of skipjack tuna (*Katsuwonus pelamis*) based on the Schaefer model

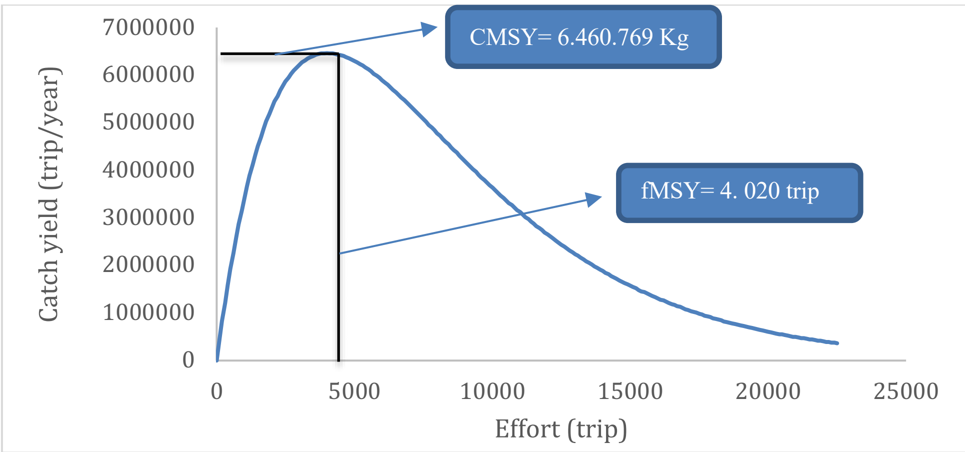

Figure 4. Fox model MSY curve for skipjack tuna (*Katsuwonus pelamis*)

Discussion

Standardization

Skipjack tuna fishing activities in the Banda Sea are predominantly conducted using various fishing gears, including gillnets, hand lines, pole and line, purse seines, boat lift nets, carrier vessels, and other gears. Based on catch data from seven fishing gear types, the highest catch was recorded in 2017 using purse seine gear, amounting to 3.903.042 kg/year, while the lowest catch occurred in 2020 using gillnet gear, with a total catch of 300 kg/year.

The results of the fishing gear productivity analysis indicate that pole and line exhibits a markedly different capability in capturing skipjack tuna compared to other fishing gears. Pole and line shows a higher probability of catching skipjack tuna than gears such as gillnets, hand lines, purse seines, boat lift nets, and carrier vessels. However, the effectiveness of pole and line in capturing skipjack tuna does not differ significantly from purse seine gear (Tuli 2019).

Fishing gear standardization requires the unification of fishing effort by selecting a single type of fishing gear as the standard based on its relative fishing efficiency (Lelono 2012). The standard fishing gear is defined as the gear with the highest (dominant) productivity and an FPI value of 1 compared to other fishing gears. According to Gulland (1983), when multiple types of fishing gears are operated within a fishing ground, the dominant gear can be used as the standard fishing gear.

Based on the analysis of standardized fishing effort for skipjack tuna over the seven-year period (2016–2022), the highest standardized effort was observed in 2018 using purse seine gear, reaching approximately 2.355 kg/trip, while the lowest standardized effort occurred in 2020 using gillnet gear, at approximately 0.08 kg/trip. Capture fisheries in Indonesia tend to be catch-oriented, with the expectation that catches will increase over time. This condition encourages fishers to intensify their fishing efforts during periods of low catch to maintain profitability, as well as during periods of high catch due to favorable conditions. However, increasing fishing effort does not always result in higher catch yields (Nababan 2022).

Cacth Per Unit Effort (CPUE)

Based on catch and effort data, the fishing effort of each fishing gear was calculated by dividing the catch of each gear by the number of fishing trips (Budiasih 2015). As shown in Figure 3, the highest CPUE value occurred in 2020, reaching 3,670 kg/trip, while the lowest CPUE value was recorded in 2018 at 1,578 kg/trip, with a total of 470 vessels operating in that year. This finding is consistent with Tomangoko (2022), indicating that the fishing effort exerted by the fleet particularly the number of operating vessels declined during that period in the Banda Sea skipjack tuna fishery. Meanwhile, according to Tuli (2019), variations in fishing effort values are influenced by increases and decreases in both the number of fishing gears used and the number of fishing trips undertaken during a given period.

The fluctuation trend of fishing effort illustrates an increase in catch production in 2020, followed by a decline in 2021. Fluctuations in skipjack tuna catches in the Banda Sea are not always attributable to changes in environmental conditions alone. The impacts of environmental variability on fish species may be either direct or indirect. This is in line with Suhaeti (2002), who stated that catch fluctuations are influenced by several factors, including fish availability, the level of fishing effort, and the success of fishing.

Maximmum Sustainable Yield (MSY)

The average annual actual catch of skipjack tuna over the seven-year period was 4,837,268 kg/year, with an average fishing effort of 2,056 trips/year. These values indicate that skipjack tuna landed at PPS Kendari remains under an underfishing condition, suggesting that catches could still be increased to achieve optimal utilization. Based on the Schaefer model, the maximum sustainable fishing effort (F_{MSY}) was estimated at 2,126 trips/year, while the maximum sustainable yield (C_{MSY}) was calculated at 6.130.516 kg/year. Furthermore, using the Fox model and skipjack tuna production data from 2016 to 2022, the estimated maximum sustainable catch (C_{MSY}) was 6.460.769 kg/year, with an optimum fishing effort (F_{MSY}) of 4.020 trips/year. When evaluated against the maximum sustainable yield, the actual catches recorded between 2016 and 2022 had not yet reached optimal levels. Therefore, comparisons between actual catch and effort values with the estimated (C_{MSY}) and (F_{MSY}) derived from both the Schaefer and Fox models indicate that the skipjack tuna fishery has not experienced overfishing.

According to the Schaefer model, fishing activities could be intensified by increasing the catch toward the estimated (C_{MSY}) by approximately 2.000.000 kg/year, while reducing fishing effort by about 70 trips/year. Similarly, the Fox model suggests that skipjack tuna exploitation has not yet reached optimal levels and that optimal yields could be achieved by increasing the catch toward (C_{MSY}) by approximately 1.600.000 kg/year, accompanied by a reduction in fishing effort of approximately 1.964 trips/year. These findings indicate that efforts to enhance skipjack tuna catches should be carefully managed to ensure that exploitation levels do not exceed the calculated MSY thresholds (Hutagaol 2023).

CONCLUSION

Based on the results and discussion, it can be concluded that the CPUE values of skipjack tuna over the seven-year period (2016–2022) ranged from a minimum of 1.578 kg/trip in 2018 to a maximum of 3.670 kg/trip in 2020. The Schaefer model estimated a maximum sustainable fishing effort (F_{MSY}) of 2.126 trips/year and a maximum sustainable yield (C_{MSY}) of 6.130.516 kg/year. Meanwhile, the Fox model produced a maximum sustainable catch (C_{MSY}) of 6.460.769 kg/year with an optimum fishing effort (F_{MSY}) of 4.020 trips/year. The utilization level of skipjack tuna resources at PPS Kendari has not yet reached an overfishing condition. Therefore, it can be concluded that the current fishing effort has not exceeded the sustainable stock limits in the Banda Sea waters. Consequently, skipjack tuna catches may be increased to achieve optimal yields, provided that fishing activities remain within the calculated MSY thresholds.

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