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Stock Study of the Skipjack Tuna (*Katsuwonus pelamis*, L., 1758) in Ternate Island, North Maluku Province, Indonesia

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ABSTRACT

Due to the continuous exploitation of skipjack tuna in the waters of Ternate Island, using active pole and line fishing gears, the skipjack tuna population is suspected to experience degradation in the waters of Ternate Island. Therefore, this research was conducted with the aim of analyzing the status of skipjack tuna populations in the waters of Ternate Island based on population dynamics studies, including parameters of growth, mortality, recruitment and exploitation rate. Experimental fishing methods were implemented to measure fish length which was then analyzed to determine the pattern of growth, mortality, exploitation rate and yield per recruit. The results showed that the parameter of the skipjack tuna population studied had an asymptote length ($L\infty$) of 77.7 cm, with a growth coefficient of 0.4 per year and a t_0 of -0.41. Furthermore, natural mortality (M) was 1.75, while the fishing mortality was determined as 1.60, and the current exploitation rate (E) showed a value of 0.48. These values indicate that the management of skipjack tuna in Ternate Island waters is close to optimum conditions (E = 0.5).

INTRODUCTION

The waters of Ternate Island are potential for pelagic fisheries, where skipjack is a type of large pelagic fish and is a superior commodity with a production value of 6,425.1 tons in 2016 and continued to increase until it reached 8,597.1 tons in 2020. Skipjack tuna (Fig. 1) is a type of fish from the *scombridae* family, belonging to genus *katsuwonus* and species *Katsuwonus pelamis*. This fish type likes to migrate to far distances and is tolerant of oceanographic conditions; it is distributed in tropical to sub-tropical waters. For the morphological characteristics of skipjack tuna fish individual, it has a rounded body resembling a torpedo with 4- 6 black stripes extending on the sides of the body; its body weight and length are in the range of 0.5- 11.5kg and 30- 90cm, respectively **(Tadjuddah *et al*., 2017; Zulham *et al*., 2017; Tangke *et al*., 2020; DKP North Mollucas Province, 2021)**.

Fig. 1. Skipjack tuna (*Katsuwonus pelamis*)

Skipjack tuna in the waters of Ternate Island has long been exploited using active fishing gear types, including pole and line, purse seine, hand line and other types of fishing gear **(Mallawa *et al*, 2014; Tangke, 2014; Tangke, 2018)**. Continuous exploitation and the use of less selective and active types of fishing gear have caused the current condition of skipjack tuna catches in the waters of Ternate Island to be degraded including the smaller size of skipjack tuna caught. Therefore, it is necessary to make efforts to manage it in order to maintain the survival of fish, especially skipjack tuna, so that they do not become extinct or disappear in the waters of Ternate Island..

Hoeng and Gruber (1990) elucidated that, the study of fish populations is an important and effective matter in fisheries management which aims to maintain a sustainable population of skipjack tuna as a biological resource that can recover. The way that can be done is to limit excessive exploitation pressure on these species through restrictions to closing fishing areas based on biological aspects, viz., stock studies and the estimation of fish population parameters **(Tangke, *et al*., 2021; Tangke, *et al*, 2022)**. Based on these data, this research was organized to analyze the status of skipjack tuna populations in the waters of Ternate Island based on the study of skipjack tuna population dynamics including parameters of growth, mortality, recruitment and exploitation rate..

MATERIAL AND METHOD

Data on the length of skipjack tuna assessed for 3,301 samples from February to May 2022 were obtained from fishermen's catches in the waters of Ternate Island (Fig. 2), using pole and line fishing gear, purse seine, hand line and and other fishing gear.

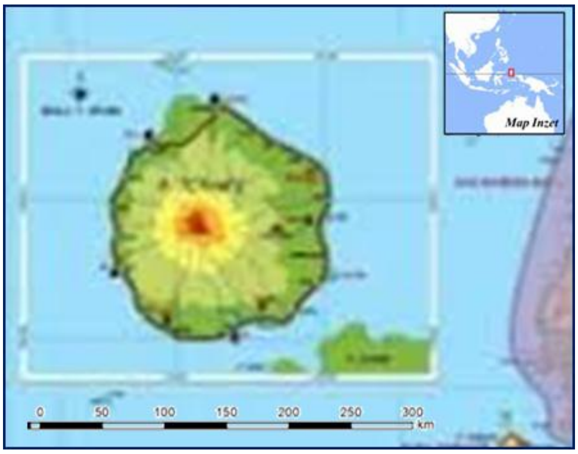

Fig. 2. Research Area (Ternate Island Waters)

The research data were then analyzed to evaluate the population dynamics assessment including growth patterns, which were analyzed using the von Bertalanffy growth model **(Sparre & Venema, 1999)**:

$$L_t = L_\infty\left[1 - e^{-K(t-t_0)}\right]$$

Where,

L_t = length of skipjack tuna at age t;

L_∞ = maximum length of skipjack tuna;

K = growth coefficient, and

t_0 = theoretical age when the length of the fish is zero.

Values of L_∞ and K were estimated using the ELEFAN method in the TropFishR package **(Mildenberger *et al*., 2017)**, while t_0 was analyzed using the equation of **Pauly (1983)**, with the following formula:

$$\text{Log}(-t_0) = (-0{,}3922) - 0{,}2752 \log L_\infty - 1{,}038 \log K$$

Whereas, the estimation of the mortality value of skipjack tuna was carried out using the empirical formula of **Pauly (1984)**, as follows:

$$M = \exp(-0{,}0152 - 0{,}279 \ln L_\infty + 0{,}6543 \ln K + 0{,}4634 \ln T)$$

In addition, the estimation of M (natural mortality) and Z (total mortality) values was determined using the Pauly's M equation method and the length convert-catch curve method in FISAT II software **(Pauly, 1984; Gayanilo *et al*., 2005)**. After obtaining the values of Z and M, the analysis of fishing mortality (F) and the utilization rate or exploitation rate (E) was assessed based on the formula of **Gayanilo et al., (2005)**, with the respective formulas of $F = Z - M$ and $E = F / Z$.

The yield per recruitment analysis was carried out using the Beverton and Holt equation recorded in the study of **Sparre and Venema (1999)**, with the succeeding formula:

$\frac{Y}{R} = \left(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} + \frac{U^3}{1+3m}\right)$, with value $U = 1 - \frac{L\prime}{L_\infty}$ and $m = \frac{1-E}{M/K}$

Where, M is natural mortality (per year); L' is the smallest limit of skipjack length caught (cm); L∞ is the asymptote length of skipjack tuna (cm), and K is the growth coefficient (per year).

RESULTS AND DISCUSSION

Production

Based on research data from February 2022 to May 2022, the skipjack tuna production was 11,554kg (3,301 fish), with a monthly average production of 2,888kg (825 fish). The monthly skipjack tuna production data during the study using pole and line fishing gear can be observed in Fig. (3), showing that the lowest production was in February 2022 and the highest production was in April 2022.

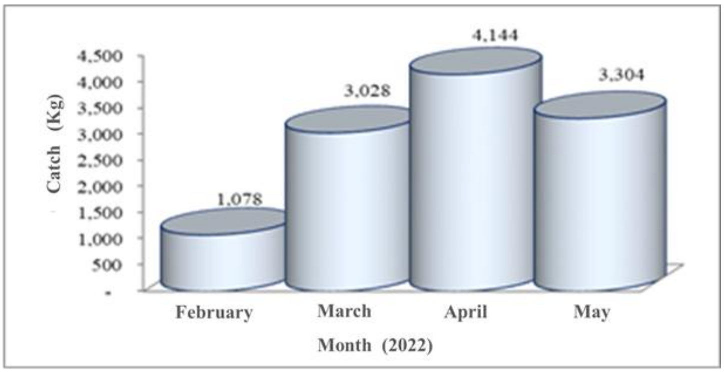

Fig. 3. Volume of skipjack tuna per month during the study

Production data consisted of 3,301 skipjack tuna, which were measured and used as the main data in the analysis of the biological aspects of skipjack tuna, including age group, growth rate, mortality and exploitation rate, recruitment pattern and yield per recruitment (Y/R).

Age group

The fish length values measured for 3,301 skipjack tuna were determined monthly from February 2022 to May 2022 as follows: in February 308, March 865, April 1,184 and May 944, while the age group per month is as shown in Fig. (4).

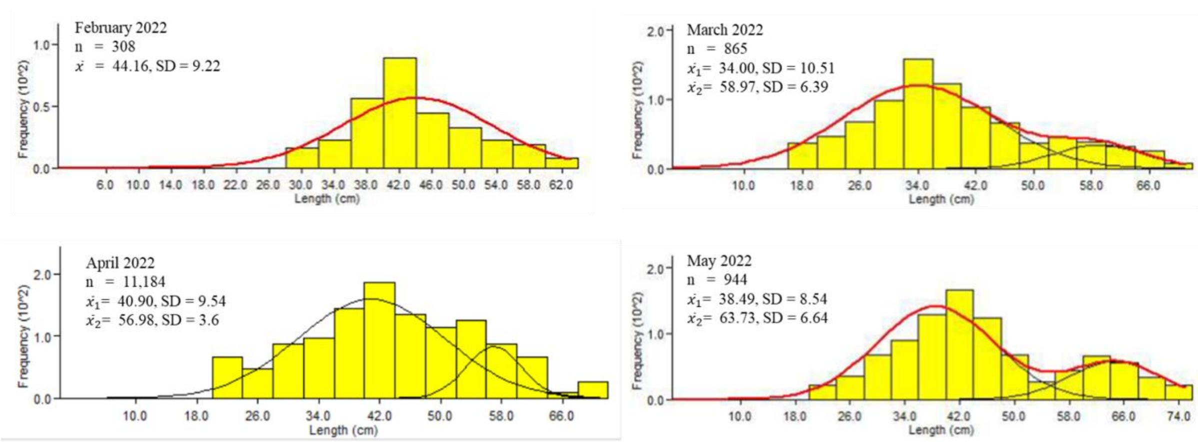

Fig 4. Monthly cohort of skipjack tuna in Ternate Island waters

For the monthly age group of skipjack tuna in February 2022, the samples of skipjack tuna measured were 308 individuals, with a length range of 20.0- 55.0cm. Based on data on the length of skipjack tuna in February 2022, two age groups (cohorts) were obtained, with the peak of the cohort in the range of fish length between 42.0 & 46.0cm. In March 2022, the number of skipjack tuna samples measured was 865 individuals, with length values ranging from 16.0- 71.0cm, consisting of two cohorts with peaks at 34.0cm and 58.0- 61.0 cm. In April 2022, the number of skipjack tuna samples measured was 11,184, with the length ranging between 16.0 & 71.0cm, and the number of age groups identified were two age groups, with peaks at 40.90 and 56.98cm. While in May 2022, the number of skipjack tuna samples measured was 944, with fish length fluctuation from 16.0 - 75.0cm and divided into 2 cohorts, with peaks for each cohort in the length range of 37.0 to 66.0cm.

Growth parameters

Results of the analysis of the estimated growth parameters using the Ford Walford method derived from the von Bertalanffy model recorded growth parameter values of skipjack tuna in Ternate Island waters as shown in Fig. (5), with asymptotic length ($L\infty$) = 77.7cm and growth coefficient (K) = 1.4 per year, while the age of skipjack tuna at length zero (t_0) = -0.08 years.

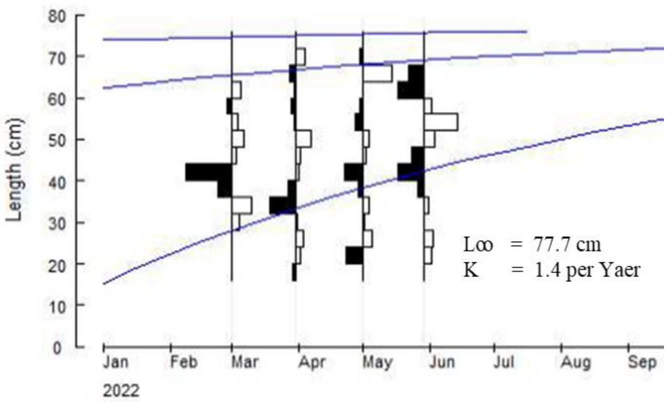

Fig. 5. Growth curve of skipjack tuna in Ternate Island waters, 2022

Given the values of $L\infty$, K and t_0, the equation for the growth of skipjack tuna in Ternate Island waters was determined as Lt = 77.7 * (1-Exp -1.4(t-0.08)), with a growth model as shown in Fig. (6). It can be seen that the growth of skipjack tuna is quite fast at the age of 0 - 3 years, and its growth begins to slow down at the age of above 3 years until it reaches a maximum length (77.7 cm) at the age of 6.87 years.

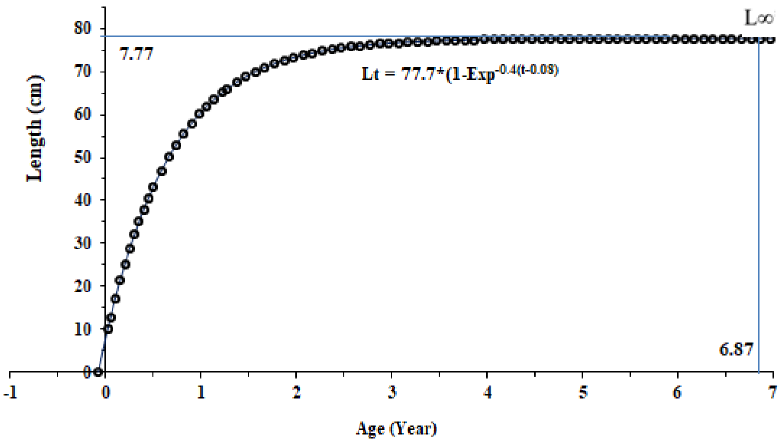

Fig. 6. Growth model of skipjack tuna in the waters of Ternate Island, 2022

The results of the study for the same species with different locations and times can be seen in Table (1), showing that the L∞ value in this study was 77.7cm. This indicates that the length of skipjack tuna in the waters of Ternate Island witnessed a decrease, which is thought to be due to pressure posed through the exploitation of these species by using pole and line fishing gear, which is a type of fishing gear that is active in fishing operations. In addition, it was realized that the growth coefficient (K) is 1.4, which indicates that skipjack tuna is a type of fish with a fast growth rate; this finding coincides with that of **Sparre and Venema (1999)** as cited in **Djamali (2005)** who explained that, such type of fish with a rate coefficient reflecting a high (K) growth > 0.5 will require a fast time to reach its maximum length.

Table 1. Estimation of skipjack growth parameters with different fishing areas

Location	Peneliti/Year	L∞	K	t_0
Sendangbiru, Malang, East Java	Mawarida *et al*., 2021	63	0.25	-0.55
Indian Ocean (WPP 573)	Zedta *et al*., 2018	67.20	0.27	-0.50
Indian Ocean (WPP 572)	Zedta *et al*., 2018	73.5	0.22	-0.59
North Waters (West Aceh)	Damora *et al*., 2021	84.78	0.22	-3.50
Tomini Bay (Indonesian)	Adam *et al*., 2017	50.2	0.58	-0.04
Indian Ocean (WPP 573)	Hidayat *et al*., 2017	101.85	0.41	-0.28
Indian Ocean (WPP 573)	Aditya & Arryanto, 2018	64.6	0.28	-0.48
Indian Ocean (WPP 573)	Sri Murti, 2019	67.8	0.34	-0.39
This research (Ternate Waters)	Tangke & Daeng, 2022	77.7	0.4	-0.41

The results of the analysis of the growth index was 3.22, with an average length of skipjack tuna at first caught (Lc) based on the von Bertalanffy equation of 40.89 cm, while the probability catches (L25) and (L75)) were estimated at 39.42 and 60.35cm, respectively. The estimated value of Lc 49.88 cm is for skipjack tuna which is 2.1 years old and is the size of fish that have been spawning with a length of > 42.8cm **(Manik, 2007)**, > 40cm **(Ashida *et al.*, 2009)** and > 46.5cm (**Jamal *et al.*, 2011**).

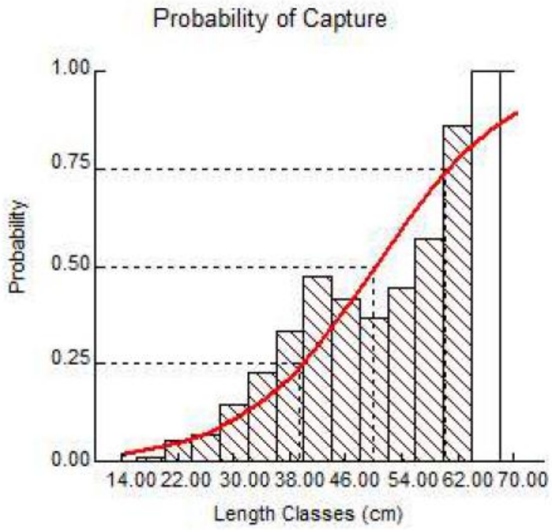

Fig. 7. Probability of skipjack catch in Ternate Island waters, 2022

The population analysis displayed in **Fig. (8)** shows that skipjack tuna mortality due to fishing starts at length size of 18cm,; however, at this size, skipjack tuna mortality is more due to natural death, while skipjack tuna mortality due to fishing begins to dominate at length ranging from 34.0cm, with a maximum mortality rate at sizes 42.0 and 62.0cm. The dominance of death due to catching starting at 34.0cm in size indicates population decline, and this occurs as a result overfishing since skipjack are usually caught during the period before spawning till the status of being spawned.

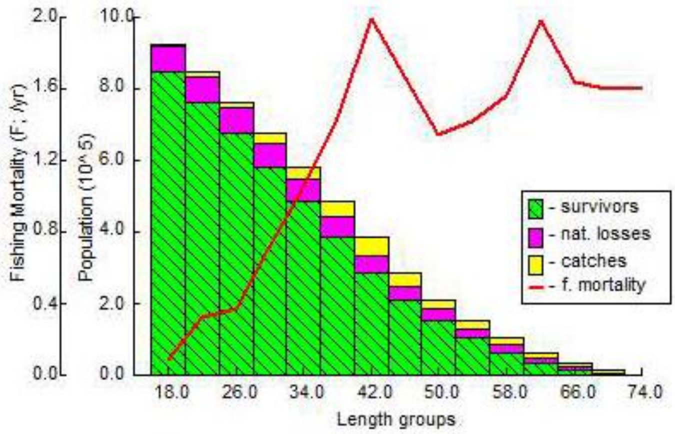

Fig. 8. Virtual population analysis of skipjack tuna in the waters of Ternate Island, 2022

Mortality and exploitation rate

Mortality is an analysis of the mortality rate of fish which is divided into natural mortality and fishing mortality. This mortality condition greatly determines the level of sustainability of a fish population, where if the fishing mortality condition exceeds natural mortality, the population condition will be considered over exploited. The results of the analysis of the length value of fish converted from the catch curve method and growth parameter variables $L\infty$ = 77.7 cm, K = 0.4 per year and t_0 = -0.41 years obtained the value of skipjack tuna mortality in the waters of Ternate Island. The values of total mortality (Z), natural mortality

(M), fishing mortality (F) and exploitation rate (E) were 3.35, 1.75, 1.60 and 0.48, respectively (Fig. 9).
The fishing mortality (F) value of skipjack tuna in the waters of Ternate Island is almost close to natural mortality. This indicates that fishing activity is currently quite intensive, this is supported by the current level of exploitation (E), which has reached E = 0.48. Upon comparing the mortality rate and exploitation rate of skipjack tuna to those determined in several locations by different researchers (Table 2), it was noticed that, the mortality rate of skipjack tuna in the waters of Ternate Island is already at optimal conditions, and the exploitation rate conditions are close to the optimum value required for preserving skipjack tuna. In addition, for a good and sustainable management, it is necessary to be careful in using this type of fish while avoiding the increase in the number of fishing efforts.

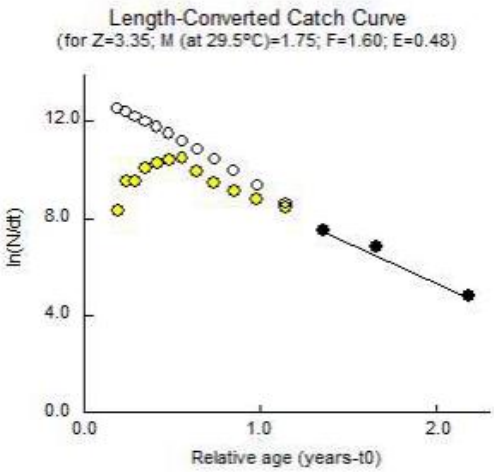

Fig. 9. Catch curve based on fish length composition data

Table 2. Comparison of the mortality rate and exploitation rate of skipjack tuna with other locations and studies

Location	Peneliti/Year	Z	M	F	E
Indian Ocean (WPP 573)	Aditya & Arryanto, 2018	0.87	0.5	0.37	0.42
Indian Ocean (WPP 573)	Sri Murti, 2019	2.4	0.56	1.84	0.77
Indian Ocean (WPP 573)	Mawarida *et al*., 2021	1.13	0.47	0.66	0.59
Pacific Ocean (North Papua)	Hidayat *et al*., 2017	1.22	0.60	0.62	0.46
Northern Waters (West Aceh)	Damora *et al*., 2021	2.96	0.50	2.56	0.83
Indian Ocean (WPP 572)	Zedta *et al*., 2018	0.70	0.49	0.21	0.30
This research (Ternate Waters)	Tangke *et al*., 2022	3.35	1.75	1.60	0.48

Yield per recruitment (Y/R) and biomass per recruitment (B/R)

Results of the analysis of yield per recruit and biomass per recruit using the parameter values of M/K = 4.4 and Lc/L∞ = 0.64 in Fig. (7), the yield value per recruit was assessed as 0.039. This values that 3.9% of new fish individuals of skipjack tuna entering the waters will be caught by fishermen as catches. While, the value of biomass per recruit shows that the remaining biomass of skipjack tuna fish that enter the waters is 30.4%. The current exploitation value is 0.48, while the maximum E value of skipjack tuna in the waters of Ternate Island (Fig. 10) is 0.402, with the optimum value for good management is 0.314, this indicates that the exploitation level of skipjack tuna has exceeded the maximum level and is categorized as overfishing.

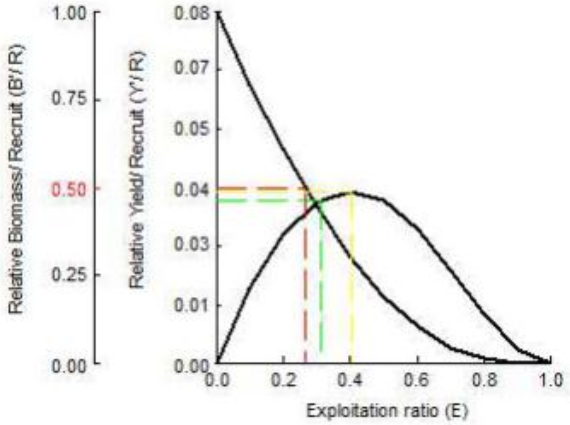

Fig. 10. Y/R and B/ R showing relationship curves

CONCLUSION

The results showed that the length of skipjack tuna caught during the study ranged from 16 - 82cm, with a growth parameter of L∞ 77.7cm and a growth coefficient of 1.4 per year; the age of skipjack tuna at length zero was -0.08 years. Furthermore, the age of the fish when it reached asymptotic length (L∞ = 77.7 cm) was 24 years, with Lc 49.88 and a natural mortality rate of 1.75, fishing mortality of 1.60, fishing mortality of 3.35 and exploitation rate (E) of 0.48. These conditions showed that the status of skipjack tuna management in the waters of Ternate Island is optimum (0.5) for the preservation of skipjack tuna. In addition, for a good and sustainable management, it is necessary to be careful in its utilization avoiding increasing amount of fishing efforts.

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