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Analysis of Population Dynamics and Stock Condition of Skipjack (*Katsuwonus Pelamis*) in Purse Seine Gear Landed at PPI Lonrae, Bone Regency, South Sulawesi

Anisa Fitri[1], Muhammad Abduh Ibnu Hajar[2]*, Safruddin[2], Muhammad Kurnia[2], Mukti Zainuddin[2]

[1]Master Program of Fishery Science, Faculty of Marine Science and Fisheries, Hasanuddin University, Indonesia

[2]Capture Fishery Study Program, Faculty of Marine Science and Fisheries, Hasanuddin University, Indonesia

***Corresponding Author: ibnuhajar@unhas.ac.id**

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ABSTRACT

Skipjack tuna (*Katsuwonus pelamis*) fishing is one of the most prominent capture fisheries activities in the Bone Bay waters. The primary fishing gear used is purse seine, often operated in association with fish aggregating devices (FADs). Skipjack caught in FAD areas tend to be smaller in size and subject to overfishing, making it difficult for Indonesia to significantly increase production through capture fisheries. Therefore, understanding the population dynamics and stock status of the skipjack caught by purse seine is essential. Catching individuals below optimal size can lead to a decline in population abundance and long-term yield. This study focused on assessing the population dynamics and stock condition of the skipjack in Bone Bay waters caught by purse seine gear with FADs. Research was conducted from February to June 2025, with a total of 1,024 skipjack samples collected. A stratified random sampling method was applied, and fish lengths were measured and classified into small, medium, and large size groups. Data were processed using the FAO–ICLARM Fish Stock Assessment Tools II (FISAT II) software to determine length–frequency structure, age composition, growth, mortality, exploitation rate, yield per recruitment, and stock condition. Results indicated that the skipjack population in Bone Bay waters, as caught by purse seine, comprised two age groups. The estimated asymptotic length ($L\infty$) was 67 cm, with a growth rate (K) of 0.42 $year^{-1}$. Mortality parameters included total mortality (Z) 2.54 $year^{-1}$, natural mortality (M) 0.84 $year^{-1}$, and fishing mortality (F) 1.71 $year^{-1}$. The exploitation rate (E) was 0.67 $year^{-1}$, while the relative yield per recruitment (Y'/R) was 0.0307 g/recruitment. Stock assessment results showed that the skipjack stock in Bone Bay waters, under purse seine fishing pressure, had a feasibility percentage of 56%, placing it in the depressed or depleted stock category.

INTRODUCTION

The catch of the skipjack in Bone Regency has shown fluctuating trends, with annual variations in landings **(DKP Bone, 2024)**. In particular, skipjack catches at the

Lonrae Fish Landing Base (PPI Lonrae) have experienced a consistent decline in recent years. According to **Jamal *et al.* (2019)**, the potential skipjack yield in Bone Bay waters is estimated at 61,800 tonnes per year. Skipjack fishing in these waters occurs year-round, resulting in high fishing pressure. While fish distribution patterns influence fishermen's decisions on fishing effort, excessive effort inevitably leads to declining stock abundance **(Zahra *et al.*, 2019)**.

Skipjack (*Katsuwonus pelamis*) is classified as a large pelagic species and is commonly targeted using purse seine gear. The purse seine fishing process in Bone Bay typically begins with identifying the fishing ground, followed by traveling from the fishing base to the selected location. Most purse seine fishers in this area deploy fish aggregating devices (FADs) as aids **(Rumpa, 2023)**. However, fishing in FAD-associated areas often results in higher catches of small-sized skipjack **(Mallawa, 2020)**. The use of such fishing aids has contributed to overfishing, which is reflected in smaller average fish sizes, reduced growth rates, and a decline in the proportion of individuals reaching catchable size.

Year-round exploitation of skipjack using purse seine gear with FADs has placed significant pressure on the population. Therefore, an in-depth assessment of the population dynamics and stock status of skipjack in Bone Bay waters is urgently needed. Understanding population dynamics offers a scientific basis for sustainable management of skipjack resources. **Rasdam *et al.* (2024)** reported that the average catchable size of skipjack in Bone Bay waters is approximately 60cm.

With increasing demand for skipjack, the absence of sustainable management measures could further deplete the population. To address this, comprehensive information on population dynamics—covering parameters such as age structure, growth, mortality (natural and fishing), exploitation rate, yield per recruitment, and stock availability—is essential.

The novelty of this study lies in its integration of population dynamics and stock condition data with the specific fishing gear used. The research focuses on skipjack caught using purse seine gear with FADs, evaluating key biological and fishery indicators.

The objectives of this study were to analyze the population dynamics of skipjack landed at PPI Lonrae, including age group composition, growth rate, natural and fishing mortality rates, exploitation rate, relative yield per recruitment, skipjack dispersal rate, percentage of catchable-sized individuals, and actual yield per recruitment

MATERIALS AND METHODS

The research was conducted at the Lonrae Fish Landing Base (PPI Lonrae), Bone Regency, South Sulawesi, from February to June 2025. Sampling was carried out using a stratified random sampling method, in which skipjack were grouped into three size categories. All specimens analyzed were caught by purse seine vessels operating around fish aggregating devices (FADs) in the waters of Bone Bay.

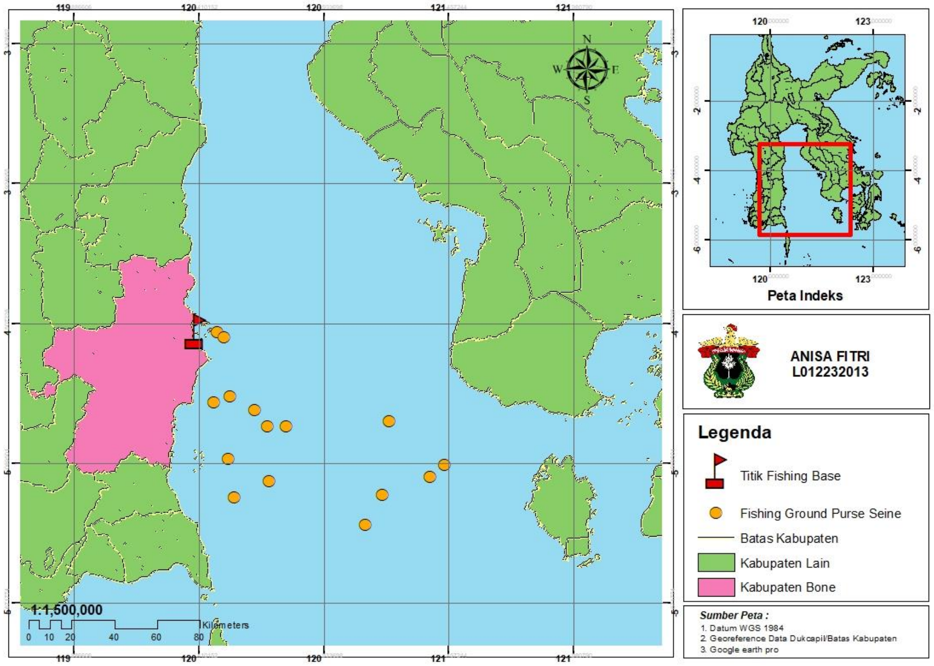


Fig. 1. Research location with fishing base and skipjack fishing area

In this study, the sample of skipjack fish was measured based on the length of the cagak, starting from the tip of the mouth to the tip of the outside of the tail curve. Prior to data collection, interviews were conducted with local fishermen to obtain information on fishing locations and operational patterns. A total of 1,024 skipjack tuna (*Katsuwonus pelamis*) specimens were sampled for this study.

Data analysis

In this research, data analysis was supported by several software applications, including FISAT II (FAO–ICLARM Stock Assessment Tools) for fisheries stock assessment and Microsoft Excel for data processing and visualization. Population dynamics were estimated using parameters such as size structure, age composition, growth, mortality, exploitation rate, and yield per recruitment.

1. Size structure and age groups

Size structure and age group analyses were conducted using the Bhattacharya method. The procedure involved first determining the length class intervals, after which the fish length data were processed using the FISAT II program to identify distinct age groups **(Umar *et al.*, 2014)**.

2. Growth

The estimation of the parameter values of growth followed the equation proposed by **Sparre *et al*. (1999)**, namely :

$$Lt = L\infty(1 - e^{-K(t - to)})$$

Description:

Lt = Length of fish at age t (cm)

L∞ = Asymptote length of fish (cm)

K = Coefficient of fish growth rate (per year)

t0 = Theoretical age of fish when length equals zero (years)

t = Age (years)

Calculation of asymptotic length (L∞) and growth coefficient (K) values in fish was done through the estimation method using the ELEFAN programme available in FISAT II software. Theoretical age (to) was estimated using the empirical equation of **Pauly (1983)** as follows:

$$\text{Log}(-t_0) = -0.3922 - 0.2752\,(\log L\infty) - 1.038\,(\log K)$$

Description:

t0 = theoretical age of fish when length equals zero (years)

L∞ = asymptotic length of fish / maximum length of fish that can be achieved (cm)

K = growth rate coefficient (per year)

3. Mortality

There are three types of mortality in fish population dynamics, namely total mortality (Z), natural mortality (M), and fishing mortality (F). Estimation of the Z value was done through the length-converted catch curve method in FISAT II software **(Pauly, 1983)**:

$$Z = k\,\frac{L\infty - \bar{L}}{\bar{L} - L'}$$

Description:

Z = Total mortality (per year)

L∞ = Fish asymptote length (cm)

K = Fish growth rate coefficient (per year)

L = Average length of fully caught fish (cm)

L' = Smallest limit of fully caught fish length class size (cm)

4. Exploitation rate

The exploitation rate (E) was calculated using the formula of **Sparre *et al*. (1999)**, namely :

$$E=\frac{F}{Z}$$

Description:

E = Exploitation Rate

Z = Total mortality rate

F = Capture mortality

5. Yield per recruitment

The yield per recruitment analysis stage was analyzed using the Asses - Baverton and Holt Y/R sub-programs using the FiSAT application. The parameters used in the analysis are parameters of the exploitation rate, growth rate coefficient and natural mortality.

6. Stock condition

To assess the stock condition of skipjack at PPI Lonrae, indicators analyzed include cohort structure, length distribution, population size, growth parameters (K), fishing mortality (F), utilisation rate (E), stock replenishment process (Y/R), and percentage of fish that meet the catch requirements.

The weight of each indicator is different according to its urgency, each indicator is divided into sub-indicators with different values. The stock condition is assessed based on the achievement (%) and the percentage of achievement was calculated using the equation proposed by **Mallawa *et al.* (2013)** and **Mallawa *et al*. (2017)** as follows:

Stock condition = {(∑ weight x value)/ full value)}x 100%.

The stock condition uses the following references:

The reference categories for stock condition assessment were as follows:

- Very good: ≥ 85–100%
- Good: < 85–65%
- Depressed or depleted: < 65%

Stock condition achievement scores were calculated using the assessment worksheet shown in Table (1).

Table 1. Analysis of skipjack stock condition achievement

Indicator Criteria	Weight	Value	Weight x value
Size structure of skipjack caught	2,00		
Dominance of juveniles		1	
Dominance of juveniles and preadults		3	
Dominance of preadults and adults		5	

Number of age groups	1,00		
One age group		1	
Two age groups		3	
Three age groups		5	
Fishing mortality rate	2,00		
F value > 2.0		1	
F value 1.0 - 2.0		3	
F value < 1.0		5	
Exploitation rate	1,00		
E value > 1.0		1	
E value > 0.5 - < 1.0		3	
E value < 0.5		5	
Population growth rate	1,00		
K value < 0.3 per year		1	
K value 0.3 - 0.5 per year		3	
K value > 5 per year		5	
Yield Per Recruitment	1,00		
Y/R actual < Y/R optimal		1	
Y/R actual = Y/R optimal		3	
Y/R actual > Y/R optimal		5	
Percentage of catcha	2,00		
< 20 %		1	
20 - < 50 %		3	
≥ 50 %		5	
			∑ Weight x value

RESULTS

1. Size structure and age groups

Sample data on skipjack size were collected from February to March 2025, with a total of 1,024 fish measured. Based on the measurement results, the size range of the samples was determined as follows:

1.1 February size structure of handline fishing gear

In February, a total of 628 skipjack (*Katsuwonus pelamis*) samples were obtained. The fork lengths were grouped into 12 class intervals for analysis.

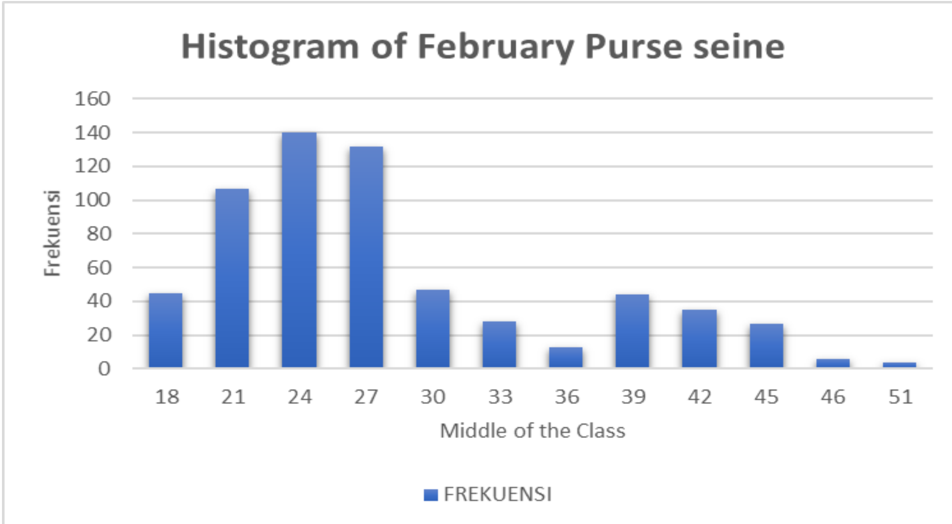


Fig. 2. February size structure purse seine gear

1.2 March size structure of handline fishing gear

The number of skipjack (*Katsuwonus pelamis*) samples obtained in January was 396 fish. The length of skipjack is grouped into 12 class intervals.

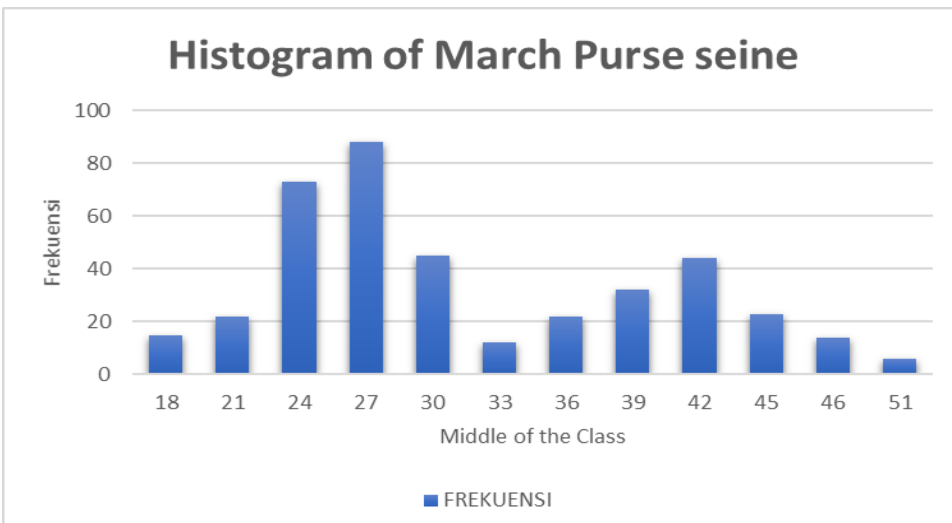


Fig. 3. March size structure purse seine gear

1.3 Size structure of combined Purse seine gear

The number of skipjack (*Katsuwonus pelamis*) samples obtained during the study was 1,024 fish. The lengths of the skipjack were grouped into 12 class intervals, resulting in 2 age groups. Cohort 1 had a length range of 18– 33cm, with an average length of 25cm and a frequency of 771.47. Cohort 2 had a length range of 36– 51cm, with an average length of 41cm and a frequency of 274.88.

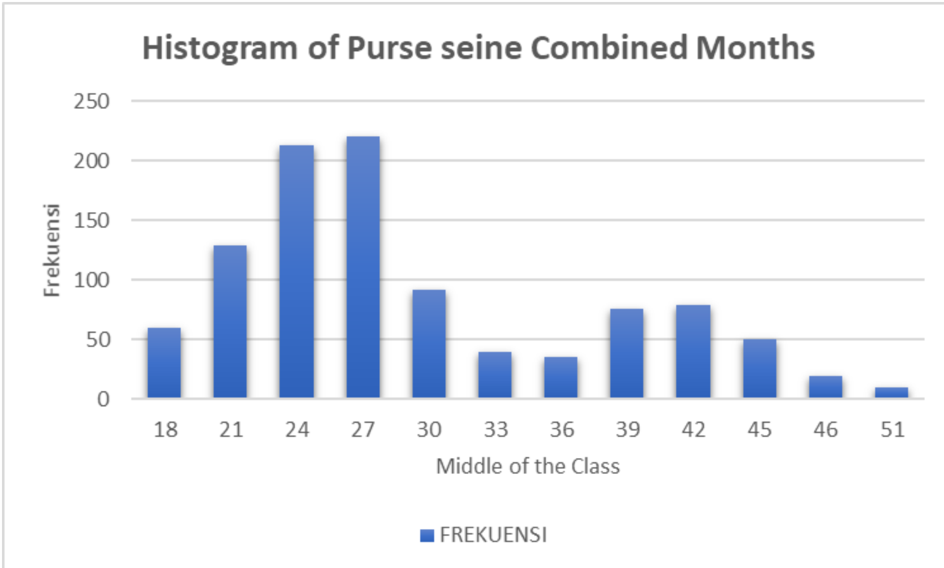
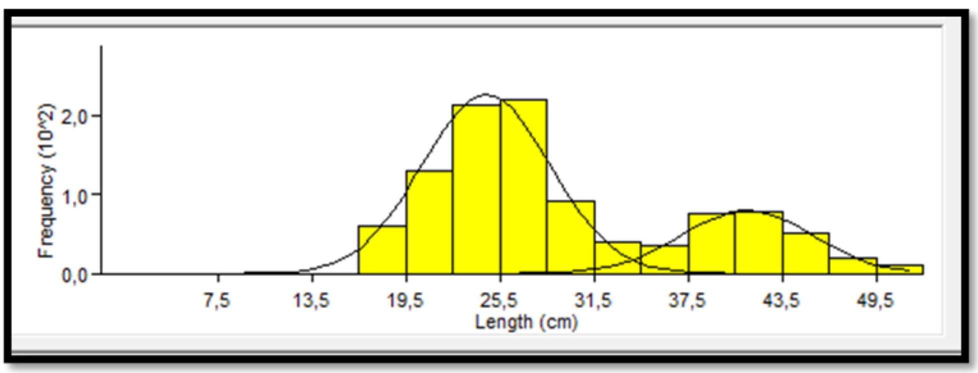


Fig. 4. Size structure of skipjack in purse seine gear

The age groups of skipjack were determined using length frequency distribution analysis. Fig. (5) for purse seine gear, illustrates the age groups of skipjack in February–March. The results of the analysis for each size group of skipjack are presented in Table



(2).

Fig. 5. Size structure of skipjack in Purse seine gear

Table 2. Results of age group analysis of skipjack (*Katsuwonus pelamis*) in the waters of Teluk Bone in February - March Purse seine gear

Cohort	Average length	Number of individuals	Separation index
1	24,60	771,47	n.a
2	41,22	274,88	2.590

Separation analysis of skipjack size cohorts (Table 2) yielded a separation index of 2, confirming that Bhattacharya's method is feasible for separation of these size groups.

2. Growth

The results of the analysis of growth parameters in the form of theoretical maximum length (L∞), growth rate (K), and initial theoretical age (t0) in purse seine caught fish are presented in Table (3).

Table 3. Estimated growth parameters of skipjack (*Katsuwonus pelamis*) for purse seine gear in Bone Bay waters

Parameter	Value
$L\infty$	67
K	0,42
t_0	-0.0517

Table (3) shows the analysis of parameters on skipjack in purse seine fishing gear, namely the value of $L\infty$= 67cm, K= 0.42 per year, t_0= -0.0517 years. The growth coefficient of skipjack fish shows that the value of K in the skipjack fish is smaller than 0.5. This indicates that the growth of the skipjack has a slow recovery from the asymptotic length of the fish. Growth parameter values ($L\infty$, K, t_0) were processed using the Von Bertalanffy equation: $L_t= 67\ (1 - e^{-0.42\ (t\ +\ 0.0517)})$. The projected growth of skipjack shown in Fig. (6) was obtained by inputting various values of age (t) into the equation.

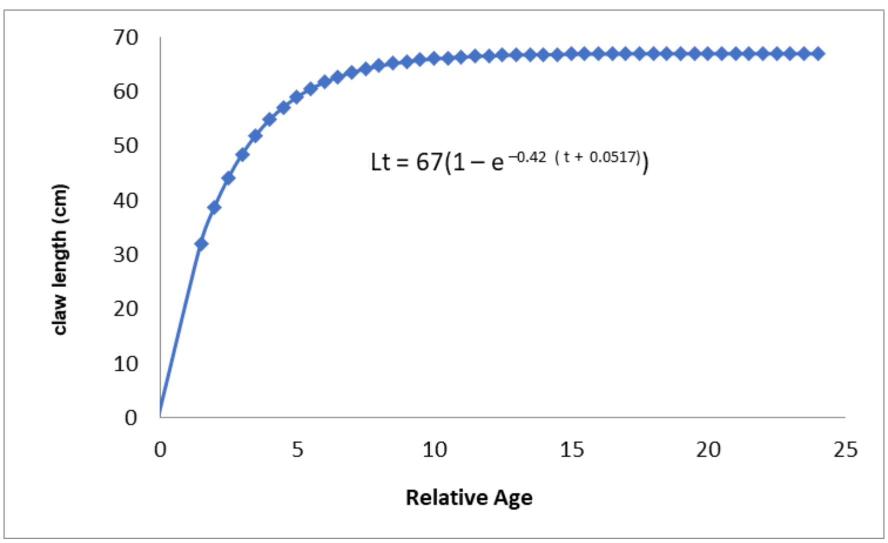


Fig. 6. Growth curve of skipjack (*Katsuwonus pelamis*) using purse seine gear

3. Mortality and exploitation rate of Purse seine gear

The results of the analysis provided estimates of the mortality parameters and the exploitation rate of the skipjack in Bone Bay waters using purse seine fishing gear, as shown in Table (4).

Table 4. Mortality and exploitation rate of skipjack (*Katsuwonus pelamis*) in Bone Bay waters using purse seine gear

Parameter	Nilai
Z	2,54
M	0,84
F	1,71
E	0,67

Description: Z (Total mortality), M (Natural mortality), F (Capture mortality), E (Exploitation) in Purse seine gear.

Table 4 shows that skipjack has a total mortality (Z) = 2.54, natural mortality (M) = 0.84, capture mortality (F) = 1.71. Capture mortality is higher than natural mortality, which means that fishing mortality is higher than habitat mortality.

The value of the exploitation rate (E) of skipjack found in Bone Bay waters in purse seine gear, indicates that skipjack has been over exploited.

4. Yield per recruitment

The current Y/R value of purse seine gear is 0.0307 grams/recruitment. This value is more than the maximum Y / R of 0.0286 grams / recruitment. As for the alleged results on the exploitation rate in purse seine fishing gear 0.67 per year with a maximum exploitation rate value of 0.50 per year which means that recruitment shows overexploitation conditions.

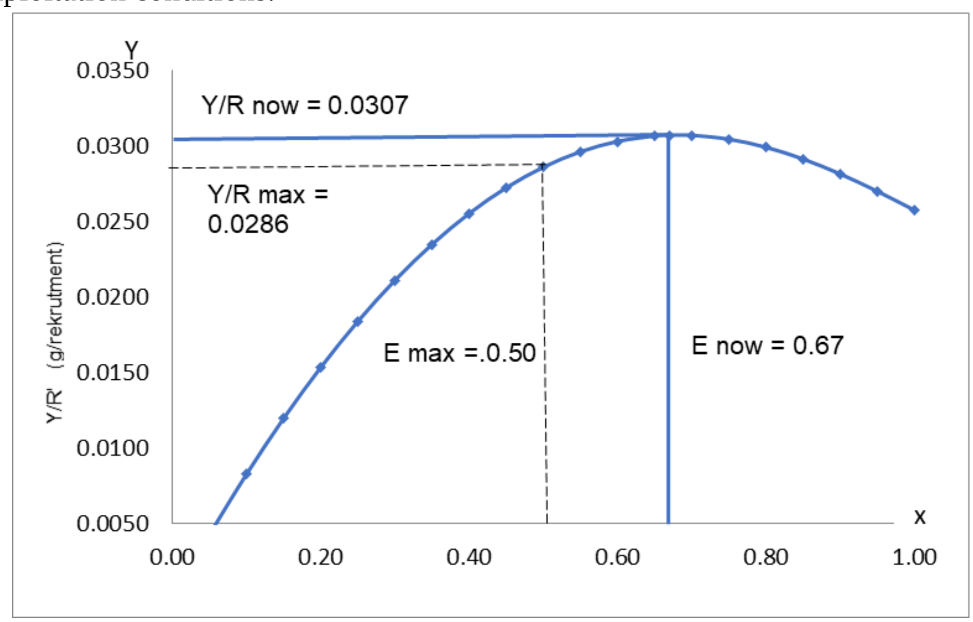


Fig. 7. Yield per recruitment of skipjack (*Katsuwonus pelamis*) using purse seine gear

5. Skipjack stock condition

In purse seine fishing gear, the size of the catch is relatively small, with all fish caught measuring less than 55cm. The size structure of skipjack in Bone Bay waters, according to **Syamsuddin *et al.* (2023)**, shows that the size composition of skipjack caught with purse seine gear ranged from 24.00 to 53.50cm. A tabulation of indicators of the skipjack stock condition in Bone Bay waters, based on purse seine catches, is presented in Table (5).

Table 5. Analysis of skipjack stock condition attainment using purse seine gear

Indicator Criteria	Weight	Value	Weight x value
Size structure of skipjack caught	2,00		
Dominance of juveniles		1	
Dominance of juveniles and preadults		**3**	6,00
Dominance of preadults and adults		5	
Number of age groups	1,00		
One age group		1	
Two age groups		**3**	3,00
Three age groups		5	
Fishing mortality rate	2,00		
F value > 2.0		1	
F value 1.0 - 2.0		**3**	6,00
F value < 1.0		5	
Exploitation rate	1,00		
E value > 1.0		**1**	
E value > 0.5 - < 1.0		3	3,00
E value < 0.5		5	
Population growth rate	1,00		
K value < 0.3 per year		**1**	
K value 0.3 - 0.5 per year		3	3,00
K value > 5 per year		5	
Yield Per Recruitment	1,00		
Y/R actual < Y/R optimal		1	
Y/R actual = Y/R optimal		3	5,00
Y/R actual > Y/R optimal		**5**	
Percentage of catcha	2,00		
< 20 %		**1**	
20 - < 50 %		3	2,00
≥ 50 %		5	
Acquisition Value			28
Feasibility Percentage			56%

The results of the stock parameter analysis in Table (5) show that the skipjack (*Katsuwonus pelamis*) population in Bone Bay waters caught using purse seine is in the overexploited category.

DISCUSSION

1. Age groups

Research in Bone Bay waters using purse seine gear identified two age groups of skipjack. In February–March, two cohorts were formed: the first cohort had an average length of 25cm, and the second cohort had an average length of 41cm. This indicates that purse seine fishing with the use of FADs still captures a significant number of undersized skipjack. The cohort distribution also shows limited age variation in the skipjack population being caught.

Growth

Based on calculations using the FISAT II application, the growth coefficient (K) for skipjack in Bone Bay waters was estimated at 0.48 per year. This value is below 0.5, indicating slow recovery from the asymptotic length. Fish with low K values are typically long-lived and take longer to reach maximum size. Factors influencing this slow growth may include exploitation pressure, environmental conditions, food availability, and seasonal variations in growth rates.

According to **Sparre and Venema (1999)**, K values below 0.5 indicate slow growth, while values above 0.5 indicate fast growth. The estimated asymptotic length ($L\infty$) for the skipjack was 67cm, meaning that the skipjack can potentially reach this size in the absence of fishing mortality. The theoretical age (t_0), calculated using the formula by **Pauly (1983)**, was –0.0517 years.

Using the von Bertalanffy growth function **(Bertalanffy & Beverton-Holt, 1965)**, the growth equation was:

$$Lt = 67 (1 - e^(-0.42(t + 0.0517)))$$

Based on this model, at t = 1.5 years, the estimated length is 32cm. The skipjack growth is relatively rapid between 1.5 and 3.5 years but slows considerably from 4.5 to 5 years, approaching the maximum body length.

Mortality and exploitation rates

Using FISAT II with a water temperature of 30°C, fishing mortality (F) was estimated at 1.71, while natural mortality (M) was 0.84. This indicates that fishing mortality is higher than natural mortality. These high fishing mortality values are likely due to purse seine operations with FADs capturing many undersized fish. Additionally, there are no regulations on minimum catch size for the skipjack in the area.

The total mortality rate (Z) was 2.54, and the exploitation rate (E) was calculated at 0.67 per year, exceeding the recommended optimal value of 0.5. This suggests that skipjack fishing in Bone Bay waters is occurring at unsustainable levels, indicating overfishing.

Yield per recruitment

The estimated yield per recruitment (Y/R) for skipjack in Bone Bay waters was 0.0307 g/recruit, exceeding the maximum Y/R of 0.0286 g/recruit. Since the current Y/R value is higher than the optimal level, the recruitment process for skipjack in the area is suggested to be already at its optimal limit under current fishing conditions.

Stock condition

The estimated stock condition index for the skipjack in Bone Bay waters, based on purse seine catches, was 56%. This places the stock in the “depressed” or “depleted” category. This condition is attributed to the absence of management policies regulating fishing gear, such as FAD use, in skipjack fisheries in the region.

CONCLUSION

Research on the population dynamics and stock conditions of skipjack (*Katsuwonus pelamis*) using purse seine fishing gear in Bone Bay waters, landed at PPI Lonrae, Bone Regency, South Sulawesi, identified two (2) cohorts in the age group analysis. The growth rate of skipjack caught with purse seine fishing gear was found to be relatively slow. Mortality in skipjack populations was dominated by fishing mortality, and the exploitation rate indicated that the stock is overexploited.

Recruitment analysis showed that the current yield per recruitment (Y/R) value is higher than the optimal Y/R (current Y/R < maximum Y/R). The stock condition index for the skipjack in Bone Bay waters was 56%, placing the stock in the “depressed” or “depleted” category.

The findings of this study highlight the need for special attention from the government and fisheries managers regarding regulations and supervision of operational area boundaries for purse seine fishing. Such measures are necessary to prevent a significant decline in skipjack stocks in Bone Bay.

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