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Biological Analysis of Mackerel Tuna (*Euthynnus affinis*) in Banda Sea Waters

(Analisis Aspek Biologi pada IkanTongkol (*Euthynnus affinis*) di Perairan Laut Banda)

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Abstrak

Ikan Tongkol (*Euthynnus affinis*) adalah komoditas perikanan penting di Laut Banda, bagian dari Wilayah Pengelolaan Perikanan 714 (WPP 714). Penelitian ini menganalisis karakteristik biologis ikan tongkol, termasuk distribusi frekuensi panjang, pola rekrutmen, parameter pertumbuhan, dan mortalitas. Penelitian dilakukan di Pelabuhan Perikanan Samudera (PPS) Kendari dengan data hasil tangkapan dari Laut Banda yang diperoleh dari observer di PPS Kendari. Panjang ikan meningkat sepanjang tahun, dengan frekuensi tertinggi terjadi antara bulan April hingga Mei, dengan panjang rata-rata 50 cm. Pola rekrutmen menunjukkan dua puncak tahunan yang terjadi pada bulan Maret dan Agustus. Konstanta pertumbuhan (K) adalah 0,632, dengan indeks pertumbuhan 1,0. Analisis mortalitas menunjukkan mortalitas total (Z) sebesar 6,70, mortalitas alami (M) sebesar 1,24, mortalitas penangkapan (F) sebesar 5,46, dan tingkat eksploitasi (E) sebesar 0,82. Hasil penelitian ini menunjukkan bahwa meskipun laju pertumbuhan tetap baik namun terjadi eksploitasi berlebihan, yang menekankan pentingnya pengelolaan perikanan yang berkelanjutan.

Kata Kunci: Ikan Tongkol (*Euthynnus affinis*), Frekuensi Panjang, Pola Rekrutmen, Konstanta Pertumbuhan, Mortalitas

Abstract

Mackerel tuna (Euthynnus affinis) is a significant fishery commodity in the Banda Sea, part of Fisheries Management Area 714 (WPP 714). This study focused on analyzing the biological characteristics of mackerel tuna, including length-frequency distribution, recruitment patterns, growth parameters, and mortality rates. Research was conducted at the Kendari Ocean Fisheries Port (PPS), with catch data from the Banda Sea provided by PPS Kendari observers. Data were analyzed using Microsoft Excel and software applying Von Bertalanffy's growth model. Fish length increased throughout the year, with the highest frequency observed from April to May and an average length of 50 cm. Recruitment patterns revealed two annual peaks in March and August. The growth constant (K) was 0.632, with a growth index of 1.0. Mortality analysis showed total mortality (Z) at 6.70, natural mortality (M) at 1.24, fishing mortality (F) at 5.46, and an exploitation rate (E) of 0.82. These results suggest that while growth rates remain favorable, mackerel tuna is experiencing overexploitation, highlighting the need for sustainable fisheries management.

Keywords: Mackerel Tuna (Euthynnus affinis), Length Frequency, Recruitment Pattern, Growth Constant, Mortality

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INTRODUCTION

The Banda Sea is one of Indonesia's marine regions with highly potential fishery resources. It is part of the Fisheries Management Area (WPP) of Kendari Ocean Fisheries Port (PPS) in Southeast Sulawesi. According to the Ministry of Marine Affairs and Fisheries (KKP) Regulation No. 1 of 2009, this area is classified under WPP 714, which covers waters located between Sulawesi Island, the Maluku Islands, and other smaller islands. It has become a key location for local fishermen to catch fish [1].

One of the pelagic fish species abundant in the Banda Sea is the mackerel tuna (*Euthynnus affinis*). Mackerel tuna (*Euthynnus affinis*) is highly nutritious, with a protein content reaching 26%, low-fat content of 2%, and is rich in omega-3 fatty acids and essential minerals. The fish is popular among the public, making it a valuable economic commodity [2].

The high demand from the public has led to increased catches of mackerel tuna (*Euthynnus affinis*). These catches are typically made using purse seines, which are considered highly non-ecological due to their non-selective nature. The purse seine is an effective fishing gear for capturing pelagic fish that live in large schools [3]. Mackerel tuna (*Euthynnus affinis*) is one of the fish species caught by purse seines. In 2012, the catch of mackerel tuna in the Banda Sea reached 711.55 tons. The high catch volume with this method has led to the overexploitation or overfishing of mackerel tuna (*Euthynnus affinis*) [4].

Studying fish biological aspects can help predict the rate of exploitation or overfishing. The size of the fish at gonadal maturity is crucial for reproductive strategies and exploitation. The biological aspects include length-frequency distribution, growth constants, mortality, catchability, and recruitment patterns. Reproductive biological parameters, such as the size at gonadal maturity, are key life-history parameters in fisheries management, particularly for exploited species [5].

Indonesia has limited analysis of the biological aspects of mackerel tuna (*Euthynnus affinis*), such as reproduction, growth, mortality, and other biological factors. This biological information is essential for managing capture fisheries to ensure the sustainability of fishery resources [6].

METHODS

This study was conducted from December 2023 to February 2024 at the Kendari Ocean Fisheries Port (PPS) in Kendari City, Southeast Sulawesi, which serves as the main fish landing site for the Banda Sea. Data were obtained from the observer documents at PPS Kendari. The observer data consists of fish sample collection conducted by following fishing operations carried out by fishing vessels based at the Kendari Ocean Fisheries Port (PPS). Observers monitor fish production to prevent illegal fishing and collect fish data using random sampling on vessels in operation. Direct field observations were made to confirm the observer data. Fish samples were measured using a 1 mm scale ruler. Fish length was measured using Fork Length (FL), from the anterior tip to the tail fin [7].

The observer data were processed using Excel to create a length frequency table for each fishing operation and to determine the maximum and minimum fish lengths as well as the class interval. The length frequency table was then used as the standard for inputting initial data into the FISAT II software. The formulas used are as follows [8]:

Determining the number of classes

$$K = 1 + 3.33 \log log\, N$$

where:
K = number of classes
N = number of observation data points

Determining the class interval

$$Ci = \frac{R}{K}$$

where:

C_i = class interval
R = the difference between the highest and lowest data values (Range)
K = number of classes

Data Analysis

The growth rate data is analyzed using the FISAT II software with the ELEFAN I subprogram (Electronic Length Frequency Analysis), which identifies the growth rate. The analysis in FISAT II yields the parameters L_∞ and K. To estimate t_0 the theoretical age of the fish when its length is zero (in years), the formula by Pauly (1983) [8] is applied:

$$\left(-t_0\right) = -0.3922 - 0.2752\,(\log log\ L_\infty) -$$

t_0 = Theoretical age of the fish when its length is zero (years)
L_∞ = Maximum length the fish can achieve if no mortality occurs (cm)
K = Growth rate coefficient (per year)

Once the growth parameters L_∞, K, and t_0 are obtained, the Von Bertalanffy and Beverton-Holt equation (1956) [8] is used to estimate fish growth :

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

where:
L_t = Fish length at age t (cm)
L_∞ = Maximum length the fish can achieve if no mortality occurs (cm).
K = Growth rate coefficient (per year).
T = Fish age (years)
t_0 = Theoretical age of the fish when its length is zero (years).

The calculation of total mortality follows the Beverton and Holt (1956) formula as cited in [9]:

$$Z = K = \frac{(L_\infty - \bar{L})}{(\bar{L} - L')}$$

Z = Total mortality rate (per year)
K = Growth rate coefficient (per year)
L_∞ = Maximum length fish can achieve without natural or fishing mortality (cm)
L' = Minimum fish length measured (cm)
$\bar{L}$ = Average fish length (cm)

Natural mortality (M) is analyzed using FISAT II software and calculated based on an empirical formula [8]:

$$\ln ln\, M = -0.0066 - 0.279 \ln ln\, L_\infty + 0.6543 \ln ln\, K$$

M = Natural mortality rate
L_∞ = Maximum length fish can achieve without mortality (cm)
K = Growth rate coefficient (per year)
T = Average sea surface temperature in the fishing area (°C)

Using the obtained values of natural mortality (M) and total mortality (Z), the following relationships are applied to calculate fishing mortality (F):

Z = F + M and F = Z – M

F = Fishing mortality rate

Z = Total mortality rate
M = Natural mortality rate

The exploitation rate is calculated using Pauly's formula (1983) [8].

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

E = Exploitation rate
F = Fishing mortality rate
Z = Total mortality rate
M = Natural mortality rate

According to Pauly (1983) [8] if E is more than 0.5, the fishery is overexploited. The fishery is at its optimal level or Maximum Sustainable Yield (MSY) when E is exactly 0.5 and underexploited when E is less than 0.5.

Recruitment pattern analysis is conducted using the recruitment pattern sub-program. This analysis requires data on L_∞, K, and t_0 determined from prior calculations. The analysis produces a histogram depicting recruitment patterns and predictions of the monthly recruitment percentage.

RESULTS AND DISCUSSION

The study revealed that the average length of Mackerel Tuna (*Euthynnus affinis*) varied over three months. The measured average lengths of *Euthynnus affinis* are presented in Table 1.

Table 1. Average Total Length Measurements of Mackerel Tuna (*Euthynnus affinis*) from the Banda Sea (October–December 2022)

Month	N (fish)	Total Length (cm)		
		Min	Max	Average
October	32	38	72	47.3
November	16	16	36	22.7
December	47	47	63	52.3
Total	**95**	**16**	**72**	**40.8**

Table 1 shows that the average length of mackerel tuna (*Euthynnus affinis*) was 47.3 cm in October, decreased to 22.7 cm in November, and increased again, peaking at 52.3 cm in December. The overall average length of all sampled fish was 40.8 cm.

Length Frequency Distribution of Mackerel Tuna (*Euthynnus affinis*)

The length frequency distribution analysis aims to determine the size of mackerel tuna (*Euthynnus affinis*) obtained from three months of sample measurements, serving as a predictor of their biological characteristics. The results, including the length frequency distribution and recruitment patterns, are illustrated in Figure 1.

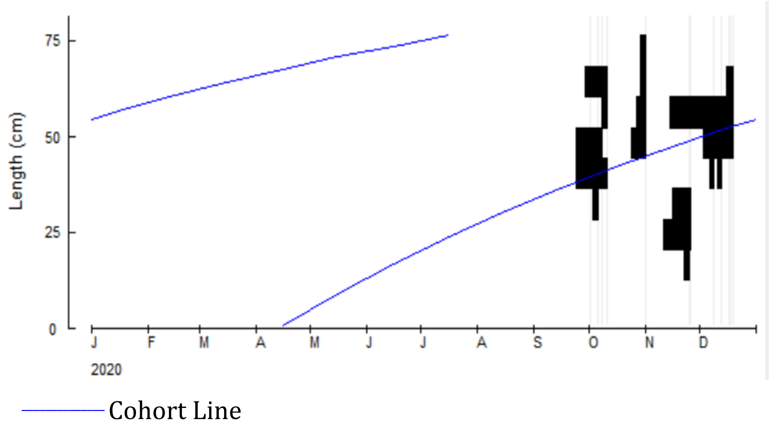

Figure 1. Length Frequency Distribution of Mackerel Tuna (*Euthynnus affinis*).

Figure 1 shows the length frequency distribution analysis for three consecutive months, October, November, and December, representing the length distribution over a year. By mid-April, the cohort line rises until July of the following year, indicating an increase in fish size from April 2020 to July 2021, with fish growing from 0 cm to 50 cm. The second cohort line shows growth from January to mid-July, with fish sizes increasing from 52 cm to 75 cm.

The length frequency distribution was analyzed using the total length data of fish samples. The analysis involved determining the required class intervals, calculating class widths, and then determining the frequency of lengths in each class. This process produced a frequency distribution graph that highlights shifts in class distribution over time, representing the age groups (cohorts) [10].

Growth Constant of Mackerel Tuna (*Euthynnus affinis*)

The growth constant of mackerel tuna (*Euthynnus affinis*) is analyzed to assess whether the fish are growing well and to observe any improvements in growth.

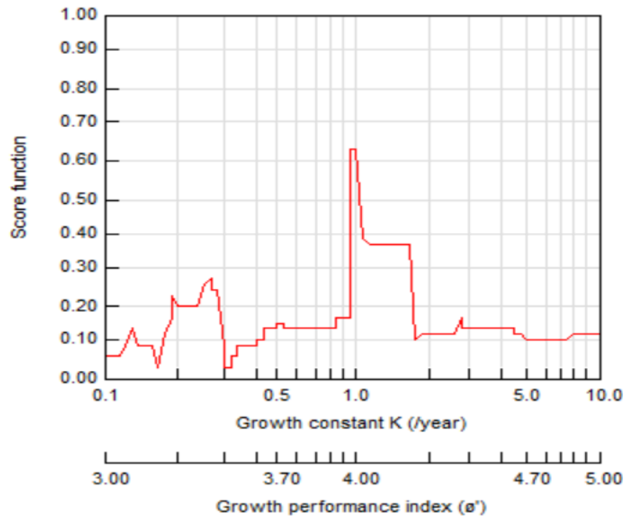

Figure 2. Growth Constant of Mackerel Tuna from WPP 714 Landed at PPS Kendari.

Figure 2 shows that the growth constant was calculated successfully. The growth constant, ranging from 0.00 to 10.0, indicates that the fish growth rate at a growth index 1.0 increased to 0.632 cm. This value was obtained using the following parameters: L∞ = 108.10, starting sample = 2, and starting length = 40.50.

Growth pattern variations are influenced by factors such as fish size, environmental conditions, differences in fish stock, developmental stages, gender, gonadal maturity, and seasonal data proportions [11]. Growth fluctuations can also result from the fish's physiological state, sex, sexual maturity, season, habitat, feeding rate, health, and environmental factors like temperature, pH, salinity, geographic location, sampling techniques, fishing activities, and diseases [12]. Growth rates of mackerel tuna (*Euthynnus affinis*) can vary depending on location, sex, or the life stage of the fish, including larvae, juveniles, and adults [13].

Recruitment Pattern of Mackerel Tuna (*Euthynnus affinis*)

The recruitment pattern helps to determine how often mackerel tuna (*Euthynnus affinis*) spawn within a year. For this species, spawning occurs twice annually.

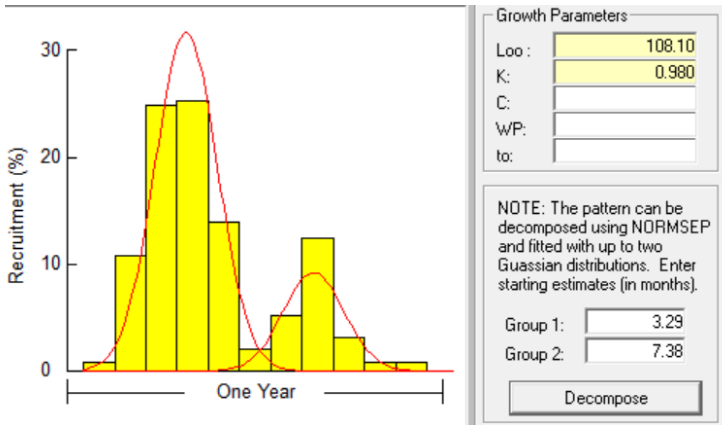

Figure 3. Recruitment Pattern of Mackerel Tuna in WPP 714 Banda Sea

Figure 3 shows that the recruitment growth pattern is progressing well, with fish growth occurring twice within the year, in the fourth and eighth months. In the fourth month, the growth rate is approximately 25%, and in the eighth month, it is around 15%. These values were obtained by using L_∞ = 108. 10 and K = 0.980.

A low growth coefficient can negatively impact productivity, and vice versa [14]. Reproductive rates depend on fish size, body weight, and length, with larger fish generally having higher reproductive rates. Mackerel tuna (*Euthynnus affinis*) has a relatively high reproductive rate, and the recruitment pattern also supports understanding its productivity.

Mortality of Mackerel Tuna (*Euthynnus affinis*)

The analysis of mackerel tuna (*Euthynnus affinis*) mortality focuses on total mortality, natural mortality, and fishing mortality to assess the fish stock in the Banda Sea.

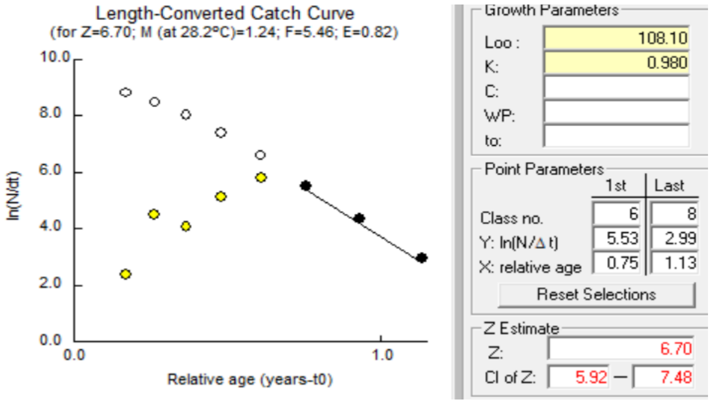

Figure 4. Mortality of Mackerel Tuna in WPP 714 Banda Sea

Figure 4 shows the mortality of mackerel tuna, with natural mortality (M) at 1.24, fishing mortality (F) at 5.46, and total mortality (Z) at 6.70. The exploitation rate (E) is 0.82. The mortality values were analyzed with a local capture temperature of 28.22^{0}C, leading to L_∞ = 108. 10 and K = 0.980.

The figure shows that fishing activities are the main cause of mackerel tuna mortality is fishing activities. The higher fishing mortality compared to natural mortality may be influenced by environmentally unfriendly fishing methods, including the gear used to catch mackerel tuna and the interactions with other fishing gear targeting different species [15].

The exploitation rate (E) of mackerel tuna in the Banda Sea is 0.82, similar to that in the Teluk Semangka waters (0.84/year), but higher than the exploitation rate in the Java Sea (0.59/year) and the Eastern Indian Ocean (0.774/year) [16]. This suggests overexploitation since an exploitation rate (E) > 0.5 indicates overexploitation [17]. The exploitation rate reflects the impact of fishing, calculated as the ratio of fishing mortality to total mortality [17].

CONCLUSION

Based on the research findings, it can be concluded that the recruitment pattern of mackerel tuna (Euthynnus affinis) in the Banda Sea occurs once a year, with the peak recruitment reaching 25.00% in April. The growth rate of mackerel tuna shows favorable growth conditions as indicated by the growth coefficient (K). Regarding mortality, the natural mortality rate, fishing mortality rate, and total mortality rate of mackerel tuna vary, with the total mortality rate (Z) estimated at 6.70 per year. The natural mortality rate (M) is 1.24, while the fishing mortality rate (F) is 5.46 per year. The exploitation rate (E), derived from the ratio of fishing mortality (F) to total mortality (Z), is calculated at 0.82, indicating a high level of exploitation.

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