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Assessing tuna populations around fads in Tabam waters for coastal management

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ABSTRACT

Tabam waters are waters in Ternate City where the average population works as fishermen using gillnet fishing gear with the target fish being tuna (Eutynnus affinis) locally called Tongkol. Fishing activities in this area are generally carried out around FADs. Fishing that is carried out on an increasing basis and accompanied by an increase in gillnet fishing gear can endanger the sustainability of mackarel tuna/ tuna fish/komo tuna. Therefore, to maintain the sustainability of tuna fish resources in Tabam waters, an assessment of the biological status is needed which includes the structure of length, weight, circumference, growth patterns, and age groups. Establish guidelines for fishermen on the appropriate size of tuna to be harvested in order to preserve the sustainability of the tuna population. This research was conducted in December 2018-March 2019, using a sample size of 200 fish, using a survey method. The survey was conducted by examining the technical characteristics of gillnet fishing gear, FAD aids, and tuna catches. The results showed that the average fish caught was gilled with an isometric growth form and the average age group of tuna fish was around 21.7 cm, 17.2 cm, 18.9 cm, and 21.0 cm.

Introduction

The waters of Tabam are one of the waters that are administratively located within the North Ternate City District, and are an area that is fertile for six types of neritic tuna, consisting of six types, namely skipjack tuna (four species) and Spanish mackerel. (2 types). The types of fish are krai tuna/frigate tuna (*Auxis thazard*), komo tuna/little tuna/kawakawa (*Euthynnus affinis*), lisong tuna/bullet tuna (*Auxis rochei*), abuabu tuna/longtail tuna (*Thunnus tonggol*), and tenggiri/Narrow-barred Spanish mackerel (*Scomberomorus commerson*) (). Catching these types of fish is done using gillnets in an environmentally friendly manner. Currently, the status of the mackerel tuna (*Skipjack tuna*) stock in the waters of Ternate is still in a healthy condition (not overfished and not subject to overfishing)). The high demand for tuna and Indo-Pacific king mackerel (Scomberomorus guttatus), as well as neritic species, and the high fishing pressure have a negative impact on the condition of the stock of skipjack tuna species. (Purimahua *et al.*, 2021; UN Comtrade 2020; Hordyk *et al.*, 2015; Yuzrizal *et al.*, 2022). Therefore, preventive efforts are needed to maintain the sustainability of the mackerel fish stock. One way to support its management is by studying the reproductive biology aspects of the species. Information about the reproductive biology aspects of fish plays an important role in understanding the productivity levels of fish populations and changes in aquatic environmental conditions, and in estimating the spawning potential ratio as an indicator to assess the stock status of the fish species. (Jalil *et al.*, 2024; Syamsinar et al., 2023; Lappalainen *et al.*, 2016).

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Research on the biological status of skipjack tuna has been conducted in several locations, some of which were carried out in Indonesian waters. (Masuswo and Widodo, 2016; Hidayat *et al.*, 2016; Ardelia *et al.*, 2016; Maya *et al.*, 2018; Nur Hasanah *et al.*, 2022; Sambein *et al.*, 2023). Research on the biological status of the Komo tuna has been extensively conducted, but studies related to the biological status of fish in the waters of Ternate using fish aggregating devices (FADs) have also been carried out. The use of FADs has become more common in recent years as a method to attract schools of fish, including komo tuna, for easier and more efficient capture. This research is crucial for understanding the impact of using fish aggregating devices (FADs) on fish populations and the overall marine ecosystem in the waters of Ternate. By studying the biological status of fish in this area, researchers can better assess the sustainability of current fishing practices and implement necessary conservation measures to protect the marine environment. However, clear counterexamples can be seen in other areas where the use of FADs has led to overfishing and a decline in fish populations, causing imbalances in the marine ecosystem. Moreover, dependence on FADs can also result in bycatch of non-target species, further disrupting the fragile ecological balance in the waters of Ternate. Therefore, this research is deemed necessary.

This research aims to understand the biological aspects of the skipjack tuna, including size structure, length-weight relationship, catch methods, and population age structure. The results can be used as material for the preparation of fishery management plans and as a source of information on komo tuna fisheries in North Maluku.

Materials and Methods

Location and time of research

This research was conducted from December 2018 to March 2019 in the waters of Tabam, Ternate City. The map of the research location can be seen in the Figure 1.

The method used in this study is the survey and structured interview method. The fish samples used were obtained from the fishing activities of fishermen, totaling 200 fish, which were then measured for total length, weighed, and the body circumference of the komo tuna samples was recorded.

Data analysis related to technical aspects such as the design, construction, and operation of the gillnet is conducted descriptively. The analysis is limited to describing the design, construction, and operation of the gillnet according to the facts observed during the research. Descriptive analysis is also conducted on the fish's morphometric distribution, which includes length, weight, and body circumference.

Figure 1. Research location map (generated from Google Earth and Novico *et al.*, 2021).

Data analysis

1) **Population structure (cohort)**

The results of the total length measurements are divided into several classes, and the frequency of each class is calculated according to Bhattacharya (1957), where the class frequencies are transformed into a logarithmic scale and the increase of each logarithmic class (Δln) is calculated. The Δln values and the mid-class values are plotted on a cross-axis pair, with the mid-class values as the X-axis and Δln as the Y-axis. By connecting the highest and lowest points, the number of age classes (cohorts) can be determined from the number of straight lines that can be drawn. Next, to obtain the average total length (X) and variance (S2), the linear method according to Bhattacharya is used. (1957). as follows:

$$Y = \frac{dl.x}{S^2} - \frac{dl.x + dl./2}{S^2}$$

this equation is substituted into a linear regression model:

$$Y = a + bX$$

Length-weight relationship

The length-weight relationship of fish has a value that allows for the conversion of length values into weight values or vice versa. The weight (W) of the fish can be considered a function of its length (L), and this length-weight relationship almost follows a cubic law expressed by the formula:

$$W = aL^3$$

Results

1.**Description of gillnet (soma) fishing gear**

Gillnet fishing gear used by fishermen in Tabam

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waters includes fishing gear whose purpose is to catch small pelagic fish that inhabit the surface and middle layers of water. local fishermen call it the soma net. This fishing gear is classified as environmentally friendly fishing gear according to research by Idzhar *et al.*, (2019), Pramesty *et al.*, (2020), Joy *et al.*, (2022) mentioning that gillnet is an environmentally friendly fishing gear based on the proportion of fish utilized, The technical specifications of fishing gear are in Table 1.

Table 1. Gillnet gear specifications (local: soma)

		Zise			
Component	Material	Length	Width	Diameter	Number
Net body	Monofilament	50 m	2 m	-	6
Float rope	PE	52 m	-	4.56 mm	4
Weight rope	PE	52 m	-	4.56 mm	4
Buoy	Rubber slippers	5 cm	-	3.76 mm	-
Ballast	Tin	-	-	3.1 mm	-

2. Description of fish aggregation device (rumpon)

Rumpon is also known as Fish Aggregation Device (FAD), which is a tool that functions to attract fish and serves as a gathering place for fish. The introduction of rumpon technology in the waters of Tabam has been known to the community since the 1990s, where this tool is considered very effective in fishing activities. This is in line with the studies by Kantun *et al.*, (2019), Chaliluddin (2022), Alfian *et al.*, (2023), Dollu *et al.*, (2023). The development of technology for deploying fish aggregating devices (FADs), which serve as fishing aids and fish aggregators, has made a significant contribution to the productivity of pelagic fisheries in the waters of Maluku and the Makassar Strait. The location of the fishing ground, usually not far from the fishing base, requires 20 to 30 minutes, with the types of fishing gear used being purse seine, gillnet, and longline in the research area.

In general, the design of the fish aggregating devices (rumpon) found in the waters of Tabam consists of four main components: (1) float, (2) rope, (3) attractor, (4) weight. (sinker). The specifications of the fish aggregating device used are found in Table 2.

Table 2. Specifications of shallow water fish aggregating devices in Tabam waters

No.	Unit	Material Size Quantity	Size	Quantity
1.	Buoy	Plastic Drum	Ø :35 cm T : 1.20 m	9 unit
2.	Rope	PE *Multifilament*	Ø : 6 mm P : 246 m	1 Unit
3.	Sinker	Materials Iron/cement/crackers/sand/stone	Ø : 35 cm T : 60 cm	2 unit
4.	Attractor	Coconut Leaf	P : 2 m	8 unit
5.	Fishman house	Wood/Bamboo/Zinc	P : 4 m L : 2 m T : 2 m	1 Unit

3. Status of komo tuna biology

3.1. Length frequency

The size of the fish is significant to know because it is used as an indicator to estimate the maturity of the fish as well as the eligibility and feasibility of the fish for capture. The size of komo tuna from southern Sumbawa is longer than that from southern East Java. Based on the results of the total length measurement study, the komo tuna in the waters of Tabam, a total of 200 fish. Nine classes were obtained with a length range of 12-25 cm. The range of the length of the komo tuna fish in various regions varies depending on the quality of the waters. The differences in length frequency values from several studies are caused by the conditions of the aquatic habitat, food availability, and growth rates. For instance, in the study conducted by Evron Azrial *et al.* (2020), the komo tuna from the southern Indian Ocean of Sumbawa differs from the skipjack tuna from the southern Indian Ocean of Java and the western and northern Sumatra. This is suspected to be due to the better quality of the Indian Ocean waters off the coast of Labangka compared to those off southern Java and western or northern Sumatra.

The highest length frequency is found in class 6 with a total of 41 individuals, with a length range of 19.10-20 cm, and the lowest length frequency is found in class 9 with a total of 7 individuals, with a length range of 24.30-25 cm. The high frequency in the 19.10-20 cm length range is due to the greater likelihood of encountering this size range, with 41 individuals, whereas the 24.30-25 cm size range is less frequent, with only 7 individuals.

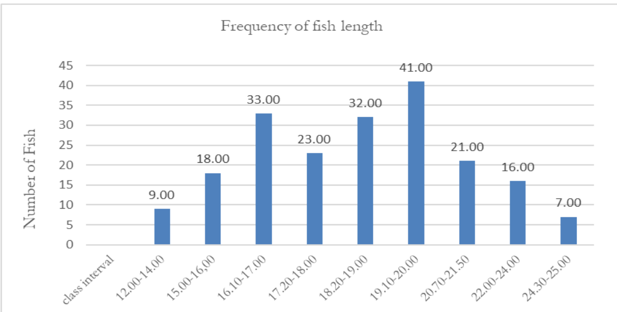

Figure 2. Number of komo tuna caught based on length frequency in the waters of Tabam

Figure 2 shows that the komo tuna caught with the highest length frequency falls within class interval 6, with a total of 41 individuals, and the lowest in class 1, with a total of 9 individuals.

3.2. Weight frequency

Based on the weight measurement research results, a total of 200 Komo tuna were caught in the waters of Tabam. Obtained 9 classes with a weight range of 10.00 grams - 170 grams. The highest weight frequency is found in class 2 with a total of 47 individuals, with a weight range of 30-40 grams, and the lowest weight frequency is found in class 9 with a total of 2 individuals with a weight range of 160-170 grams.

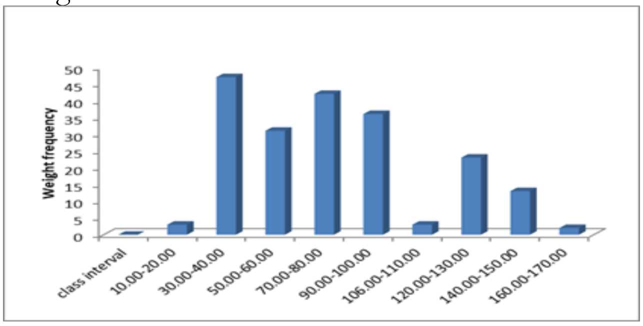

Figure 3. The number of Komo Tuna caught based on weight frequency in the waters of Tabam

3.3. Body circumference frequency

Based on the research results measuring the body circumference of komo tuna in the Tabam waters, a total of 200 fish were measured. Nine classes were obtained with a body circumference range of 3.20-86 cm. The highest body circumference frequency was found in class 6 with a total of 48.00 individuals, with a height range of 9.80-10.50 cm, and the lowest body circumference frequency was found in class 9 with a total of 4 individuals with a body circumference range of 12.50-86 cm. The body girth frequency is used to determine the process of fish capture by the fishing gear.

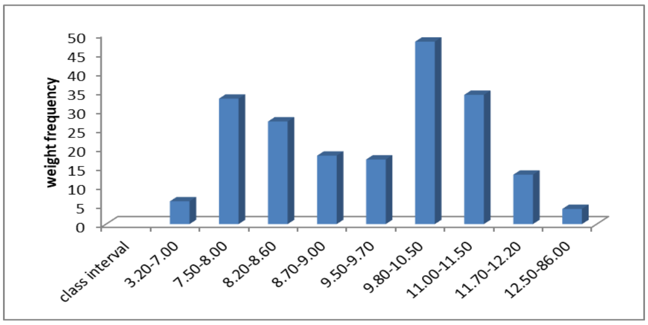

Figure 4. Number of komo tuna caught based on body circumference frequency

3.4. Length-weight relationship

The results of the length-weight relationship analysis yielded the equation Y = 1.919 + 2.953, where 1.919 is the value of a and 2.953 is the value of b, with a coefficient of determination (R) of 0.803. This indicates that for every 1 cm increase in the length of the komo tuna, the average weight increases by 1.919 cm. The coefficient of determination (R) of R^2 = 0.803 shows that the length of the fish affects the weight of the fish by 80.3%, while other factors influence the remaining 19.7%.

The length-weight relationship is very important in estimating a population, while the growth model is specifically designed to explain and estimate the changes that occur in a population over time. Effendie (2002), if the value of $b = 3$, it is called an isometric growth pattern, where the increase in length and weight is balanced. And if $b < 3$ or $b > 3$, it is called an allometric growth pattern, where the growth in weight is not balanced with length or vice versa.

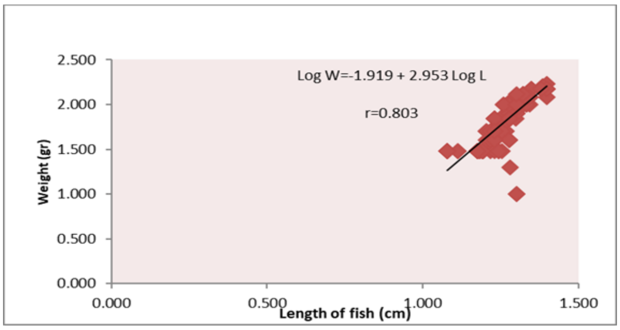

Figure 5. The relationship between length and weight of komo tuna

According to a comparison of earlier studies by Muzel et al. (2023), the E. affinis intercept (a) was 0.0969 and the exponent (b) was 2.53, with a correlation coefficient of r2 = 0.91. The T. tonggol's LWR study yielded an intercept "a" of 0.0807 and an exponent "b" of 2.59 with a correlation coefficient of r2= 0.94. A high degree of correlation and a better fit of the length-weight connection were indicated by a high coefficient of determination value (> 0.90).This means that the proposed model is able to explain 95% of the data and the coefficient value (R2) approaches 1 or -1, where this number indicates a linear relationship between the two variables. (Walpole, 1992). From the values obtained after conducting a t-test ($\alpha = 0.05$) on the b value, it was found that the komo tuna has an isometric growth pattern. The analysis of the length-weight relationship of 1,840 gray komo tuna conducted by Hidayat and Tegoeh (2018) resulted in the equation

W=0.0162L3.004 (r^2=0.9671) with a b value of 3.00. Based on the t-test results at a 95% confidence interval, the value of b is equal to 3, indicating an isometric growth pattern. This means that the increase in weight is equal to the increase in length.

3.5. Age structure of komo tuna population

To determine the age structure of the komo tuna population in the waters of Tabam during the study, the data obtained were subsequently analyzed using the Bhattacarya method(1957). The results of the calculation of the class midpoints, the transformation of class frequencies to a natural logarithm (Ln) scale, and Δ Ln of the size of the caught skipjack tuna can be seen in Table 4.

Table 4. Results of ln and Δln analysis of the total length frequency

No	Interval Class	Median Class (Xi)	Frequency Class (fc)	Ln fc	Ln fc (Y)	Xi+(dL/2) (X)
1	12.00-14.00	12.50	9.00	2.20	0.00	11.50
2	15.00-16.00	15.50	18.00	2.89	0.69	14.50
3	16.10-17.00	16.50	33.00	3.50	0.61	15.50
4	17.20-18.00	17.60	23.00	3.14	0.36	16.60
5	18.20-19.00	18.60	32.00	3.47	0.33	17.60
6	19.10-20.00	19.50	41.00	3.71	0.25	18.50
7	20.70-21.50	21.10	21.00	3.04	0.67	20.10
8	22.00-24.00	23.00	16.00	2.77	0.27	22.00
9	24.30-25.00	24.60	7.00	1.95	0.83	23.60

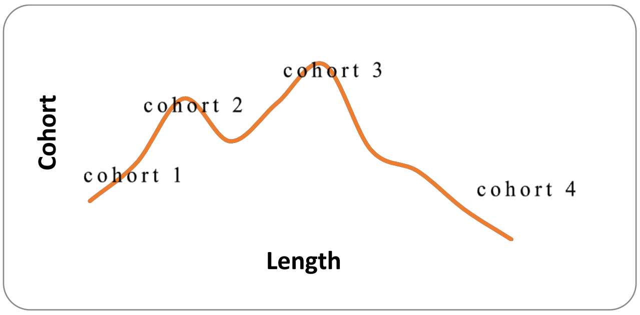

Figure 6. Total length in each age group (cohort) of Komo tuna.

Efendi (2002) states that knowledge and the ability to explain the age of fish play an important role in fishery biology because if the age is known accurately, growth analysis can be conducted properly. Based on the results of the population structure analysis of komo tuna, a histogram was created to explain the obtained age groups, as shown in the following figure 6.

The research results show that certain age groups of komo tuna in the waters of Tabam range from 21.7 cm, 17.2 cm, 18.9 cm, and 21.0 cm. The analysis results indicate that the captured komo tuna have nearly the same length and age in the fish distribution, where the length of fish from a certain age class will spread normally, with different individuals at certain boundaries. The age group of skipjack tuna in cohort 3 with an average length of 18.9 cm is more abundant in the waters of Tabam. It is assumed that the factor causing the highest frequency in cohort 3, based on interviews with fishermen, is that February-March is the peak season for catching komo tuna. The variation in size based on the total length of komo tuna obtained in the waters of Tabam is caused by different processes of natality and mortality, resulting in the formation of specific age groups. Effendi (2002) stated that the natality and mortality occurring in the population result in one age group having a different number. The population's age structure in the waters depends on the mortality of each cohort. Studying the age of fish using the length frequency method (Peterson method) depends on the reproductive and growth characteristics of the fish. This method is a widely applied method in waters, including Indonesia. Length data analysis usually begins with examining length about age. (Effendie, 2002). And it is concluded that the size group (cohort) is a group of fish individuals of the same species that originate from the same spawning.

3,6 The relationship between length and body circumference of komo tuna

Regression and correlation analysis of the relationship between the length of the fish and the body Circumference of the komo tuna are used to determine the effect of length on the girth of the skipjack tuna. The results of the analysis can be seen in the following figure 7.

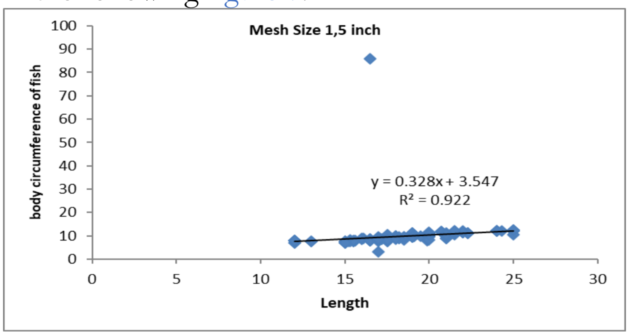

Figure 7. Linear graph of the effect of length on the body circumference

Based on the above Figure 6 and regression and correlation analysis, the regression function obtained is Y = 0.328x + 3.547. This indicates that for every 1 cm increase in the length of the skipjack tuna, the average body circumference increases by 0.328 cm. The coefficient of determination (R) of R^2 = 0.922 indicates that the fish's length factor affects the fish's body circumference by 92.20%, while other factors influence the remaining 7.80%. Meanwhile, the correlation value (r) of 0.92 means that there is a very significant relationship between length and body circumference. The t-test results show that t-test = 212.67 and t table (0.05) = 1.652. This t-test result indicates that the t-test is greater than the t table, thus it can be concluded that there is an influence between the length and the body circumference of the komo tuna in the waters of Tabam.

3.7. The relationship between mesh size and the body circumference of komo tuna

The way fish are caught in a gillnet according to Sparre and Vanema (1998) can be distinguished as Snagged, Gilled, Wedged, and Entangled. The total catch of komo tuna using a gillnet with a mesh size of 1.5 inches was 200 fish. Based on the method of capture, the fish caught by gilling amounted to 168 individuals or 84.00% of the total catch, wedged 28 individuals or 14.00% of the total catch, and entangled 4 individuals or 2.00% of the total catch.

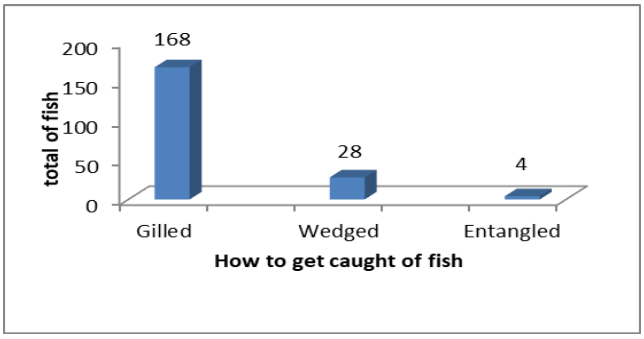

Figure 8. Distribution of komo tuna based on the method of caught

To determine the strength of the relationship between the length and girth of the skipjack tuna, correlation analysis was used. The correlation coefficient, r, is a measure of the linear relationship between two quantities, both of which are influenced by random variations (Spare and Venema, 1998), as shown in Figure 9.

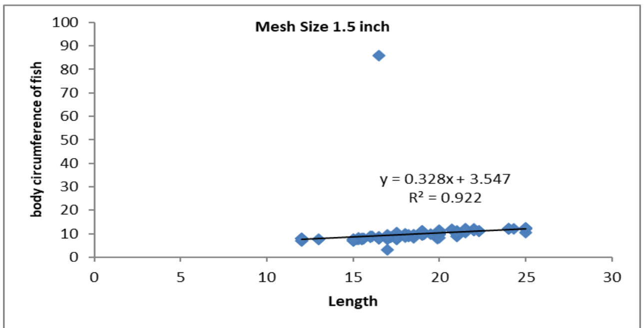

Figure 9. Relationship to the body circumference of Komo tuna

Based on Figure 8 above, it can be seen that the formed regression function is Y = 0.328x + 3.547. This indicates that for every 1 cm increase in the length of the komo tuna, the average body circumference increases by 0.328 cm. The coefficient of determination (R) of R^2 = 0.922 shows that the length of the fish affects the body circumference of the komo tuna by 92.20%.

Discussion

In fisheries biology, fish length-weight relationship is one of the information that needs to be known in fisheries resource management. Fish growth is very important to determine the biological condition of fish and stock and the level of maturity of fish gonads (Hasibuan *et al.*, 2018; Katherive *et al.*, 2024; Adi *et al.*, 2023), so that it can be the basis for managing the sustainability of fish resources. This means there is a very significant relationship between length and body weight. The value obtained based on the t-test shows that komo tuna has an isometric growth pattern, meaning that the increase in fish length is equal to the increase in weight. This research is in line with the research of Mahmud *et al.*, (2019), Pratiwi (2019), Gumay (2022Herath *et al.*, (2019). Three species of neritic tuna *Euthynnus affinis*, *Auxis thazard,* and *Auxis rochei*, caught in Sri Lankan seas had length-weight and length-shortness relationships. All three species had highly significant R^2 values ($p<0.001$) of more than 0.9. For E. affinis, A. thazard, and A. rochei, the condition factors K were 1.427, 1.476, and 1.361, respectively. The length-weight equations showed that the three species had a positive allometric growth trend with b values of 3.115, 3.431, and 3.408. In addition, the b values of the three species for the studied provinces were higher than 3.0. In addition, there were significantly significant relationships ($p<0.001$) between standard length, fork length, and overall length.

Meanwhile, there was no significant relationship ($p<0.001$) between gillnet and snagged fish. According to Takashi *et al.*, (2020), fish behavior is believed to be the cause of snagged fish. When fish are caught, they will continue to try to escape from the net when the net is blocking or entangling them, which makes their bodies more entangled. The tightness of the net stretch is also another element; the net is not too tight so that when the tide pushes the fish trying to break through, the net will form a pocket. The ratio of the gillnet mesh size to the size of the fish caught through the entanglement will remain constant. If the size of the fish increases by a constant k, then the mesh size required to catch the fish also increases by the same constant k (Gashaw, 2019; Cilbis *et al.*, 2024). On the other hand, fish caught by trapping methods often do not have a fixed ratio between the mesh size and the size of the fish caught.

The biological status of the tuna komo fish (*Euthynnus affinis*) caught using gillnets around fish aggregating devices (FADs) in the Tabam waters indicates that these fish are generally captured gilled, reflecting an isometric growth pattern, which suggests that the environmental conditions in these waters remain favorable with adequate food availability for the species (Aurelie *et al*., 2022; Cilbiz *et al*., 2023). This is further supported by the strong correlation between the length and body circumference of the komo tuna, as indicated by the high coefficient of determination. The increase in body circumference with length suggests that the fish are healthy and well-nourished, likely due to the abundant food sources in the Tabam waters. The use of gillnets around FADs may also contribute to the consistent catch of komo tuna fish with a similar growth pattern, indicating sustainable fishing practices in the area (Grashaw, 2019; Joe *et al*., 2022; Nurhasanah *et al*., 2022). Overall, these findings highlight the importance of monitoring environmental conditions and fishing practices to ensure the continued health and abundance of komo tuna populations in the region. By understanding the factors that contribute to the thriving komo tuna population in the Tabam waters, conservation efforts can be more effectively targeted to maintain sustainable fishing practices. This study underscores the significance of balancing human consumption with the preservation of marine ecosystems to support the long-term viability of this important fish species. By implementing measures to protect both the fish and their habitat, we can ensure a future where skipjack tuna continue to thrive in the region for generations to come.

Conclusion

The biological status of the komo tuna fish (*Euthynnus affinis*) caught using gillnets around fish aggregating devices (FADs) in the Tabam waters indicates that these fish are generally captured gilled, reflecting an isometric growth pattern, which suggests that the environmental conditions in these waters remain favorable with adequate food availability for the species. Additionally, collaboration between government agencies, conservation organizations, and local communities will be crucial in enacting and enforcing regulations that protect skipjack tuna populations. Sustainable fishing practices, such as using selective gear and implementing catch limits, can also help prevent overfishing and ensure the long-term survival of this species. Ultimately, by taking proactive steps to preserve the delicate balance of the marine ecosystem, we can secure a healthy future for komo tuna in the Tabam waters.

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