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Status of Utilization and Catch-at-Size Distribution of the Yellowfin Tuna in West Sulawesi Waters

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ABSTRACT

The yellowfin tuna is a pelagic species with significant potential and economic value in the waters of West Sulawesi Province. This resource is primarily harvested through tuna handlines and purse seine units, and these fishing methods continue to increase. As a result, proper management is essential to ensure the optimal productivity and sustainability of the tuna fishery. The research aimed to provide detailed insights into various fisheries aspects, including catch per unit effort (CPUE), utilization rates, and the size distribution of catches from small-scale tuna fisheries, particularly those employing handlines in West Sulawesi waters. In this study, the estimated catch and effort to the maximum sustainable yield (MSY) of the yellowfin tuna were examined based on CPUE data collected over 16 years (2007–2022). Additionally, the size structure of the tuna caught and their growth patterns were analyzed across different seasons (September 2022–August 2023). The MSY analysis was conducted using an equilibrium approach, applying the Schaefer and Fox models. The findings indicated that the average CPUE for the yellowfin tuna in West Sulawesi is 33.6 tons per unit per year, with an estimated CMSY of 18,565.9 tons per year and EMSY of 344 units per year. However, the biomass trend is declining, and overfishing has been observed over the past five years. The size structure of the yellowfin tuna caught across seasons ranges from 17 to 186cm, with most fish being undersized, except during the eastern season. The growth pattern of the yellowfin tuna during the eastern season is isometric, while in the other three seasons, a positive allometric growth was shown. Given the current pressure on the yellowfin tuna stock, government intervention is necessary to implement effective management measures to prevent further overexploitation and to ensure the resource's long-term sustainability.

INTRODUCTION

The yellowfin tuna is a globally significant fish often caught by fishing vessels in more than 85 countries and contributes 2%, or 1.6 million tons, to global seafood production in 2020 **(FAO, 2022)**. This species has a high export value in Indonesia, totaling US$677.9 million in 2017. Consequently, the yellowfin tuna is an essential wealth generator in all fishing fleets, making it the most important seafood category. The variety of species caught in the Indonesian waters typically comprises the yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), albacore (*Thunnus alalunga*) and the skipjack (*Katsuwonus pelamis*) **(Wiryawan *et al*., 2020)**. However, the status of the utilization level of large pelagic fishery resources (other than tuna and skipjack) in Indonesia Fishing Management Area (IFMA) 713, according to Ministerial Decree 19/2022, shows a value of 0.8. This value indicates the attainment of the 'fully exploited' level, thereby necessitating fishing efforts that are controlled and maintained with strict monitoring. Understanding the globally accepted biological requirements of various fish species, such as tuna, is essential to achieving the Sustainable Development Goals ("Life Below Water" and "Zero Hunger") of the UN for 2030.

According to previous studies, West Sulawesi Province is an example of the yellowfin tuna fisheries in Indonesia. In addition, it is one of the major landing sites in Indonesia Fisheries Management Area (IFMA) 713. The province has a sea area of 22,012.75km², a coastline length of 617.5km, and three fish landing infrastructure units in Mamuju, Majene, and Polewali Mandar Regencies. In addition, its small-scale tuna fishing fleets are typically dominated by outboard engines (54.5%), boats without engines (18%), and inboard engines < 10 GT (25.7%). Several studies have also shown that the prospects for developing the yellowfin tuna fishing businesses in West Sulawesi Province are up and coming. This can be seen from the production of large pelagic fish reaching 31,316.025 tons in 2021, greater than small pelagic (22,273.949 tons) and demersal (8,707.669 tons) **(West Sulawesi Provincial Marine and Fisheries Office, 2022)**.

Despite the fisheries potential in South Sulawesi, interviews with fishing groups showed that potential yellowfin tuna fishing areas are becoming increasingly difficult to find, and the fishing distances have become farther compared to five years ago, with some reaching regions as far as Berau (Kalimantan) and Lombok. This condition indicates a spatial contraction of the biomass of large pelagic fish stocks as the target of North Mamuju fishermen, primarily due to the increased fishing pressure **(Adrianto *et al.*, 2014)**. In addition, data from the **West Sulawesi Provincial Marine and Fisheries Office (2022)** revealed that yellowfin tuna production in 2011 was 20,873 tons, significantly decreasing by more than 50% to 8,055 tons in 2021. Several studies have also revealed a drastic decline in fish stocks over the past 40 years, and there are projections of a further decrease in fish stocks in the future **(Pauly & Zeller, 2017)**. This indicates that effective management is necessary to ensure optimal productivity of resources.

In this context, several reports related to the yellowfin tuna fisheries in the waters of West Sulawesi have been conducted **(Kantun & Mallawa, 2014)**, such as a comparison of the size structure of species (*Thunnus albacares*) caught on deep-sea and shallow-sea fish aggregating devices (FADs) in the waters of the Makassar Strait. **Kantun and Mallawa (2016)** also studied the biology of the yellowfin tuna in the

Makassar Strait, while the population dynamics of species in the Makassar Strait were explored by **Kantun and Mallawa (2012)**. Therefore, this study aimed to provide detailed information on the technical aspects, including CPUE, exploitation rates, and catch size distribution of the yellowfin tuna fisheries caught using hand lines. The findings could be considered input for fisheries management measures in West Sulawesi.

MATERIALS AND METHODS

1. Study area

This study was conducted from August 2022 to July 2023 in West Sulawesi, focusing on the tuna migration route in the Makassar Strait. Data were collected in 3 regencies: Mandar Regency, Karama Village, Mamuju Tengah Regency, Babana Village, and Majene Regency, Banggae Sub-district. These locations are places where tuna fish landed in West Sulawesi Province. Tuna fishermen in the study locations used fish aggregating devices (FADs) for exploitation (Fig. 1).

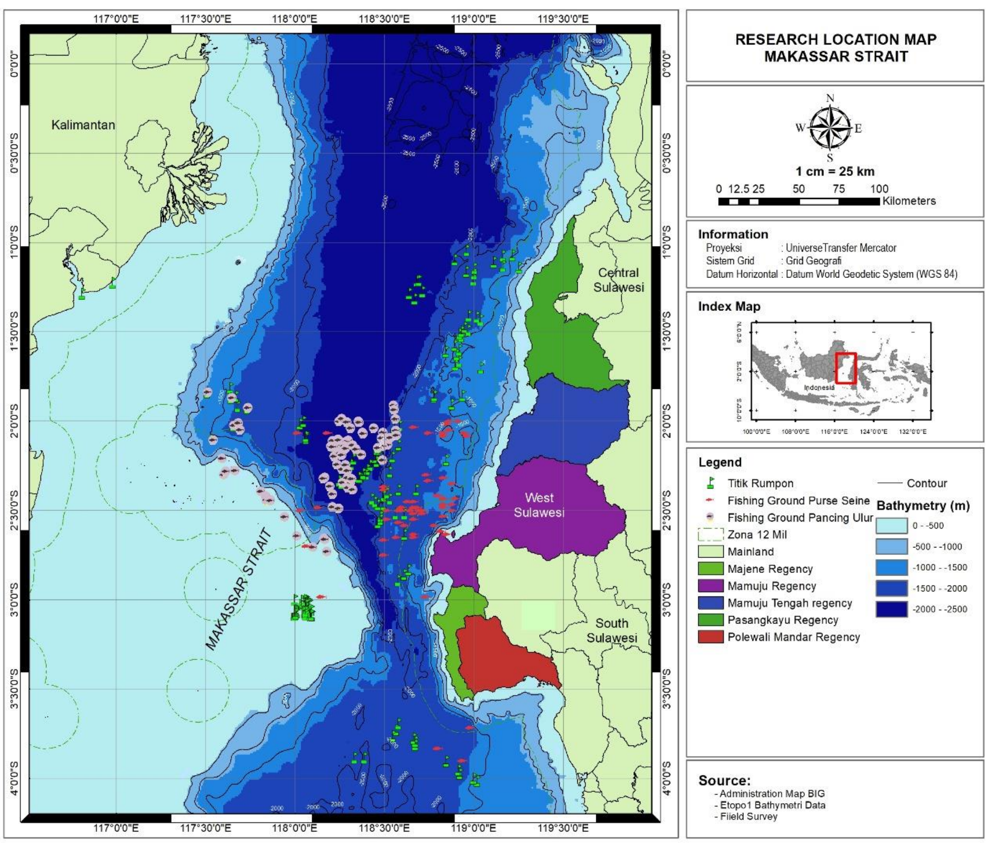

Fig. 1. Study location map

2. **Data source**

The study procedures were conducted using a survey method, and sampling techniques were used to determine the size structure of tuna caught by longline fishing operating around FADs. The tuna handline fishing grounds data collection was divided into 2 areas: the southern part, covering the waters of Majene, and the central part, covering the Makassar Strait, which included the waters of Mamuju and Centre Mamuju. The southern fishing grounds of the Makassar Strait were located at geographic positions of 03°50' - 04° 15.557' South Latitude and 117° 15' - 119°32.311' East Longitude. Meanwhile, the central fishing grounds of the Makassar Strait are situated at geographic positions of 01°34.785' - 02°24.484' South Latitude and 117°44.167' - 118°46.408' East Longitude.

In this study, the yellowfin tuna (*Thunnus albacares*) was studied, and the biological data consisted of fork length (cm) and weight (kg) of the species caught by handline fishing using FADs. In addition, the data obtained were used to analyze the length size structure of tuna and the length-weight relationship. Secondary data were collected from the sample production data provided by the West Sulawesi Provincial Marine and Fisheries Agency and Tuna Collectors from 2007 to 2022. These production data were analyzed to explain the variability of catch datasets and efforts from previous years for CPUE estimation.

3. **Data analysis**

Standardization of the fishing gear units used was carried out before estimating the potential of tuna fishery resources. The catch of the species was conducted solely with tuna handline; hence, the fishing unit used as the standard effort was tuna handline for CPUE estimation. The method used to estimate the sustainable potential of the yellowfin tuna was surplus production models consisting of Schaefer and Fox. In addition, one of these models was selected depending on the coefficient of determination (R^2) from the CPUE equation generated using regression analysis. The model with the highest R^2 value was deemed suitable for analyzing the obtained data. The coefficient of determination (R^2) is a value that indicated the extent of change in the dependent variable y due to x.

The data processing steps in the production surplus method were:

a. Plotting the value of f against c/f and estimating the intercept value (a) and regression coefficient (b) with linear regression (Schaefer model). Meanwhile, the Fox model plotted the value of f against ln CPUE and estimated the values of a and b with linear regression.
b. Calculating estimates of sustainable potential (Maximum Sustainable Yield = MSY) and optimum effort (optimum effort = f_{opt})

Determining the value of sustainable potential (MSY) and optimum effort (fopt) could be formulated as follows:

a. Schaefer's model
   The Schaefer equation model could be written as: CPUE = a + bf
   The relationship between C and f could be written as: $C = af + b(f)^2$
   The sustainable potential value could be written as: $MSY = - a^2 / 4b$
   The optimum effort value could be written as: fopt = - a / 2b
b. Fox's model
   The Fox equation model could be written as: ln CPUE = a + bf
   The relationship between C and f could be written as: C = f x exp (a + bf)
   The sustainable potential value could be written: MSY = - (1 / b) x exp (a – 1)
   The optimum effort value could be written as: fopt = - 1 / b

The level of exploitation (TE) of fish resources was calculated using the formula TE = current catch (Ci) / MSY x100%. The number of permitted catches or TAC was estimated using TAC = 80% x MSY. Fish size data were obtained by measuring samples of caught fish that landed at both fishing and non-fishing ports in the study location. The measurement of fish size distribution was analyzed according to seasons; hence, the determination of class numbers used Sturges' rule, as described by **Effendie (2002)**, with the formula:

$$k = 1 + 3{,}3 \log n$$

The class interval was determined using the formula:

$$c = Xn - X1 / k$$

Description:
k = number of classes
n = number of data
c = Class interval
Xn = largest data value
X1 = smallest data value

The FL of the yellowfin tuna obtained from fishbase.com was compared to determine the catchability. The relationship between the FL of the species and its weight was analyzed using length-weight analysis techniques. This analysis could yield regression coefficients that indicated their growth. According to **Effendie (2002)**, b is the exponent value needed to match the organism's length to its weight. The exponent values for all fish species ranged from 1.2 to 4.0, but most b values were between 2.4 & 3.5. The value of b in the length-weight relationship equation indicated the type of fish growth. When b = 3, the growth was considered isometric, meaning changes in growth occurred continuously and proportionally throughout the body. However, when $b \neq 3$, the growth was termed allometric, indicating the presence of small changes in some parts of the body, which were only temporary, such as alterations related to gonad maturation.

RESULTS

1. CPUE

The yellowfin tuna caught in the waters of the Makassar Strait were captured or produced using longline fishing with fleet capacities of <10 GT. In addition, tuna of all sizes, ranging from small to large, were predominantly caught using longline fishing. The yellowfin tuna was the dominant species caught in the waters of West Sulawesi. The catching ability of tuna handline, indicated by the catch per unit effort (CPUE) value in relation to fishing effort (units), provided an overview of the tuna fishery resource utilization rate in the waters of West Sulawesi. When the CPUE trend could be assumed to be linearly related to fish abundance **(Branch *et al*., 2006)**, a decrease in CPUE rate in a water area indicated the effectiveness of fishing fleet efforts approaching imbalance with the fish stock conditions **(Branch *et al*., 2006; Maunder *et al*., 2006)**.

The time series data of the species production and fishing effort in the waters around the Makassar Strait from 2007 to 2022 were obtained from the Fisheries Statistics of the West Sulawesi Provincial Marine and Fisheries Office. Production and fishing effort data, standardized results, and CPUE are presented in Table (1). Based on data in Table (1), the average production of yellowfin tuna over the past 16 years was recorded to be 10,043 tons per year. Due to the annual fluctuations in production (Table 1 & Fig. 2), the highest value was recorded in 2008 at 24,556 tons. Subsequently, production decreased until 2011, with a drastic decline in 2012. From 2013 to 2022, the value obtained also fluctuated downward.

Table 1. Production/catches and efforts to catch yellowfin tuna using hand lines in the waters of the Makassar Strait from 2007 to 2022

Years	Production (Tons)	Effort (Units)	CPUE (Tons/Units)
2007	18053	227	79,6
2008	24556	227	108,0
2009	20593	228	90,4
2010	20508	227	90,3
2011	13838	233	59,3
2012	5065	483	10,5
2013	6824	492	13,9
2014	5500	486	11,3
2015	4036	494	8,2
2016	4383	514	8,5
2017	1478	511	2,9
2018	8852	598	14,8
2019	7699	592	13,0

2020	6408	810	7,9
2021	8008	637	12,6
2022	4887	829	5,9
Average	10043,0	474	33,6

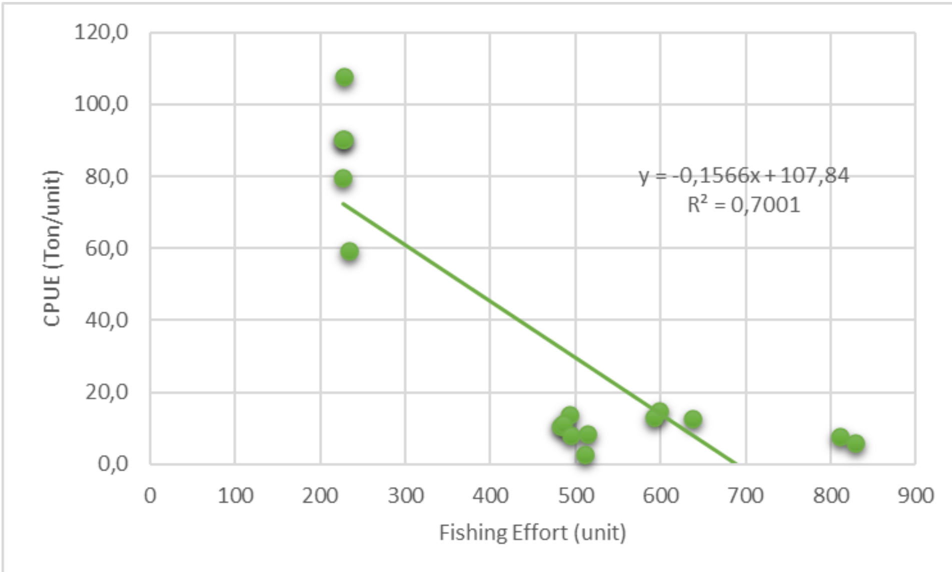

Fig. 2. Relationship between CPUE and tuna fishing effort for the period 2007 – 2022 in the Makassar Strait

2. **Sustainable potential**

The estimated stock potential (MSY) calculation results are exhibited in Fig. (2), while an optimum fishing effort and TAC of the yellowfin tuna, as presented in Table (2).

Table 2. MSY, fMSY, and TAC of yellowfin tuna in the waters of the Makassar Strait

Parameter	**Potency**
MSY (Tons/Year)	18.565,9
FMSY (Standard Unit/Year)	344
TAC (Tons/Year)	14.852,7

Due to the regression analysis results between CPUE and fishing effort, the intercept (a) and slope (b) values were obtained for each type of large pelagic fish (Table 2 & Fig. 3), thereby enabling the estimation of the MSY for the yellowfin tuna to be 18,565.9 tons/year. The MSY value for each type of pelagic fish in the waters of the Makassar Strait, specifically the yellowfin tuna, was 344 units/year. Meanwhile, the TAC value for the yellowfin tuna was 80% of MSY, totaling 14,852.7 tons/year. Fig. (8) indicates that in the last 10 years, they experienced excessive fishing effort symptoms.

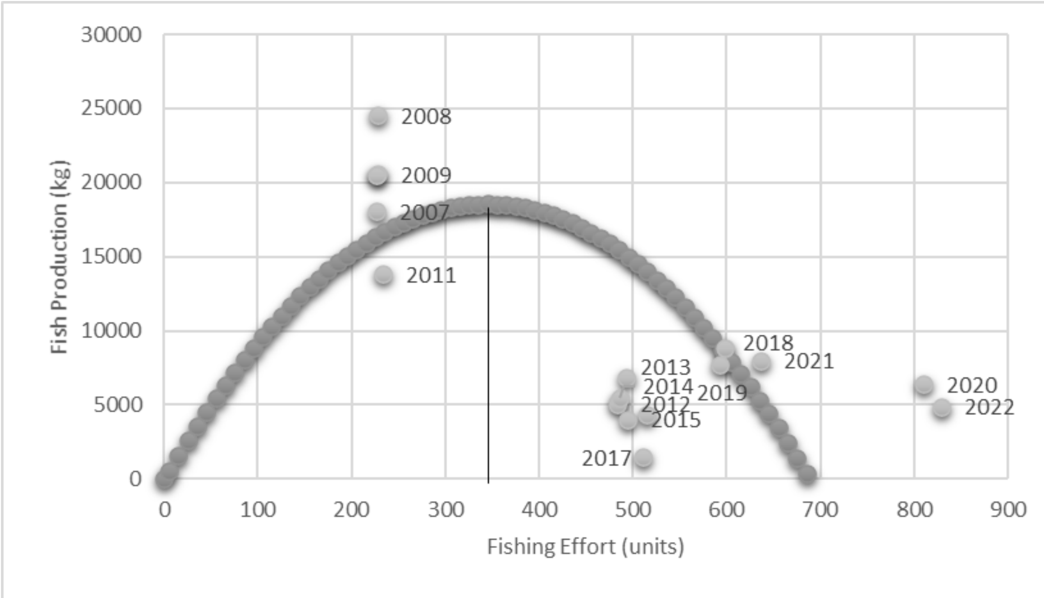

Fig. 3. MSY value of the yellowfin tuna in the waters of the Makassar Strait

3. Utilization rate

The utilization rate is consisted of the production and fishing effort utilization rates. The production utilization rate stands for the percentage of the actual production divided by the MSY value, while the fishing effort utilization rate referred to the percentage of the fishing effort divided by the MSY value. The exploitation of yellowfin tuna fish resources in the Makassar Strait waters fluctuated from 2007 to 2022 (Fig. 4).

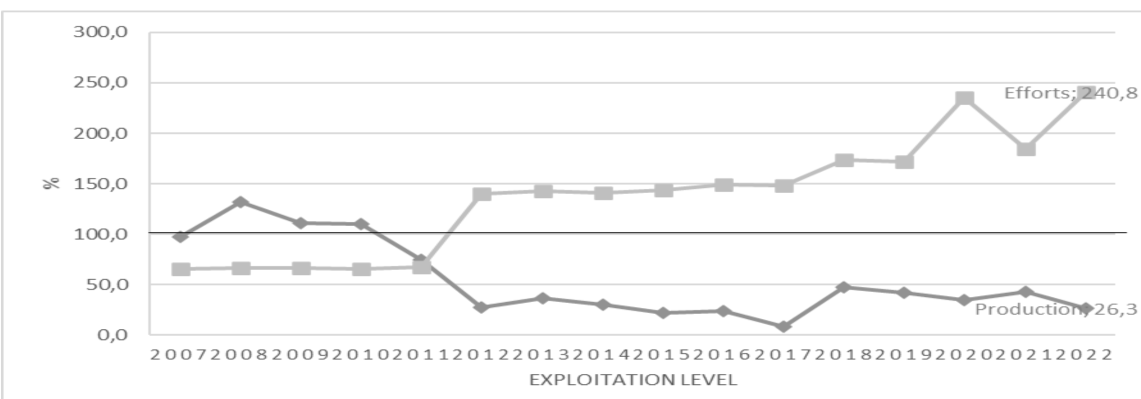

Fig. 4. Graph of the level of production utilization and fishing effort for the yellowfin tuna in the waters of the Makassar Strait in 2007 - 2022

4. **Size structure**

The length distribution of captured yellowfin tuna varied considerably during each season. Differences observed from month to month or season to season were associated with migration patterns influenced by food availability or spawning. Analysis results indicated that the yellowfin tuna caught throughout the year ranged from 17 to 186cm in length, with a nearly uniform distribution across all seasons, dominated by small-sized fish classified as juveniles. **Robinson and Simonds (2006)** classified the yellowfin tuna and bigeye tuna ranging from 20 to 99cm in length as juveniles or sub-adults. They stated that these species were considered adults at sizes >100cm. The studies by **Kantun *et al.* (2011)**, **Kantun and Amir (2013)** and **Kantun and Mallawa (2014)**, justified the presence of the yellowfin tuna in the waters of the Makassar Strait due to migration, food, and reproductive needs, specifically spawning. These studies revealed that the yellowfin tuna spawned in the waters of the Makassar Strait, as evidenced by the abundance of juvenile-sized fish caught. This was also evident in this study, with many caught at sizes <100cm.

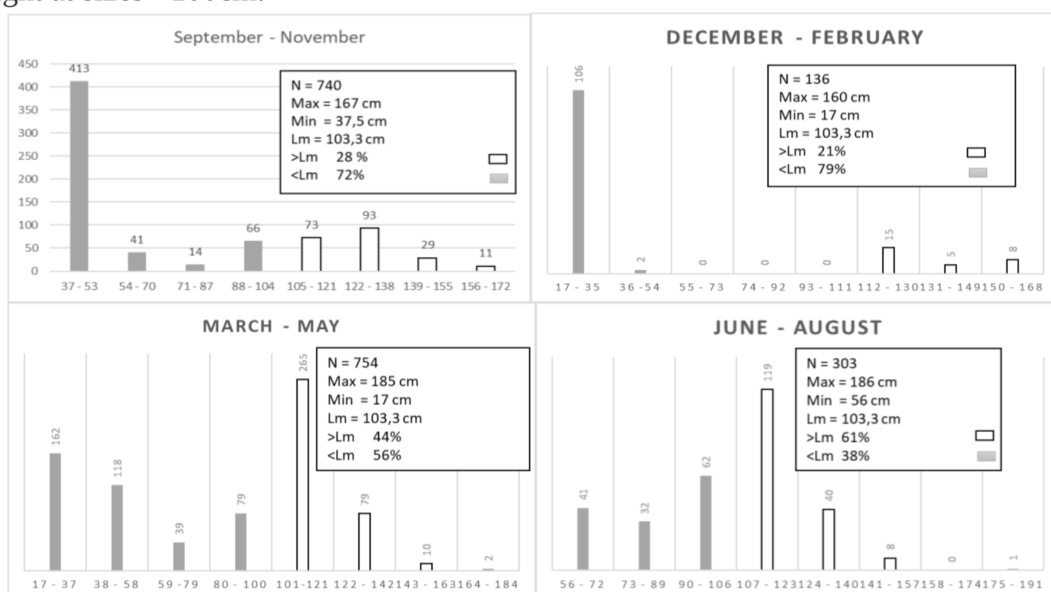

Fig. 5. Length size structure of the yellowfin tuna

During the transitional season II (September-November), the length structure of the yellowfin tuna (*Thunnus albacares*) caught, with a sample size of 740 individuals, ranged from 37.5 to 167cm (Fig. 5). The most caught length class of tuna was 37-53cm, with 413 individuals, followed by the second most abundant class in the length range of 122-138cm, comprising 93 individuals. In the exact location and at the same time, a study conducted by **Kantun and Mallawa (2014)** found that the length structure of the yellowfin tuna caught in the Makassar Strait in September ranged from 27 to 157.5cm, dominantly 102.5cm, accounting for 9.09% of the catch. In October, the length ranged from 42.5 to 157.5cm, with the dominant size being 62.5cm, representing 19.5% of the total population.

5. Length-weight relationship

According to the analysis of the length-weight relationship during the transitional season II (September-November), the determination coefficient (R^2), which represented the goodness of fit of the regression line to the data, was extremely high at 97.39% (Fig. 6).

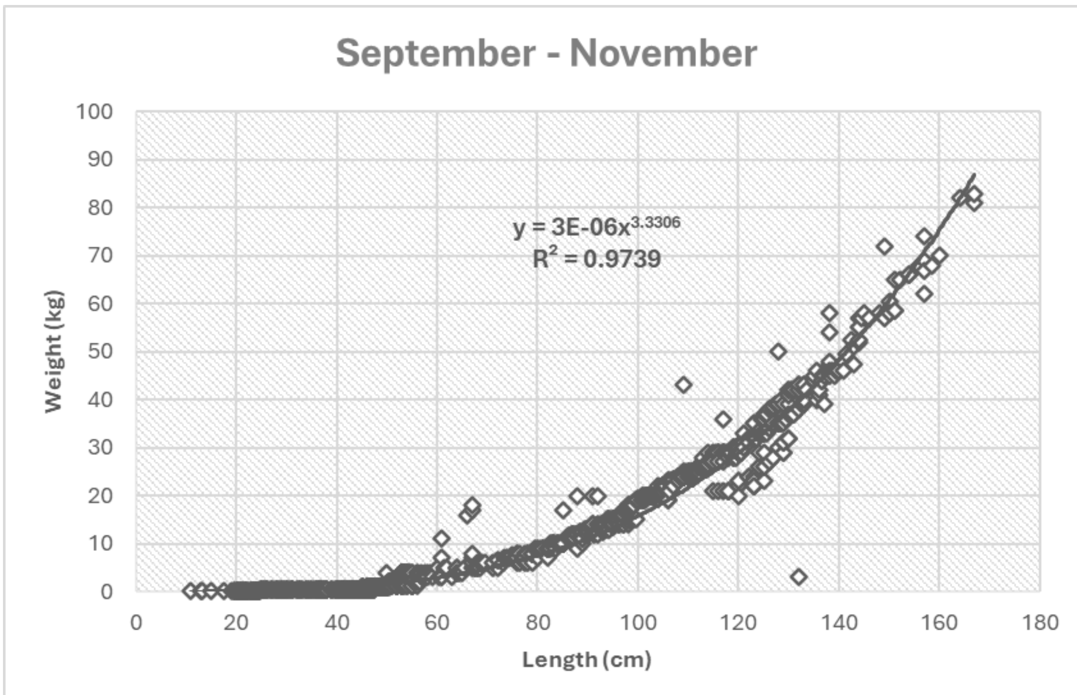

Fig. 6. Relationship between length and weight of yellowfin tuna during season II (September-November)

This indicated that the correlation or relationship between the length and weight of landed yellowfin tuna was robust. The equation shows that the regression coefficient was calculated as 3.3306 (Fig. 6). With a regression coefficient value greater than 3, the growth pattern of the landed species exhibited a positive allometric growth, showing that the length growth was slower than its weight.

Based on the analysis of the length-weight relationship during the western season (December-February), the determination coefficient (R^2), which represented the goodness of fit of the regression line to the data, was extremely high at 96.8% (Fig. 7).

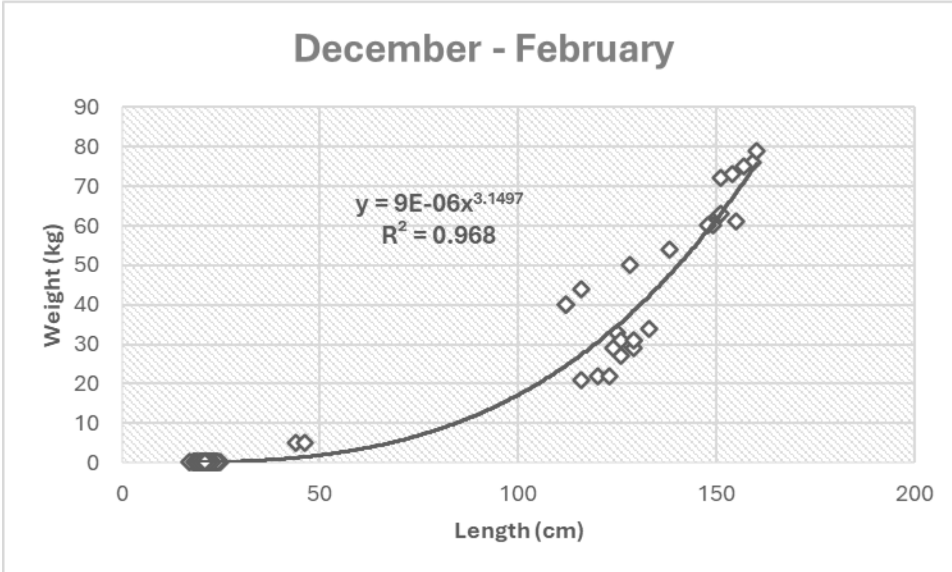

Fig. 7. Relationship between length and weight of the yellowfin tuna during the west season (December-February)

This indicated that the correlation or relationship between the length and weight of the landed yellowfin tuna was extremely strong. The equation provided calculated the regression coefficient as 3.1497 (Fig. 7). With a regression coefficient value greater than 3, the growth pattern of landed yellowfin tuna exhibited positive allometric growth, indicating that the length growth was slower than the weight.

The analysis of the length-weight relationship during the transitional season I (March-May) revealed that the determination coefficient (R^2), representing the goodness of fit of the regression line to the data, was very high at 97.58% (Fig. 8).

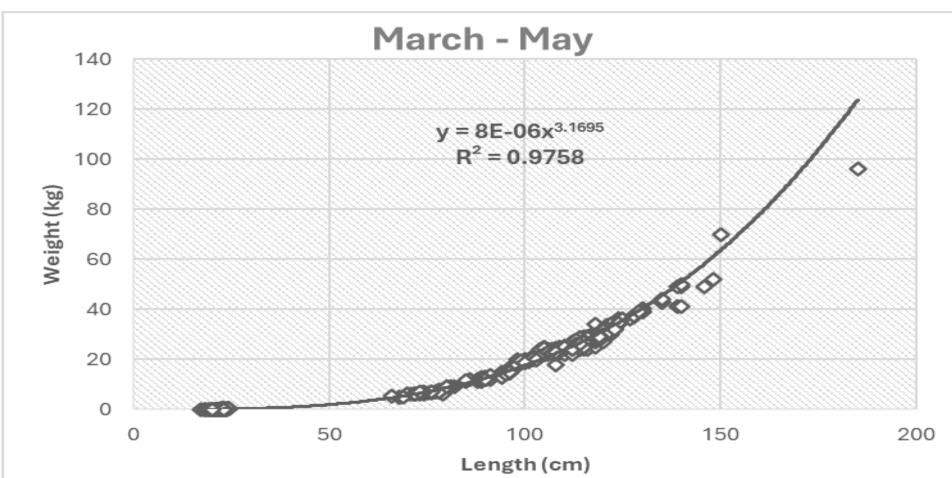

Fig. 8. Relationship between length and weight of yellowfin tuna during season I (March-May)

Based on the findings, the correlation or relationship between the length and weight of the landed yellowfin tuna was extremely strong. The equation provided calculated the regression coefficient as 3.1695 (Fig. 8). With a regression coefficient value greater than 3, the growth pattern of the landed species exhibited positive allometric growth, indicating that its length growth was slower than the weight.

Based on the analysis of the length-weight relationship within the east season (June-August), the determination coefficient (R^2), which represented the goodness of fit of the regression line to the data, was very high at 91.89% (Fig. 9).

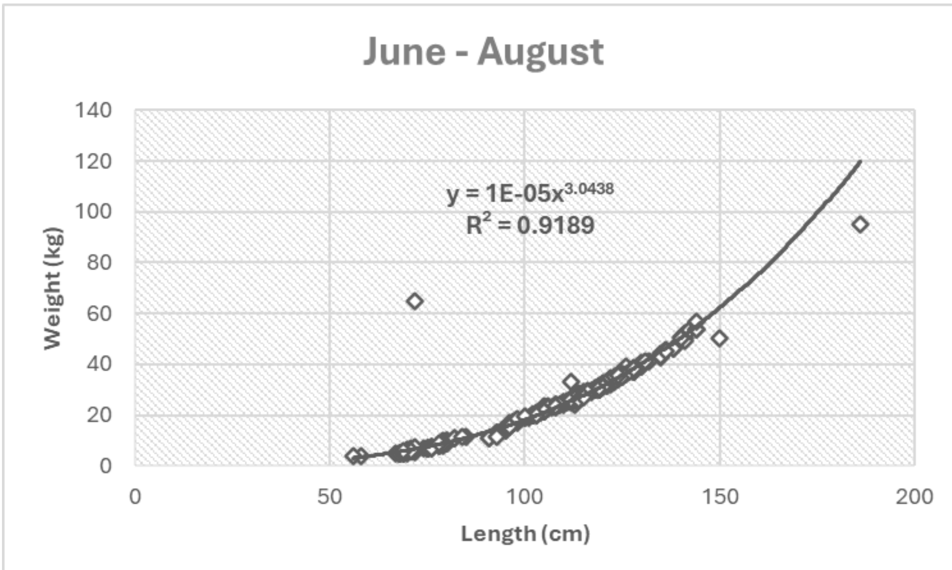

Fig. 9. Relationship between length and weight of the yellowfin tuna during the east season (June-August)

This indicated that the correlation or relationship between the length and weight of the landed species was extremely strong. The equation provided calculated the regression coefficient as 3.0438 (Fig. 9). With a regression coefficient value equals to 3, the growth pattern of the landed yellowfin tuna exhibited an isometric growth, indicating that the growth of the yellowfin tuna in the waters of the Makassar Strait during the east season was proportional to the weight.

DISCUSSION

The abundance index is one of the most important sources of information for fish stock assessment and monitoring **(Maunder *et al*., 2006; Francis & Chris, 2011; Punt, 2023)**. When survey data are insufficient, CPUE is widely used to develop abundance indices, specifically for fisheries. Nominal CPUE provides valuable information about stock conditions, and the results of linear regression analysis of CPUE with fishing effort for the yellowfin tuna are presented in Fig. (1). According to Fig. (1), a linear regression equation of the relationship between CPUE and fishing effort (f) was obtained, with the general equation being CPUE = 107.84 - 0.1566f. This equation relationship could be interpreted as follows: When the fishing effort was conducted at a rate of f units per year, the productivity value (CPUE) of tuna was reduced by the value of b tons/year of tuna. Yellowfin tuna CPUE tended to decline over the past 10 years in the waters around the Morotai Island **(Sofiati & Alwi, 2019; Talahatu *et al.*, 2020)**.

CPUE of the species indicated a declining trend, specifically after 2011. Intensive catches from the entire Indian Ocean region, primarily by purse seiners, were suspected to be the leading cause of the production decline, as it targeted a large portion of juvenile schooling tuna around FAD/DFAD **(Fonteneau *et al.*, 2015)**. Since the yellowfin tuna was a migratory species **(UNCLOS, 1982)** and its species connectivity ecology fell under the RFMO – IOTC, some related information indicated that the average catch in the Indian Ocean ranged between 2017 and 2021 at 435,225 tons per year. Meanwhile, in 2021, the annual catch was 416,235 tons, exceeding the MSY (349,000 tons). This showed that the yellowfin tuna stock had been determined to be overfished and experiencing overfishing **(IOTC, 2020)**. The subsequent action recommended by the IOTC was to reduce catches by 20% from the current level (2021) to maintain the stock. This action could be challenging in some coastal countries, primarily operating in small-scale areas heavily associated with FAD usage.

According to the MSY curve (Fig. 3), tuna caught from 2012 to 2022 exceeded the optimal fishing effort, indicating that excessive fishing capacity had occurred in certain years. However, tuna production from 2011 to 2022 remained below the maximum sustainable yield (CMSY), with production in the preceding years (2007-2010) exceeding the maximum sustainable yield (MSY). This suggested that since 2011, the environmental carrying capacity has been unable to support the recovery of tuna resources landed at the West Sulawesi Fisheries Port based on the excessive utilization of resources in previous years. Each water body has a different carrying capacity. Hence, using fish resources must consider the carrying capacity **(Sun *et al*., 2024)**. Meanwhile, fishing efforts were increasing every year. The increasing number of vessels in a fishing fleet could exert pressure on resources and decrease resource rents **(FAO, 2003)**. Several studies also indicated that the utilization of tuna fish in some regions of Indonesia was already at the level of overexploitation **(Rihi, 2013; Jaya *et al*., 2017; Rahmah *et al*., 2021)**.

Over 16 years, the utilization rate of tuna resources ranged from 8 to 132%, with an average of 54.1%, while the fishing effort utilization rate ranged from 66 to 241%, with an average of 137.8% each year (Fig. 4). The utilization rate of the yellowfin tuna production exceeding 100% was found in 2007-2010, while it was revealed in 2012-2022 for fishing effort utilization. A FAO study on the condition of the species stocks showed a percentage status of 68%, which indicated high and excessive exploitation or overfishing **(FAO, 2021)**. This revealed an excessive fishing effort (overexploited) in those years, necessitating management actions due to precautionary principles. Yellowfin tuna population parameter in the Banda Sea had exceeded the optimal limit, and tuna and skipjack resources had experienced depletion, thereby requiring preventive management actions **(Firdaus *et al*., 2018; Haruna *et al*., 2018; Haruna *et al*., 2019)**.

In the following season, namely west (December-February), small-sized tuna still dominated, with 106 individuals falling into the length class of 17-35cm. This was followed by the second most abundant class in the length range of 112-130cm, comprising 15 individuals. In the western season, the length classes were broader than the previous season, but some size classes (55-111cm) were not caught during this period. The dominance of small-sized tuna was observed during the transitional season II (September-November) and the western season (December-February). The results are similar to those obtained by **Novitasari *et al.* (2019)** in the Gulf of Bone, where the dominant size was 60-85cm, still considered juvenile, as well as by **Darondo *et al.* (2020)** in the waters of Bitung, where the yellowfin tuna was found in sizes ranging from 23-67cm and 35-61cm using pole, line, and purse seine fishing methods.

The length structure of yellowfin tuna caught within the transitional season I (March-May) ranged from 17 to 185cm. During the east season (June-August), the structure ranged from 56 to 186cm. The length structure of species obtained in the transitional season I (March-May) and the east season (June-August) was dominated by adult sizes. These included the 101-121cm class, comprising 265 individuals during the transitional season I (March-May), and the 107-123cm class, comprising 119 individuals during the east season (June-August). **Kantun and Malawa (2015)** in the Makassar Strait reported that the dominant size of the yellowfin tuna caught ranged from 100-115cm.

The first gonad maturation size for the yellowfin tuna in the Makassar Strait was almost the same for 3 different years, measuring 118.61 for males and 119.27 for females, with an average length of 118.88 for both genders **(Kantun, 2011, 2012, 2013)**. However, according to **Itano**'s **(2001)** study, the initial gonad maturation size for the species in Indonesia was reported as 104.6cm. According to Fishbase.com, the first gonad maturation size for the yellowfin tuna was documented as 103.3cm. The percentage of tuna suitable for capture during transitional season II was 28%, while 72% were not suitable, predominantly comprising juvenile-sized species. During the west season, the percentage of tuna suitable for capture was 21%, with 79% deemed unsuitable, also dominated by juvenile-sized tuna. In transitional season I, 44% of tuna were deemed suitable for capture, while 56% were unsuitable, dominated by juvenile-sized species. In the east season, the percentage of tuna suitable for capture was higher at 62% compared to 38% deemed unsuitable.

Based on these sizes, yellowfin tuna caught in the waters of West Sulawesi were considered suitable for capture during the east season, while the other 3 seasons predominantly comprised of sizes deemed unsuitable for capture. The findings suggested that yellowfin tuna fishery resources in the waters of West Sulawesi were vulnerable to recruitment overfishing.

Due to the discussion above, it was evident that the growth pattern of the yellowfin tuna was isometric during the eastern season. **Jatmiko *et al*. (2014)** conducted a study using longline fishing samples, leading to a value of b of 3.029, which indicated an isometric growth pattern. However, during the other 3 seasons, the growth pattern was positively allometric. Similar findings were observed in studies conducted in various locations, such as India, Pelabuhan Ratu (Indian Ocean), and the Eastern Indian Ocean, where the growth pattern of the yellowfin tuna was positively allometric (b>3) **(Rohit & Ramohan, 2012)**. The study of **Kantun (2012)** in IFMA 713 on the relationship between the length and weight of the female and male yellowfin tuna (data from January to December 2011) revealed that the growth pattern of the yellowfin tuna was negatively allometric (b<3). This is ascribed to the tuna caught being generally in the condition of immature gonads (GMI I-III).

Positive allometric growth during the three seasons in this study from September 2022 to May 2023 indicated that the yellowfin tuna >100cm in size were generally in a fat condition. This is related to the gonadal maturation and spawning season during those months. In line with the findings of **Kantun (2012, 2012a-b, 2013c)**, primary gonadal maturation occurred in March, and secondary maturation was observed in October, as indicated by the peak values of the gonadal maturity index.

Variations in the value of b could occur between different populations of the same species or between the same populations in different years, depending on biological and ecological conditions known as the environmental carrying capacity of the fish habitat. Environmental changes and fish biological conditions could lead to changes in the length-weight relationship of fish. These changes were influenced by food availability, age, gender, and gonadal maturity **(Kantun & Mallawa, 2016)**.

Further research is necessary to formulate robust recommendations for sustainable yellowfin tuna management in the specified region. These recommendations should be predicated on a comprehensive analysis of multiple factors. A comprehensive approach combining harvest strategies, genetic analysis, sustainable fishing technologies, and climate change considerations is necessary for the sustainable management of the yellowfin tuna. Regular monitoring and assessment of stock status and international cooperation are essential, given the migratory nature of the species and its importance to multiple nations' economies and food security **(Artetxe-Arrate *et al*., 2020)**.

CONCLUSION

The average CPUE for tuna in West Sulawesi was 33.6 tons/unit/year, with a CMSY of 18,565.9 tons/year and an EMSY of 344 units/year. The biomass trend continued declining, and overfishing occurred over the past 5 years. In addition, the size structure of the captured yellowfin tuna in each season ranged from 17-186cm, dominated by fish unsuitable for capture except during the eastern season. The growth pattern of the yellowfin tuna during the eastern season was isometric, while the other 3 seasons exhibited a positive allometric growth. The state of tuna is under high pressure, and management action is needed to sustain these resources.

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