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Biological parameters and spawning potential ratio of Longtail Tuna *Thunnus tonggol* landed in Kranji fishing port, Lamongan District, Indonesia

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Abstract. *Harlyan LI, Rahman MA, Rihmi MK, Abdillah SFA. 2023. Biological parameters and spawning potential ratio of Longtail Tuna* Thunnus tonggol *landed in Kranji fishing port, Lamongan District, Indonesia. Biodiversitas 24: 6527-6535.* Longtail Tuna (*Thunnus tonggol*), one of the small-pelagic tropical fisheries in the Fisheries Management Area (FMA-712), is important in supporting global food security. Therefore, to ensure its sustainability, this fishery is applying for fishery certification to be an ecolabel fishery by the Marine Stewardship Council (MSC). However, limited information about Longtail Tuna's biological parameters and stock status in this management area will lead to failure in certification completion. This study aims to provide biological parameters and stock status of Longtail Tuna landed in the Kranji fishing port, Lamongan, Indonesia. Length, weight, and gonad weight of female Longtail Tuna individuals which landed in the Kranji fishing port were conducted from January to April 2023. Several analyses were carried out to figure out the biological parameters of Longtail Tuna, such as length-weight relationship, length at first maturity (L_{50}) and length at first capture (L_c) estimation. Length-Based Spawning Potential Ratio (LB-SPR) analysis was conducted to estimate fish exploitation. Results showed that the Longtail Tuna landing in the Kranji fishing port exhibited a negative allometric growth pattern with the length-weight relationship model $W = 0.0433\ FL^{2.7608}$. A comparison between L_{50} (43.9±0.11cm) and L_c (43.6±0.04cm) indicated that most female Longtail Tuna landed in the Kranji fishing port are mature (60% of the total samples). The LB-SPR analysis showed moderate exploitation status (SPR = 34%). Fishing activities are still manageable in this situation by focusing on stock sustainability. An overlapping fishing ground occurs in the Kranji water, showing the domination of two species landed in the Kranji fishing port, Longtail Tuna and Eastern Little Tuna (*Euthynnus affinis*). Therefore, Longtail Tuna fishery management might also consider fishery management of Eastern Little Tuna or other species with overlapped habitats.

Keywords: Ecolabel certification, fisheries management, length-weight relationship, species composition, stock status

INTRODUCTION

Longtail Tuna, known as *Thunnus tonggol*, has traditionally contributed significantly to Indonesia's food supply (Abdussamad et al. 2012). As a small pelagic fishery, it contributed up to 37% of the total fish production in the Fisheries Management Area (FMA-712) (Hidayat et al. 2020; Rizal et al. 2023). They are located exclusively in the neritic waters, geographically distributed within the Indo-Pacific region between 47°N and 33°S. In Northern Java, part of FMA-712, Longtail Tuna is the most dominant species caught by many fishing gears, such as purse seines and gillnets, indicating high fishing pressure (Hidayat et al. 2020). As a result, the sustainability of the fishery must be preserved. Together with the other group of species, Anchovy fisheries, the Department of Marine and Fisheries, Province of East Java, applies a fishery certification for these fisheries to ensure their sustainability in Northern Java (Wiadnya et al. 2023). The Marine Stewardship Council (MSC) is a nonprofit organization that aims to establish criteria for sustainable fishing. The Conformity Assessment Bodies (CAB) evaluate fisheries that exhibit that they are sustainably managed and up to the criteria set by the MSC. Therefore, to be certified by the MSC certification, the fisheries must meet the MSC Fisheries Standard (Southall et al. 2016; Pierucci et al. 2022).

As part of the certification process, a fishery can complete a pre-assessment conducted by the CAB, which informs whether the fishery is ready for a full assessment (Southall et al. 2016; Wakamatsu and Wakamatsu 2017; Le Manach et al. 2020). The pre-assessment of the Longtail Tuna caught by the purse seine fishery in the FMA-712 has been done and stated that there needs to be more information on the current stock status for the populations caught by Unit of Assessment (UoA) vessels, which the stocks are poorly defined. It is also specified that the Longtail Tuna stocks are likely to be above the Point of Recruitment Impairment (PRI) as a reference point limit for the reproductive part of the stock. However, more information is required on stock status (Bioinspecta 2019). Therefore, some actions need to be taken to improve the fishery and fulfill the requirement of the MSC fishery certification (Southall et al. 2016; Wakamatsu and Wakamatsu 2017; Le Manach et al. 2020).

The Spawning Potential Ratio (SPR) is a typical approach for estimating the biological reference point of a fish stock under fishing pressure (Hordyk et al. 2015b). It can be used to help minimize over-exploitation, which can threaten the sustainability of fisheries. However, in small-scale and data-poor fisheries, due to a lack of technical skill and financial support, the only available data to be collected is length composition data. (Ault et al. 2005; Harlyan et al. 2019, 2021, 2022). Furthermore, measuring an exploited stock's length data is relatively practical and is among the most common data available. Since the length of data for many stocks is readily available, various length-based approaches have been developed and deployed to estimate biological characteristics and explain the dynamics of fish populations (Pauly and Morgan 1987; Klaer et al. 2012). Length-based strategies leverage the population's length structure to determine stock status and provide helpful management advice (Ault et al. 2005; Klaer et al. 2012; Hordyk et al. 2015a).

The former studies assessed the applicability of Length-Based SPR (LB-SPR) as a tool for analyzing data-poor and small-scale stocks by testing some of the fundamental assumptions of the Length-Based SPR (LB-SPR) model (Hordyk et al. 2015a, 2015b). In this study, the possibility of fish stock estimation was developed by the LB-SPR with several assumptions to the supporting data, such as growth and mortality parameters (King 2007). The Northern Java Longtail Tuna fishery, which only has length frequency data available, may benefit from adopting the LB-SPR model as a data-poor fishery since it may be an effective technique to provide a preliminary estimation of stock status and management recommendations.

The Northern Java Longtail Tuna fishery must ensure its structure, productivity, and diversity of the ecosystem to meet the MSC fisheries standards, including other supporting species, which are defined as species that are also caught together with target species (Southall et al. 2016; Yusrizal et al. 2018). Lack of information on other species as supporting species of the Longtail Tuna fishery might raise problems in identifying the Longtail Tuna fishery's impact on other species. This study also provides the characterization of other species assumed as the supporting species into primary, secondary, and Endangered, Threatened and Protected Species (ETP) for baseline data on assessing the impacts of the Longtail Tuna fishery in Northern Java.

The Kranji fishing port, located in Lamongan regency, is the dominant Longtail Tuna fishery landing site in Northern Java. This study was conducted to estimate the stock status of Longtail Tuna landed in Northern Java using the LB-SPR model and assess the impacts of the Longtail Tuna fishery on other supporting species by characterizing its landing composition. Longtail Tuna Fishery's Improvement Program (FIP) might lead to MSC certification by completing these information gaps, leading to fishery sustainability and elevating its global market.

MATERIALS AND METHODS

Study area

The Kranji fishing port in Northern Java is a small fishing port that primarily lands for Longtail Tuna (Figure 1). A field survey was conducted to gather biological information on Longtail Tuna and the landing information from January to April 2023, representing the fishing season in Northern Java, as a part of the Western Central Pacific. The fishing season of Kranji water is divided into two seasons; the Longtail Tuna was dominantly caught from October to April, while other small pelagic fish were dominantly caught from May to September.

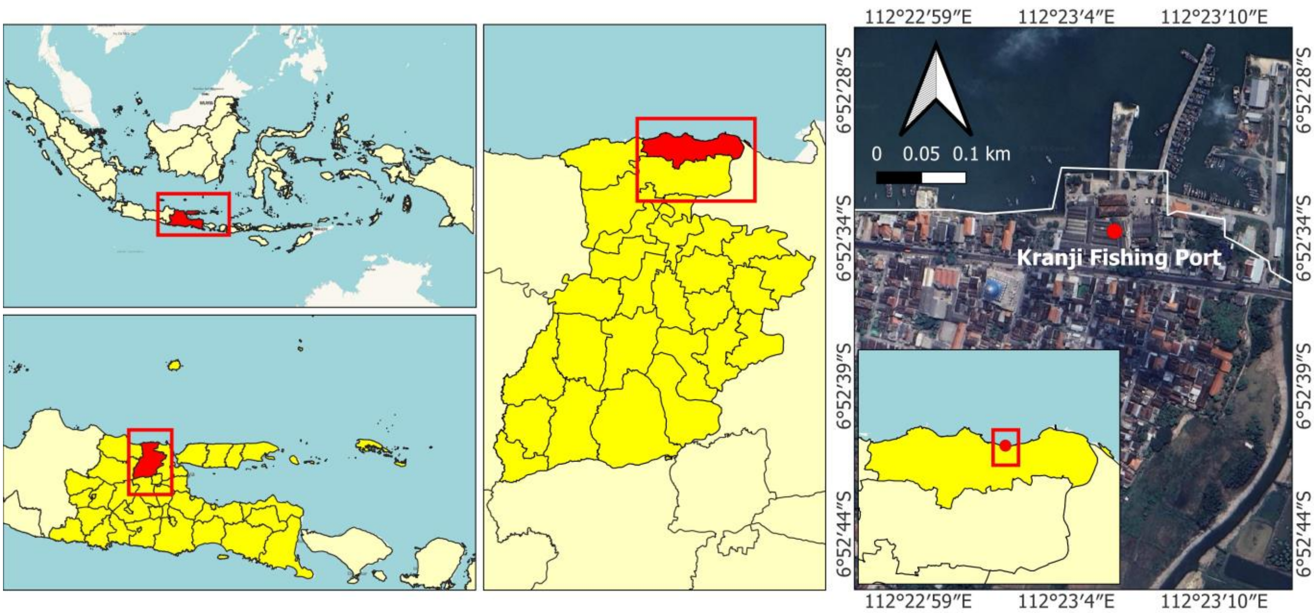

Figure 1. Kranji Fishing Port is located in Northern Java as a part of the Western Central Pacific

Data collection

The field survey collected information on all species based on their fishing ground, fishing gear, landing sites, and the number of landings. A systematized questionnaire was used during the fishery surveys to collect fishing data, including fishing ground coordinates and caught data, through face-to-face interviews with local fishermen and enumerators. Participatory mapping was used to assist respondents in providing their fishing ground coordinates. At the time of the survey, there were 150 boat owners, including 120 purse seine fishers and 30 gillnet fishers.

Moreover, 2,000 samples were collected to gather Longtail Tuna's fish length and weight data for both male and female individuals. The length data gathered was forked length (cm), and the weight data were taken by digital scale (g). Dissection was performed to observe fish gonad macroscopically to observe gonad maturity for 45 female individuals.

Data analysis

Several analyses were performed to describe the biological parameters of Longtail Tuna landed in the Kranji fishing port.

Species composition

The species composition of the landings and fishing coordinates collected from fishery surveys were used to digitize for landing composition of each fishing ground.

Length-weight relationship

Growth parameters are conducted by length-weight relationship analysis through this equation:

$$\boldsymbol{W = aL^b} \text{...(1)}$$

Therefore, to estimate the constant, a and b, the equation was transformed into a linear regression model as follows:

$$\boldsymbol{lnW = a + blnL} \text{..(2)}$$

Where *W* and *L* are, respectively, fish weight (g) and forked length (cm). The constants a and b are the intercept and slope of the linear regression model. The b value describes the growth pattern (isometric vs. allometric). Furthermore, to test whether Longtail Tuna exhibits isometric growth or not, a partial t-test was conducted by considering $\mathbf{t_{table(\alpha,df)}}$ with 95% confidence interval (α=0.05) and degree of freedom is $\boldsymbol{n-1}$. The $\mathbf{t_{count}}$ was estimated by the following equation:

$$\mathbf{t_{count}} = \left|\frac{b_0 - b_1}{Sb_1}\right| \text{.................................(3)}$$

Where b_0 equals 3, b_1 is the regression slope, and Sb1 is the standard deviation of b applying hypotheses:

H0: b=3 indicates an isometric growth pattern

H1: b≠3 indicates an allometric growth pattern

Allometric patterns are divided into two: positive allometric and negative allometric. If *b*<3, the growth pattern is negative allometric, indicating accretion of length is faster than accretion of weight, and if *b*>3, the growth pattern is positive allometric, indicating accretion of weight is faster than accretion of length.

Gonad maturity level

Gonad maturity can be determined by observing both morphometric and meristic data. Several aspects are observed, including color and size. Male and female individuals have four to five stages of gonad maturity levels (Table 1) (Ngabito et al. 2023).

Mean length at first maturity L_{50}

This analysis can be applied to evaluate fish stock management and conservation (Soares et al. 2020). In addition, $\boldsymbol{L_{50}}$ was calculated by adapting the equation created by King (2007):

$$P = 1/(1 + exp[-r(L - Lc)]) \text{……………….(4)}$$

To calculate $\boldsymbol{L_{50}}$, the equation is transformed as:

$$P = \frac{1}{(1+e^{-r(L-L50)})} \text{…………………………..(5)}$$

Where P is the proportion of mature individuals, L is fish length (cm), $\boldsymbol{L_{50}}$ is the mean length at a proportion of 50% at maturity (cm), and r is the coefficient related to the slope of the logistic curve.

Length at first capture (L_C)

The length at first capture (L_c) and the length at both 25 and 75 captures correlated to the cumulative probability at 25% and 75%, respectively. They were estimated using the ascending left arm of the length converted catch curve included in the FiSAT II tool. The likelihood of catch provides a clear picture of the approximate size of the fish in the fishing region that will be captured with a certain piece of equipment. It is a crucial tool for fisheries managers to determine the minimum mesh size of a fishing fleet, which is necessary to sustain targeted fishery management. The results of L_{50} and L_c were compared to determine allowable fish length and stock status.

Length-Based Spawning Potential Ratio (LB-SPR)

Therefore, to estimate the stock status of the Longtail Tuna fishery, the LB-SPR method was performed using the barefoot ecologist application (Prince 2003; Castello et al. 2013). The input of the application is length data and several life history parameters, such as average maximum asymptotic length (L_∞), growth rate coefficient (K), natural mortality (M), and length at 50% maturity (L_{50}), and length at 95% maturity (L_{95}) (Hordyk et al. 2015b; Halim et al. 2020).

Asymptotic length (L_∞) and growth rate coefficient (K). Growth parameters were estimated from the Von Bertalanffy growth curve equation using the FAO-ICLARM Stock Assessment Tools (FISAT-II) - Electronic Length Frequency Analysis I (ELEFAN I) software, as follows:

$$L_t = L_\infty\left(1 - e^{-K(t-t_0)}\right) \text{..........................(6)}$$

Where Lt is the fish length at age t (cm), and t_0 is the theoretical age at which the fish is age 0.

Natural mortality (M). Natural mortality can be calculated using the Pauly (1980) equation:

$$LogM = -0.0066 - 0.279LogL_{\infty} + 0.6543LogK + 0.4634LogT \ldots (7)$$

Where: T is the seawater temperature (°C) collected from NASA Ocean Color (https://oceancolor.gsfc.nasa.gov/) in the study period.

L_{50} and L_{95}. L_{50} is obtained from the L_{50} analysis described above, while L_{95} was estimated by applying the equation from Kindong et al. (2022) as follows:

$$L_{95} = 1.1 \times L_{50} \ldots\ldots (8)$$

The SPR value is expressed as a percentage, representing the decline in the proportion of the spawning biomass produced by each recruit relative to the spawning production that would have occurred in an unfished state. An SPR of 100% means the resource is under-exploitation. An SPR <20% indicates an overexploitation fishery, while 20%<SPR<40% indicates that the exploitation status is moderate, and SPR>40% indicates that the fishery is under-exploitation (Prince et al. 2015).

Catch composition distribution overfishing coordinates

Fishing coordinates and species composition were combined to generate a fishing ground distribution map. The fishing coordinates were gathered from participatory mapping; respondents directly gave their fishing coordinates information in the fishing ground map with minimal intervention from researchers. The species composition data was collected from the landings of 150 fishing boats. The ArcMap 10.3 application digitized the landing data of each coordinate.

RESULTS AND DISCUSSION

Species composition

Longtail Tuna is the primary species landed in the Kranji fishing port, exploited by gillnet and purse seine gears. Figure 2 shows the caugth composition of the Longtail Tuna fishery from two fishing gears. The charts show Longtail Tuna represent more than half of the landings for both fishing gears, followed by mackerel tuna (*Euthynnus affinis*) and small portions of other supporting species, such as Black Marlin (*Istiompax indica*), Narrow-barred Spanish Mackerel (*Scomberomorus commerson*), Indo-Pacific king Mackerel (*Scomberomorus guttatus*), Needlescaled queenfish (*Scomberoides tol*), Military barracuda (*Sphyraena putnamae*), Common Blacktip Shark (*Carcharhinus limbatus*), Barracuda (*Acanthocybium solandri*), Shortbodied Mackerel (*Rastrelliger brachysoma*), and Fourfinger Threadfin (*Eleutheronema tetradactylum*). During the study period, landings of purse seines were five times higher than those of gill nets. The length distribution data was collected from two gears to ensure that the length data covered all size distributions of Longtail Tuna individuals.

Length-weight relationship

The length-weight relationship was estimated using 2,000 individual length and weight measurements. Figure 3 shows the scatter plot and fitted curve for the length-weight relationship of Longtail Tuna. The length-weight equation is estimated as follows:

$W = 0.0433\ FL^{2.7608}$, where the a and b constants are 0.0433 and 2.7608, respectively (Figure 3).

Results from the t-test (t_{count} = 18.54; t_{table} = 1.96) indicated that the Longtail Tuna has a negative allometric growth pattern. The increase in fish body weight is slower than in fish body length.

Gonad maturity analysis

The determination of the gonad maturity level was based on the gonad maturity stage (Table 1), and 45 individuals were examined. From 45 samples, 25 males and 20 females were distributed in various stages (Figure 4).

In Figure 4, stage I indicates immature gonads, while stage III indicates mature gonads, and stage IV should be the post-spawning; hence, there are many fish in stage IV. No individual was found in the post-spawning stage (where the gonads shrink and empty). According to samples, more mature samples were found in the landings at Kranji fishing port.

Mean length at first maturity (L_{50})

The fish's mean length at first maturity is when 50% of the population mature (L_{50}) or individuals in stages III and IV of the gonad maturity level. The L_{50} value was obtained from the linearized regression analysis between the length class and the proportion of mature individuals (Figure 5).

Table 1. Morphometric characterizations to aid in determining male and female maturity stages

Stages	Female	Male
I (Immature)	Gonads are clear	Gonads are clear
II (Early maturation)	Gonads are yellowish-white	Gonads are milky-white
III (Maturation)	Gonads fill almost half of the peritoneum, and the eggs are fine granules, greenish-yellow.	Gonads fill almost half of the peritoneum and are milky-white.
IV(Mature)	Gonads fill most of the peritoneum and are brownish-green.	Gonads fill most of the peritoneum and are milky-white
V (Post spawning or spent)	Gonads shrink	Gonads are empty

Source: Ngabito et al. (2023)

The L_{50} on Longtail Tuna was estimated at 43.9±0.11cm, as the linear regression model results suggested, with a determination coefficient of 59.25%. Figure 6 shows the graph to determine whether the length frequency of the Longtail Tuna landed in the Kranji fishing port is more or less than the L_{50}. The graph shows that in the length frequency, most landing fish have a length more than the L_{50}.

Mean length at first capture (L_C)

The value of L_C can be applied to several approaches for determining the exploitation level. A fishery can be assumed to be a sustainable fishery if most landings are in a mature stage. The L_C value can be defined by applying a regression analysis, which was performed between length class (FL, cm) and the difference of log-normal number individuals ($d \ln N$) (Figure 7). The regression model for L_c is $y = -0.1621x + 6.337$ with the determination coefficient is 64.4%. The calculation shows that the L_C of the Longtail Tuna landed in the Kranji fishing port is 43.6±0.04 cm. Based on the calculation of L_{50} and L_C, the value of L_{50} significantly differs from L_C. It is assumed that the landings of Longtail Tuna in the Kranji fishing port are stable since individuals in the mature stage dominate it.

Length based-Spawning Potential Ratio (LB-SPR)

This analysis was applied to determine the exploitation status of Longtail Tuna landed in the Kranji fishing port by inputting the fork length and several parameters.

Growth rate (K), asymptotic length (L_∞), and natural mortality (M). Below is the von Bertalanffy plot shown from January to April 2023 (Figure 8). The K value is 0.67/year, while the L_∞ is 55.4 cm FL.

The natural mortality calculated by the Pauly equation is determined as 1.53/year. Therefore, the M/K ratio is 2.29. This means the removal of Longtail Tuna in Kranji waters due to causes not associated with fishing, which can be characterized by fishing intensity by comparing with F and Z values.

Selectivity-Maturity analysis. In this analysis, the L_{50} was estimated at 43.9 cm FL, while the L_{95} was 48.9 cm FL. By completing the calculations of several biological parameters, the barefoot ecologist tool provided the selectivity-maturity curve (Figure 9) that shows the gear selectivity of fishing gears used, purse seines and gillnets, in Kranji waters.

The selectivity curve falls on the right of the maturity curve. It indicates that the gears used by the Kranji fishers were selective, as they could dominantly catch mature individuals. Similarly, the SPR value of the Longtail Tuna landed in the Kranji fishing port was 34% (Figure 10), indicating modest stock status. It is suggested that the Longtail Tuna still can be fished with proper monitoring and surveillance.

Fishing ground distribution

The fishing grounds of the Longtail Tuna fishery and other supporting species are concentrated vertically from the Kranji coastline (Figure 11). It is shown that the overlapping of fishing coordinates between the fishing ground of the Longtail Tuna and the mackerel tuna demonstrates that both species are dominant.

Longtail Tuna are widely distributed from Kranji waters to Bawean Island with fishing distances ranging from 13 to 56 miles from the coast. The Longtail Tuna has no distinct fishing ground since it overlaps with other species, such as mackerel tuna.

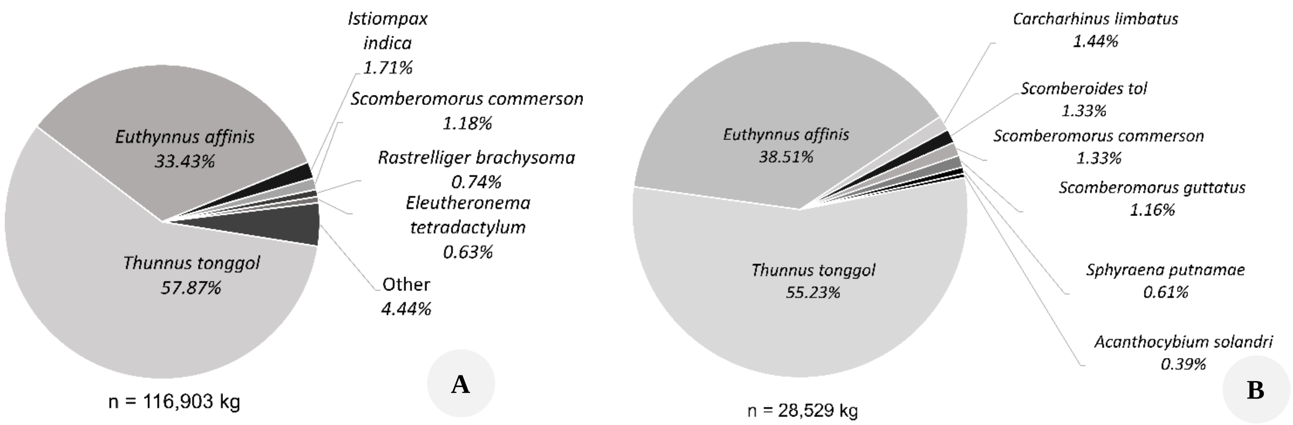

Figure 2. Species composition by weight of Longtail Tuna fishery from two fishing gears: A. Purse seines, B. Gillnets

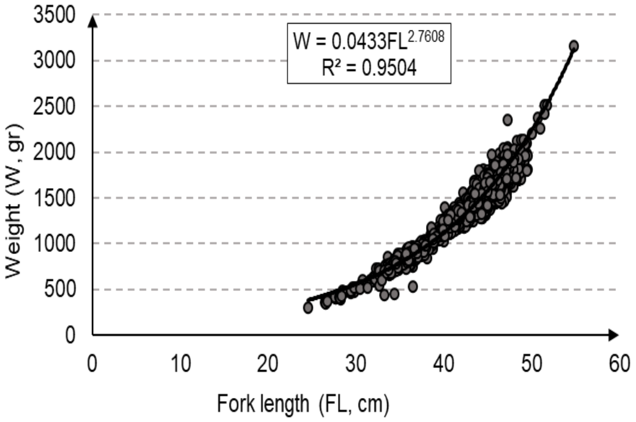

Figure 3. Length-weight relationship estimated for Longtail Tuna landed in the Kranji fishing port

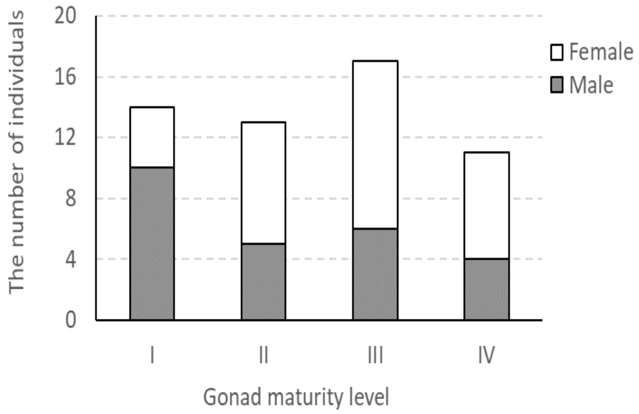

Figure 4. The Gonad maturity level of the Longtail Tuna landed in the Kranji Fishing Port

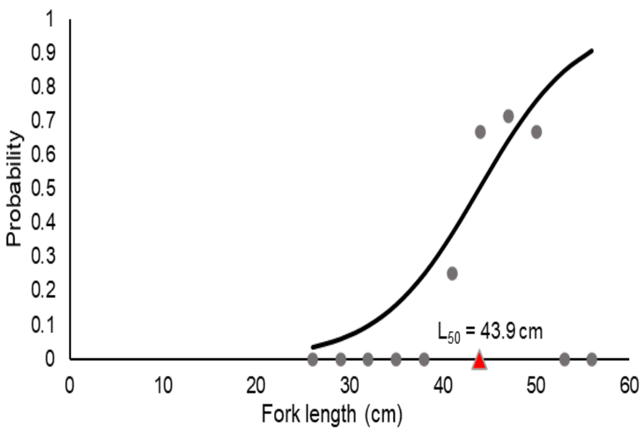

Figure 5. The mean length at first maturity (L_{50}) of the Longtail Tuna fishery landed in the Kranji fishing port. The red triangle indicates the value of the L_{50}

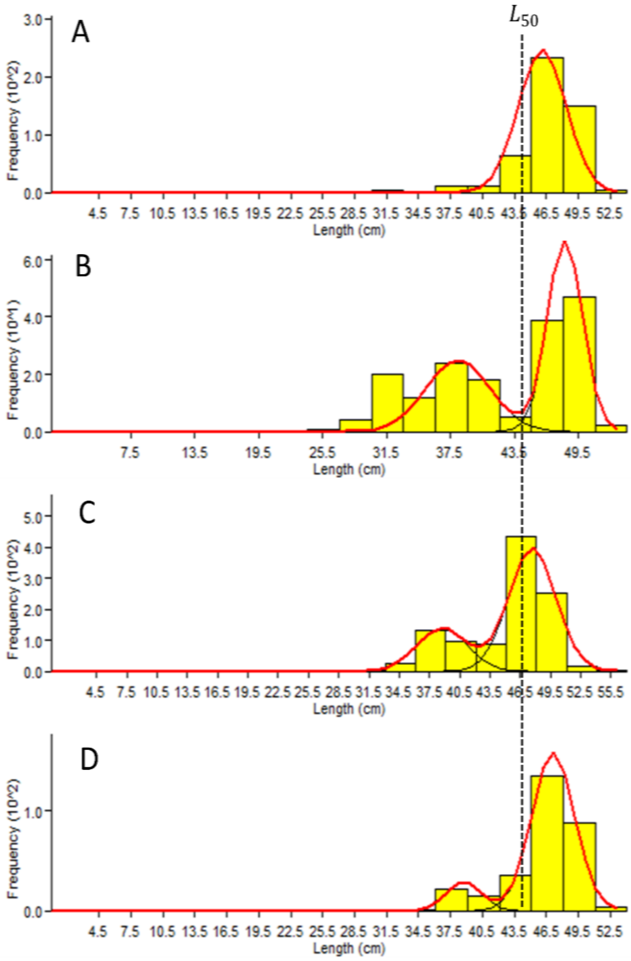

Figure 6. The length frequency of the Longtail Tuna landed in the Kranji fishing port in: A. January, B. February, C. March, and D. April 2023 showed a multimodal normal distribution which contain more than one peak. The dashed line indicates the L_{50} of Longtail Tuna. The red line is to connect the data points of each length class

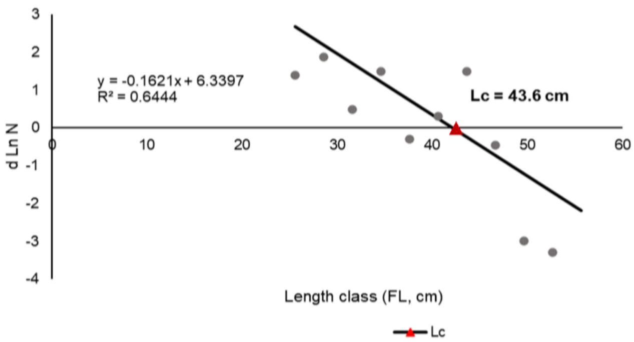

Figure 7. Length at first capture (L_C) of the Longtail Tuna fishery landed in the Kranji fishing port. The red triangle indicates the value of L_c. The $d \ln N$ is the difference of normal log number individuals

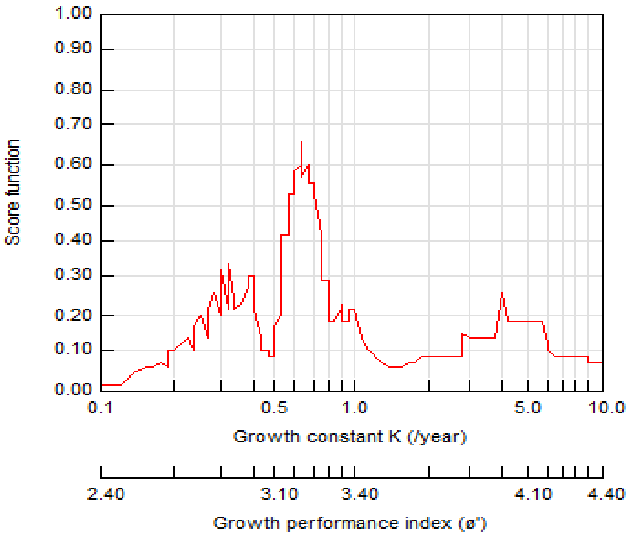

Figure 8. The von Bertalanffy plot of the Longtail Tuna fishery landed in the Kranji fishing port

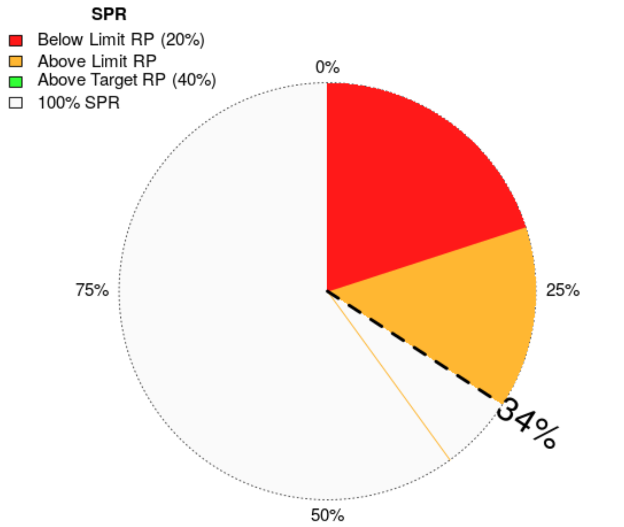

Figure 10. The spawning potential ratio of the Longtail Tuna fishery landed in Kranji waters

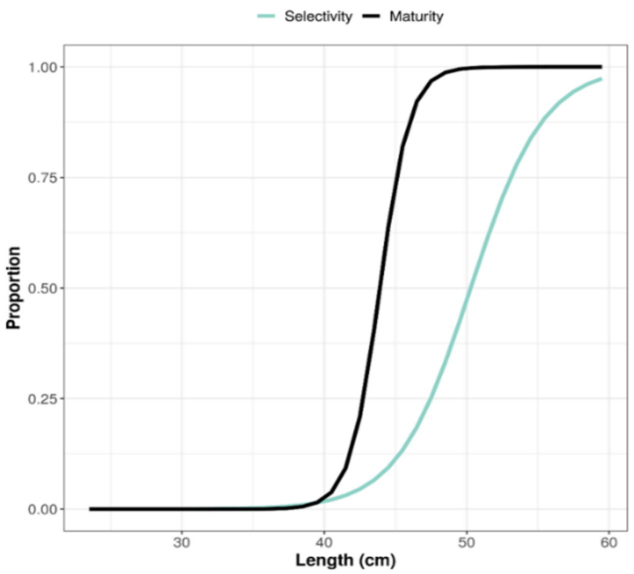

Figure 9. Gear selectivity of the Longtail Tuna fishery in the Kranji waters. The gear selectivity was estimated from purse seine and gillnet operated for the Longtail Tuna fishery

Discussion

Results of the analysis comparing length at first maturity (L_{50}) (or in this study, is L_{50}) to length at first capture (L_c) showed that these two values were very close to one another for Longtail Tuna landed in Kranji. This shows that mature fish dominate the catch of Kranji fishermen. The L_{50} and L_C values, which are almost the same, are influenced by the biological characteristics of Longtail Tuna, which tends to cluster in the same species and size range (Koya et al. 2018). It is known that the L_{50} value might vary within species; differences in environmental conditions and geographical location influence this.

Geographical location is related to changes in sea surface temperature, which influence differences in habitat preferences and fish distribution patterns (Koya et al. 2018). The L_C value varies at each research location; differences in fishing gear and fishing methods can cause differences in L_C values. This affects the fish size data obtained and the analysis size results' (Griffiths et al. 2020). Other factors that influence the size of the L_C values are net mesh size, differences in seasons, and differences in fishing areas (Hidayat et al. 2020).

Fish are stated to be sustainably caught if the length at first capture is larger than half the asymptotic length or the $L_C \geq L_{50}$ (Hidayat et al. 2020). Since the Longtail Tuna landed at the Kranji fishing port has an L_C value nearly equal to the L_{50} value, the fishing activities are still considered sustainable because they catch fish with developed gonads.

Results from the LB-SPR analysis indicated that the stock of Longtail Tuna in the Java Sea is still in a stable condition with an SPR value of 34%. This means that 34% of the adult Longtail Tuna population still has the opportunity to spawn. Biomass is said to restore its population if the SPR value exceeds the reference threshold of 30% (Prince et al. 2015). On the other hand, an SPR value of 34%, if related to the SPR categorization by Abdussamad et al. (2012), would indicate a fully exploited condition. This condition occurs if the SPR value obtained is in the range of 20-40%. This is supported by research from Bintoro et al. (2022), which states that the utilization status of large pelagics in FMA-712 has reached 63% of the MSY (Maximum Sustainable Yield) value and shows a fully exploited condition. Fishing activities for Longtail Tuna at the Kranji fishing port can still be conducted but must be monitored closely to ensure long-term sustainability. Management actions that could help avoid over-exploitation include limiting fishing trips and implementing regulations on the size of purse seine fishing gear, particularly mesh size regulation.

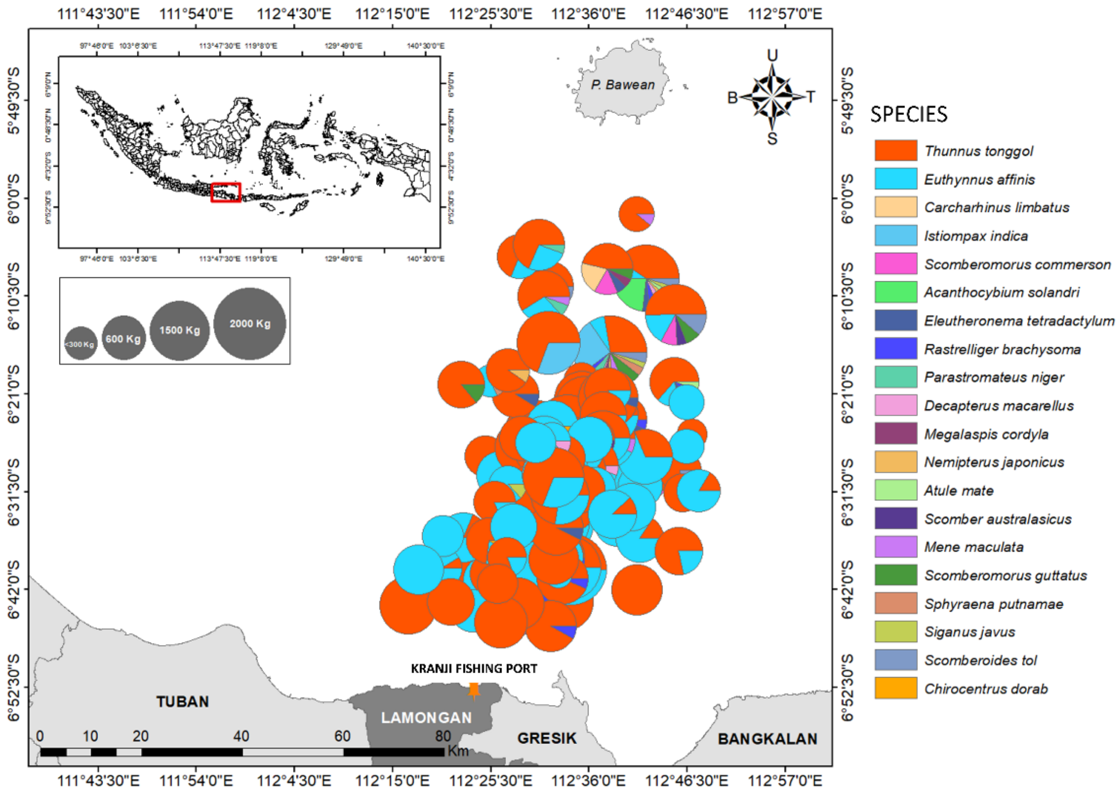

Figure 11. Fishing ground distribution of the Longtail Tuna fishery landed in the Kranji waters.

The distribution of species composition revealed an overlap in the fishing grounds of species landed in Kranji waters, as demonstrated by the fishing distribution of Longtail Tuna and mackerel tuna (*Euthynnus affinis*). As a result, Longtail Tuna fishery management might also consider fishery management of Eastern Little Tuna or other species that have overlapped habitats. As more biological and ecological information becomes available, the Kranji waters, as part of FMA- 712, may get fisheries certification in the coming years.

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