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Size Distribution and First Capture of Yellowfin Tuna in Makassar Strait: Purse Seine and Handline

Syamsinar[1]*, Muh. Aldhy Hatmar[2]

[1] *Fisheries Science Study Program, Faculty of Science and Technology, Sipatokkong Mambo University, Jl. Dr. Wahidin Sudirohusodo No. 75 Watampone, Bone 92733, South Sulawesi, Indonesia*
syamsinar@unsima.ac.id
[2] *Faculty of Animal Science and Fisheries, University of West Sulawesi, Majene 91412, Indonesia*
muh.aldhyhatmar@unsulbar.ac.id

**Correspondence*: *syamsinar@unsima.ac.id*

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ABSTRACT

Yellowfin tuna (Thunnus albacares) is a high-value fishery commodity. Many yellowfin tuna are caught in the waters of the Makassar Strait using purse seines and longlines targeting juvenile-sized fish. This study aimed to compare the length-frequency distribution and the estimated length at first capture (Lc) of Yellowfin tuna (Thunnus albacares) caught by purse seine and handline fisheries. The study was conducted in Majene and Polewali Mandar Regencies from August to November 2022. Sampling was performed randomly at fish collectors, with fork length measured using a tape measure with a precision of 0.1 cm. The data analyzed consisted of 479 individuals from purse seine catches and 1,620 individuals from longline catches. The results showed that the size structure of the purse seine catch ranged from 14 to 49.5 cm and was dominated by the 22.5 cm size class, while the handline catch ranged from 15.5 to 165 cm and was dominated by the 55 cm size class. The first-catch size (Lc) for the purse seine was 23 cm and for the longline was 63.9 cm. Differences in size distribution and Lc between the two fishing gear types indicate distinct catch characteristics that can provide information regarding the utilization of yellowfin tuna resources. This information can be used to support the sustainable management of yellowfin tuna fisheries in the waters of the Makassar Strait.

Keywords: *Catch size; distribution; first capture size; handline; purse seine; yellowfin tuna*

INTRODUCTION

Yellowfin tuna (*Thunnus albacares*) is a large pelagic fishery commodity with high economic value and is an important part of the global fish trade (Jatmiko *et al*. 2017; Pecoraro *et al*. 2018). In Indonesia, yellowfin tuna is among the top five global tuna producers and is the primary source of livelihood for fishermen in eastern Indonesia, including West Sulawesi (FAO 2022). The increasing global and domestic market demand for tuna products has driven the intensification of fishing efforts, which are often not in line with the recovery capacity of natural stocks. (Nugroho *et al*. 2018). According to Indonesia's Ministry of Marine Affairs and Fisheries (KKP 2024), data from the Ministry of Marine Affairs and Fisheries (KKP) show that yellowfin tuna production in West Sulawesi reached 29,760 metric tons between 2019 and 2024, with an average annual production of approximately 4,960 metric tons. Production fluctuated significantly, rising from 4,908 metric tons in 2019 to a peak of 7,780 metric tons in 2021 (+54.5%), then dropping sharply to 3,000 metric tons in 2024 (-61.4% compared to 2021). The production declined at an average annual rate of 2.6%, indicating a long-term

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downward trend. These production fluctuations reflect intense exploitation pressure on yellowfin tuna resources in the Makassar Strait.

The waters of the Makassar Strait, especially in Majene and Polewali Mandar Regencies, have long been the centre of tuna fishing activities using purse seine and handline gear (Jamaddin *et al*. 2020; Kantun *et al*. 2018). Gear selectivity is the ability of fishing gear to catch target fish of a specific size while minimizing bycatch and fish that are not yet suitable for fishing (Usman & Abudarda 2025). Purse seine is an active fishing gear used for multi-species fishing, and yellowfin tuna is generally caught using a Fish Aggregating Device (FAD) in the Makassar Strait (Kantun *et al*. 2018). Because *purse seine* catches often include a mix of adult tuna, juvenile tuna, and other small pelagic species (such as skipjack tuna and scad), the use of small *mesh sizes results in the capture of large numbers of juvenile tuna as* unavoidable bycatch (Chumchuen *et al*. 2016; Hatmar & Nelwan 2024; Jurwanto *et al*. 2025; Kalangi *et al*. 2024). In contrast, handlines are generally more selective about fish size but can still potentially catch juveniles if the hook specifications are not adjusted. The use of small hook sizes by handline fishers—often driven by a desire to maximize catch regardless of Size—can undermine the sustainability argument for this gear and contribute significantly to juvenile mortality. (Hargiyatno *et al*. 2021; Nelwan *et al*. 2015; Yulianto *et al*. 2023) .

The increase in fishing intensity without data-driven management can lead to overfishing of fish in the recruitment stage, especially when non-selective fishing gear targets juvenile or immature fish. A predominance of small-sized fish in the catch can hinder stock regeneration and reduce long-term productivity. Previous studies in Indonesian waters, however, have generally been conducted in isolation. Most of them either describe the catch composition of a single gear type, whether purse seine (Chumchuen *et al*. 2016; Hatmar & Nelwan 2024; Kalangi *et al.* 2024) or handline (Hargiyatno *et al*. 2021; Yulianto *et al*. 2023), or estimate reproductive parameters such as the length at first maturity (Lm) without linking them to the performance of the gear that removes the fish (Haruna *et al*. 2018; Kantun *et al*. 2018; Darondo *et al*. 2020). Consequently, no comparative evaluation has yet integrated the selectivity of the two gears, expressed as the length at 50% retention (L50, hereafter length at first capture, Lc), against a common biological reference point (Lm) for the same stock, season, and fishing ground. This fragmentation is not merely a bibliographic gap: without paired Lc estimates benchmarked against Lm, fisheries managers have no empirically derived minimum capture size on which to base gear-specific technical measures for yellowfin tuna in the Makassar Strait.

This study addresses these limitation by evaluating and comparing the selectivity of FAD-based purse seine and handline gear on the size structure of yellowfin tuna sampled in the same waters and over the same period, and by interpreting the resulting Lc values against the published Lm range for the species. Unlike earlier descriptive studies, this study explicitly contrasts the exploitation pattern of an active, multispecies gear with that of a passive, single-hook gear against a biological maturity reference point, so that the Lc/Lm ratio of each gear can be translated directly into technical management options: regulation of purse seine mesh size, combined with juvenile bycatch limits and control of FAD density, on the one hand, and regulation of the minimum hook size used by handline fleets on the other. Accordingly, this study aims to compare the length-frequency distribution and to estimate the length at first capture (Lc) of yellowfin tuna caught by purse seine and handline gear in the waters of the Makassar Strait, and to assess the implications of each Lc value relative to Lm as a basis for gear-specific technical regulation under the harvest strategy for FMA 713.

METHODS

The study was conducted from August to November 2022 in Majene and Polewali Mandar Regency, West Sulawesi Province, which is part of the Makassar Strait. Sampling was carried out twice a week at collection points after the catch was landed using handline and purse seine fishing gear.

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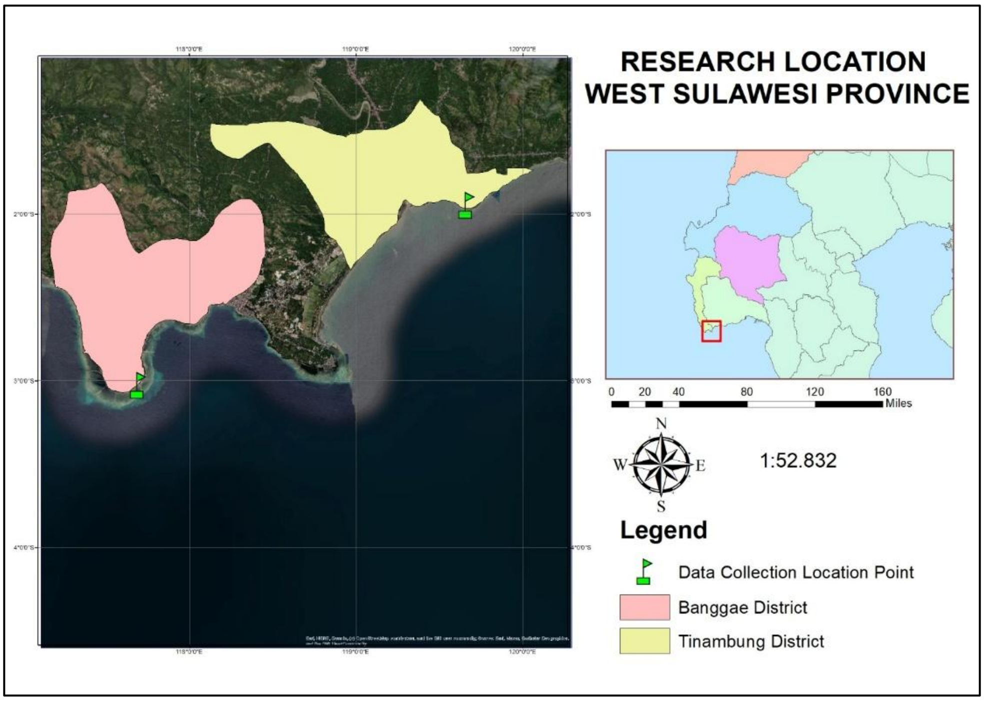

Figure 1 The study was conducted in Banggae District (Majene Regency) and Tinambung District (Polewali Mandar Regency), South Sulawesi Province, Indonesia

Yellowfin tuna samples were randomly collected from catches of fishermen using purse seine and handline fishing gear. Sampling was conducted at the collectors' locations after the catch was landed. The Number of samples analysed was 479 from purse seine catches and 1,620 from handline catches. This disparity in sample size reflects the landing characteristics of the study sites, where the frequency of landings by small-scale handline fishing fleets is higher and more consistent than that of *purse seine fleets*, which are seasonal or land in large volumes but less frequently. Each yellowfin tuna sampled was measured for fork length (FL) using a measuring tape with an accuracy of 0.1 cm, in accordance with fisheries biology measurement standards. Measurements were taken from the tip of the snout to the middle fork of the tail.

Size Structure

The size structure of the catch was analysed descriptively using a histogram of fork length frequencies. Length classes were determined based on the data range and sample size, with class intervals adjusted to visually optimize the distribution of the data. To visualize the size distribution of fish caught, length data were grouped into interval classes using Walpone (1995) formula:

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

With:

k= Number of interval classes

n = Total Number of data (observations)

Based on the Number of classes (k) and the data range (*range* = maximum value - minimum value), the class interval width (i) is determined using the formula:

$$i = \frac{Range}{k}$$

The frequency distribution was then plotted as a histogram for each fishing gear. Descriptive analysis was performed to identify key parameters: minimum length (Lmin), maximum length (Lmax), mean length (L), and mode (the most frequently occurring Size).

Size first caught

According to Anggarini *et al*. (2016), the Number of individuals in each length class of fish is converted into a total fractional proportion of 1. The proportion is accumulated gradually, starting from the smallest to the most significant class midpoint, so that the cumulative proportion for the most significant value reaches 1, which is called the SL column. From the SL value, an additional column is formed with the value of Ln(1/SL-1). The relationship between Ln(1/SL-1) as the dependent variable (y) and the class midpoint as the independent variable (x) is analyzed using linear regression with the following equation:

$$Ln\frac{1}{SL} - 1 = S1 - S2 \times L$$

So :

$$Lc = \frac{S1}{S2}$$

With:

Lc = Size first caught

S1 = Constant (intercept)

S2 = Constant (slope)

RESULTS

Size Structure

The size of the fish caught with purse seine nets ranged from 14 to 49.5 cm, and a total of 479 fish were caught. The yellowfin tuna caught with purse seine nets ranged in length from 22.5 cm, totaling 157 fish, as shown in Figure 2.

The size distribution of fish caught with handlines ranged from 15.5 to 165 cm in length, with a total of 1,620 fish. The most commonly caught yellowfin tuna measured 55 cm, with 466 fish. This is shown in Figure 3.

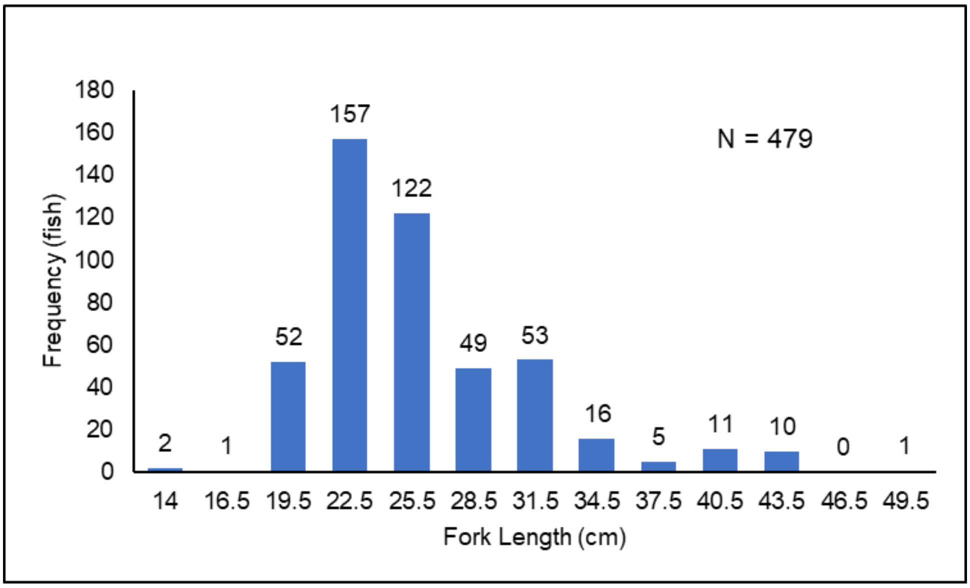

Figure 2 Length-frequency distribution of yellowfin tuna (*Thunnus albacares*) caught by purse seine gear in the waters of West Sulawesi, Makassar Strait (N= 479, fork length range: 14.0-49.5 cm)

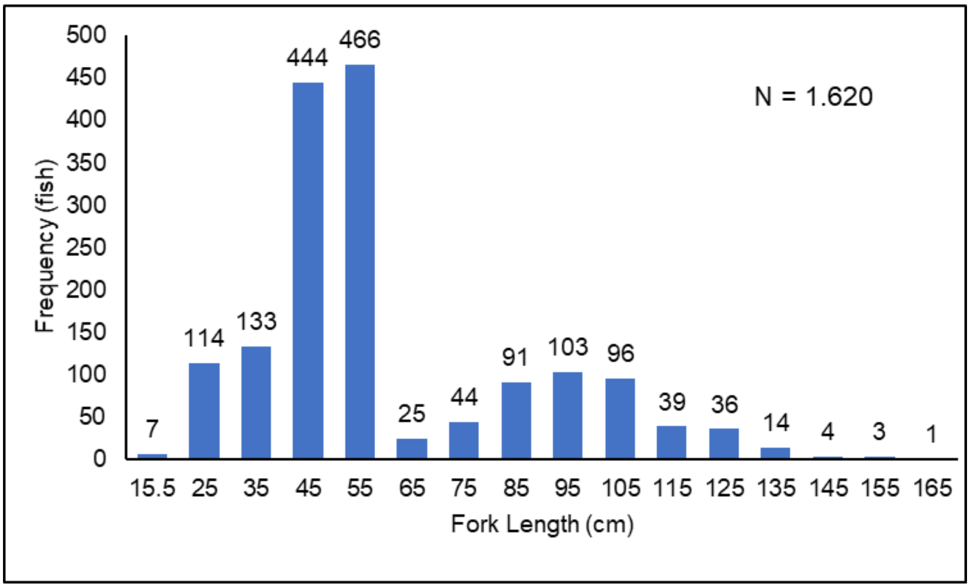

Figure 3 Length-frequency distribution of yellowfin tuna (*Thunnus albacares*) caught by handline gear in the waters of West Sulawesi, Makassar Strait (N=1.620, fork length range: 15.5-165 cm)

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Table 1 The statistical summary of the size structure of yellowfin tuna (*Thunnus albacares*) caught using purse seine and handlines in the Makassar Strait, Indonesia (August-November 2022).

Fishing gear	Purse Seine	Handline Fishing
Number of Samples (n)	479	1,620
Minimum Length (Lmin)	14 cm	15.5 cm
Maximum Length (Lmax)	49.5 cm	165 cm
Mode (Dominant Class)	22.5 cm	55 cm
Population Distribution	Concentrated (Narrow Unimodal)	Wide Range
Dominant Biological Phase	Early *Juvenile*	Late Juvenile / Sub-adult

Size First Caught (Lc)

Applying linear regression analysis to cumulative proportion data yields quantitative selectivity parameters (Lc) for both fishing gears. The resulting selectivity curves illustrate the probability of catching fish at each length.

1. **Purse Seine Selectivity** Based on the analysis, the Lc value for *the purse seine* was estimated at **23 cm**. This is very low and far too the left of the yellowfin tuna growth curve. This confirms that *the purse seine* at the study site operates as a mass-fishing device for tiny tuna. This Lc value nearly coincides with the mode catch size (22.5 cm), indicating the high efficiency of this fishing gear at that Size.
2. **Selectivity of Handline Fishing**. The first Size caught (Lc) on the long-handline fishing gear was 63.9 cm, with a length range of 15.5-165 cm, and a total of 1,620 fish. This value is nearly three times the Lc *for purse seine*, indicating a significant shift in selectivity toward larger sizes. However, this 63.9 cm value is still within the rapid growth phase of yellowfin tuna and has not yet reached the adult growth. This indicates that although handline fishing is more selective, the primary target in the Makassar Strait is currently tuna in their adolescent growth *phase.*

Data visualization (as described in Figures 4 and 5) shows a steeply rising *purse seine logistic curve* at sizes <20 cm, with an asymptote (100% chance of being caught) at sizes <30 cm. The handline curve, on the other hand, has a more *gradual slope*, reflecting the variation in hook sizes used by different fishers.

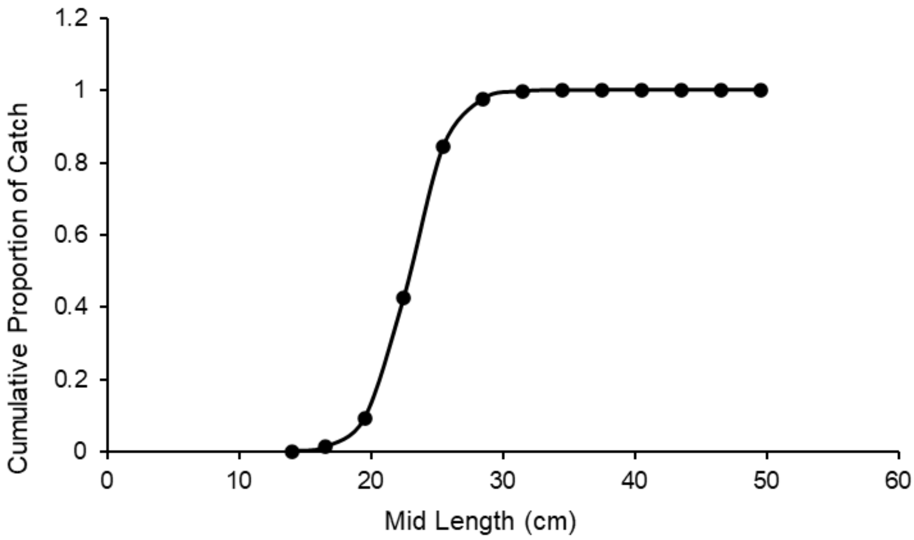

Figure 4 The selectivity curve for yellowfin tuna (*Thunnus albacares*) caught using purse seine nets in the Makassar Strait, with an estimated length at first capture (Lc) of 23 cm

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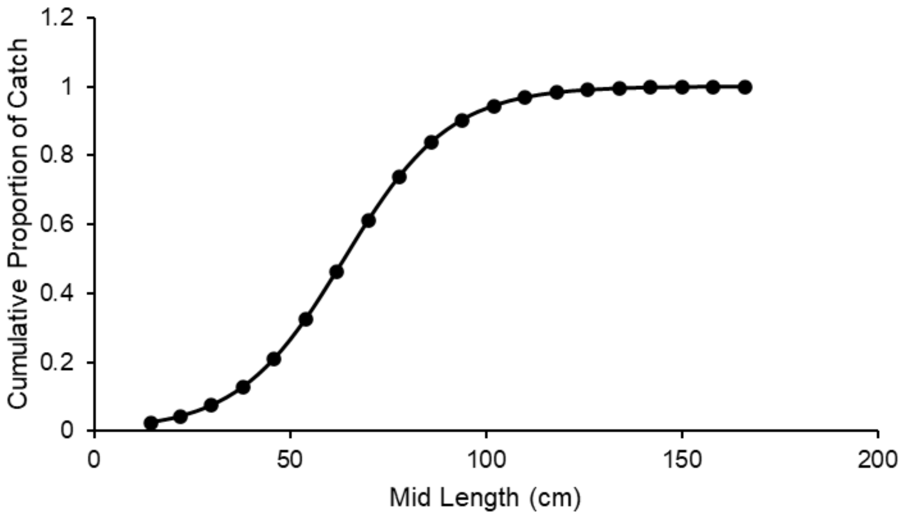

Figure 5 The selectivity curve for yellowfin tuna (*Thunnus albacares*) caught using handline in the Makassar Strait, with an estimated length at first capture (Lc) of 63.9 cm

DISCUSSION

Size Structure of the Catch

The two gears produced markedly different catch size structures within the same waters and the same sampling period. Purse seine catches spanned a narrow range of 14.0-49.5 cm FL and were strongly unimodal around 22.5 cm, indicating that the fleet operates almost entirely on a single cohort of early juveniles that has recently shifted from the planktonic to the nektonic phase. Handline catches spanned a much wider range of 15.5-165.0 cm FL, with a mode at 55 cm and a long right-hand tail reaching the adult size classes. The narrowness of the purse seine distribution, rather than its position alone, is the more informative result: it indicates that the gear encounters and retains one juvenile aggregation with almost no escapement, whereas the handline distribution reflects a fishery that intercepts several cohorts simultaneously.

Size ranges reported for yellowfin tuna elsewhere place these results in context. Hutubessy *et al.* (2021) recorded fish of 34-168 cm FL dominated by the 105 cm class, while Patanda *et al*. (2022) reported a range of 30.9-101.9 cm with most individuals between 46.7 and 54.5 cm. Safitri *et al*. (2019) found a range of 91-165 cm with most catches between 131 and 135 cm, and in Dilasag Bay, Philippines, the catch ranged from 120 to 145 cm with a mode at 125-130 cm (Reyes *et al.* 2021). In the Eastern Indian Ocean the range was 54-162 cm with most catches near 150 cm (Arnenda *et al*. 2018). Against this background, the size structure recorded in the Makassar Strait is displaced towards the smallest classes reported anywhere in the region, and the purse seine distribution in particular has no comparable counterpart in the studies cited above.

Gear Selectivity and Length at First Capture (Lc)

The findings of this study highlight the extreme disparity in gear selectivity rooted in the interaction between species biology and fishing technology. The extremely low Lc value *of purse seine (23 cm) is not a coincidence, but rather a logical consequence of the fleet's reliance on fish aggregating devices* (FADs). In tropical waters like the Makassar Strait, FADs act as more than just aggregating devices; they create what has been termed an "ecological trap" (MRAG 2017). Yellowfin tuna juveniles have a strong biological instinct to associate with floating objects as a defense mechanism against predators and for orientation in the vast pelagic environment. The 22.5 cm structures that dominate *purse seine catches* represent a cohort of recruits that have recently migrated from the planktonic to the nektonic phase and congregate around FADs.

The problem is exacerbated by the technical design *of purse seines*. Purse seine nets in Indonesia are generally designed with a tight *mesh size (often <1 inch at the bunt) to target small pelagic species such as scads (Decapterus spp.*) and small skipjack tuna. When these nets are looped around fish aggregating devices (FADs), mixed *schools of* *juvenile yellowfin tuna* lack a physical escape route*.* Consequently, they are caught in large numbers as technical *bycatch*. This finding aligns with global studies showing that FAD-based *purse seine fisheries* are responsible for the highest mortality rates among juvenile tropical tuna (Naunet Fisheries Consultants 2021).

In contrast, handlines exhibit a different selectivity mechanism, driven by feeding behavior *and* gape size*.* With an Lc of 63.9 cm, handlines target fish that are beginning to venture beyond the protection of surface fish aggregating devices (FADs) and dive into the deeper thermocline (free-swimming zone) to hunt for prey. However, the presence of small fish (15.5 cm) in the handline samples indicates the practice of "shallow handline fishing" operating right on the surface of the fish aggregating device (FAD) using large hooks (small physical Size) (Yulianto *et al*. 2023). According to Burhanis *et al*. 2017, yellowfin tuna caught in the waters of the Simeulue Islands with a length of 45.5-111.5 cm were more often caught on handline rods measuring 67.5 cm. This proves that the "environmentally friendly" label for handline fishing is not absolute, but rather depends heavily on the discipline of hook size selection by fishermen.

Regional Comparison and the Role of the Makassar Strait as *a Nursery Ground*

Based on this study in the Makassar Strait, the Lc value for *purse seine* is estimated at **23 cm**, while the first Size caught (Lc) on longline fishing gear is 63.9 cm. According to Ghofar *et al*. (2021), the first recorded length at first capture (Lc) of yellowfin tuna was 140 cm in WPP 573 in the Indian Ocean. The first Size caught (Lc) of yellowfin tuna at the Cilacap Oceanic Fisheries Port was 137.5 cm, using longline gear (Azizi *et al*. 2020). Research conducted by Haruna *et al*. (2018) found that the first Size caught (Lc) was 94.54 cm in the Banda Sea.

These striking differences are likely not simply due to differences in fishing gear, but rather reflect differing natural population structures. The Makassar Strait, with its nutrient-rich Arlindo current, serves as a giant *nursery ground* for tropical tuna in the Indo-Pacific region (Kantun *et al*. 2018). Juvenile concentrations in this region are naturally higher than in the open ocean waters south of Java. Therefore, applying the same fishing standards as in oceanic areas may be unrealistic and instead requires a more stringent protection approach. This region acts as a "source" *for* tuna populations in the surrounding WPP. Management failures in the Makassar Strait could have a detrimental *ripple effect* on tuna fisheries in the Flores Sea (WPP 714) and the Indian Ocean, hindering the supply of adult stocks migrating out of the strait (Haruna *et al*. 2018).

Length at First Capture (Lc) Relative to Length at First Maturity (Lm)

The most crucial indicator of fisheries stock health is the ratio between catch size (Lc) and gonad maturity size (Lm). Scientific consensus from various studies in WPP 713 and WPP 714 places yellowfin tuna Lm in the range of 94.5 cm to 118.8 cm FL (Darondo *et al*. 2020; Haruna *et al*. 2018; Kantun *et al*. 2018; Kantun & Mallawa 2016; Syamsinar 2023). Because Lm was not estimated from the samples of this study, these published values are applied here as a reference range rather than as a single fixed threshold, and the ratios below are therefore expressed as intervals.

Comparing the findings of this study with those thresholds paints a bleak picture:

1. Purse Seine (Lc 23.0 cm vs Lm 94.5-118.8 cm):

   The Lc value for purse seine is only about 19-24% of the reported length at first maturity. This is an extreme deviation. Biologically, this means that purse-seine fleets harvest "baby" tuna years before they are capable of reproducing. Research by Darondo *et al*. (2020) found an Lc of 47.32 cm for purse seine fishing gear. According to Darondo *et al*. (2020), the first Size caught (Lc) for purse seine is smaller than the first Size at gonadal maturity (Lm). The impact of this practice is a loss of growth potential (very low yield per recruit) and the termination of the life cycle before reproductive contributions occur. In the long term, this directly erodes Spawning Stock Biomass (SSB) and pushes stocks towards recruitment overfishing (Burhanis *et al.* 2017).

2. Handline (Lc 63.9 cm vs Lm 94.5-118.8 cm):

   Despite its improvement, the Lc of handlines only reaches about 54-68% of the reported length at first maturity. The dominance of catches in the 55 cm size indicates that handlines in the Makassar Strait still rely heavily on juvenile stocks. Fish at this Size are in their fastest somatic growth phase. Catching them at this stage, although better than the early juvenile stage, remains a form of growth overfishing that is detrimental both economically (loss of weight/biomass added value) and biologically. This comparison confirms that **both fishing gears** currently operating in the Makassar Strait contribute to *overfishing*, with *purse seines* being the primary contributor to early juvenile mortality and handlines contributing to juvenile mortality.

Implications for Policy and *Harvest Strategy*

These findings have direct implications for the implementation of the Tropical Tuna *Harvest Strategy* (HS) for WPP 713, 714, and 715 as mandated by Ministerial Decree No. 121/2021. HS has established *a Limit Reference Point* (LRP) to maintain spawning biomass above critical levels. The dominance of juvenile catches by *purse seine fishing* is the greatest threat to achieving this LRP target. Current regulations, such as Ministerial Regulation No. 26/2020, focus more on protecting spawning grounds in WPP 714 (Banda Sea) (Pet *et al.* 2022). However, these data suggest that protecting nursery grounds *in* WPP 713 (Makassar Strait) is equally crucial. Without controlling juvenile mortality in the Makassar Strait, broodstock conservation efforts in the Banda Sea may not be sufficient to recover stocks.

Mitigation measures that should be integrated into *Harvest Control Rules* (HCR) include:

1. **Quota-Based FAD Management:** Reducing the density of FADs in the Makassar Strait is an absolute step toward breaking up juvenile aggregations and reducing the efficiency of *purse seine fishing* for small fish.
2. **Technical Selectivity:** For *Purse Seine*: Experimentation and mandatory use of larger mesh sizes or sorting grids *that* allow juvenile tuna to escape while retaining other small pelagic targets. For Hand Line: Regulation of hook size*.* Research by Hoshino *et al*. (2020) and Kurnia *et al*. (2015) demonstrated that increasing hook size (e.g., from no. 9 to no. 6 or 7) effectively shifts the selectivity curve to the right, avoiding small fish catches without significantly reducing large fish catches (Hoshino *et al*. 2020; Kurnia *et al.* 2015).
3. **Economic Incentives: Implementing minimum** *trading* size standards to cut the market demand for "baby tuna." As long as the market accepts 20 cm tuna, fishermen will continue to catch them.

CONCLUSION

The capture of yellowfin tuna (*Thunnus albacares*) in the Makassar Strait reveals striking differences in selectivity between FAD-based purse seine gear and handline gear. The catches of the purse seine were entirely dominated by early juveniles (FL 14.0–49.5 cm, mode: 22.5 cm; Lc = 23.0cm, whereas the handline catches spanned the FL range of 15.5–165.0 cm (mode: 55.0 cm; Lc = 63.9cm). Since both Lc values are below the first maturity length (Lm = 94.5-118.8 cm), purse seine fishing risks causing overharvesting at the recruitment stage (Lc approx 22% of Lm) due to mass capture of juveniles around FADs, whereas handline fishing causes overfishing of the growth class (Lc approx 60% of Lm) by targeting juvenile stocks. Given the critical role of the Makassar Strait as a nursery area, the implementation of the Harvesting Strategy in FMA 713 through strict regulations on purse seine mesh size, FAD density, and handline hook size is urgently needed to ensure the sustainability of the stock.

SUGGESTION

Based on the above conclusions, urgent policy recommendations to be considered within the framework of the national *Harvest Strategy* are:

1. **Partial Moratorium or Seasonal Closure:** Consider closing fish-aggregating device fishing areas (*time-area closure*) in the Makassar Strait during the peak juvenile recruitment season (usually detected during the transition season).
2. **Revitalisation of Fishing Gear Regulations:** Require the use of minimum hook sizes (e.g., number 7 and above) for handline fishing fleets and establish strict juvenile *bycatch limits for purse-seine fleets*.
3. **Data Strengthening:** Conduct further research on post-release mortality *if* juveniles are returned to the sea, to assess the effectiveness of *catch-and-release policies* or juvenile landing quota restrictions.

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