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Comparison of the catch of two fishing technologies for yellowfin tuna (*Thunnus albacares* Bonnaterre 1788) in Bone Bay waters, South Sulawesi Indonesia

Comparison of the catch of two fishing technologies for yellowfin tuna (*Thunnus albacares* Bonnaterre 1788) in Bone Bay waters, South Sulawesi Indonesia

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Abstract. Yellowfin tuna is one of the important pelagic fishery commodities in the Bone Bay waters, exploited using hand lines and pole and line. This study aims to compare the size structure, the number of the cohort, compositions of catch according to fish maturity stage and percentage of catch suitable size. Fish length data were collected from January to August 2020. Size structure and age groups were analyzed using the Bhattacharya method. The gonad maturity stage observed morphologically using the Schaefer and Orange method, the percentage of catch suitable size using the Mallawa method. The hand line catches measuring 39 to 111 cm, dominant size 49 to 57 cm and 66 to 73 cm, consisting of three age groups and dominated by young. The pole and line catch measuring 34 to 87 cm, dominant size 35 to 37 cm, consisting of three age groups and dominated by the young fish. The percentage of catch suitable size in both fishing technologies is low.

1. Introduction

Indonesian waters have high biodiversity or species richness, namely more than 0.46 to 0.70 on a scale of 0.0 – 1.0 [1]. Indonesian waters consist of 11 Indonesian Fishery Management Areas (IFMA) and one of them is IFMA 713, which includes the waters of the Makassar Strait, Bone Bay, Flores Sea and Bali Sea. The waters of IFMA 713, especially the waters of the Bone Bay, have the potential for large pelagic fish resources and one of them is yellowfin tuna [2,3]. The Bone Bay waters have the potential for small pelagic fish such as anchovies, sardine, mackerel, thus encouraging large pelagic fish such as skipjack and tuna to use these waters as a feeding area or nursery area and after reaching adult size migrate to spawning areas [4]. During its existence in the nursery area, the yellowfin tuna was caught by fishermen using the hand line, trolling line, drift surface gill net, pole and line and boat lift net, and the most catches were obtained from the hand line and pole and line [5]. Yellowfin tuna is a cosmopolitan species distributed mainly in the tropical and subtropical ocean waters of three major oceans where it forms large schools. This fish caught using purse seine free school, longline, handline, gill net, trolling line and others gear net. The differences in the fishing gear used can lead to differences in size structure, fish maturity level, and the percentage of eligible fish to be caught in the catch of fishers [4,5,8]. Besides, the use of FAD can

difference in the size structure of the fish caught in different fishing gears and the same fishing gear [5,6,7,9,10,11]. Even though based on statistical data, yellowfin tuna production has continued to increase in the last twenty years, and this fish has been declared to have experienced overfishing or object to overfishing [6,7], so a management policy is urgently needed. Information that is very important to be used as guidance in determining the yellowfin tuna management policy is related to biological aspects, population dynamics and the condition of these fish stocks. Several studies in Indonesian waters reported that the size structure of yellowfin tuna varies according to fishing gear and fishing ground [12,13,14,15,16,17,18,19], and outside Indonesian waters [20,21,22,23,24]. The results also show that the level of gonad maturity according to length of yellowfin tuna varies according to fishing technology and fishing area [12,13,19,22,25,26]. Based on the above description, it is essential to conduct research on yellowfin tuna, especially regarding the size structure, maturity level and the percentage of the suitable size to catch according to fishing gear.

The study aims to compare the size structure, age group, maturity level and the percentage of the suitable size to catch of yellowfin tuna between a hand line and pole and line catches to compare size structure, age group, maturity level and the percentage of the suitable size to catch of yellowfin tuna between the pole and line-free school and associate school. The results of the research can be used as information in determining the management policy of yellowfin tuna in the waters of Bone Bay and can serve as a reference for other researchers.

2. Material and Method

2.1. Time and place

This study was conducted from January to August 2020 in the Bone Bay waters. The area of the research was presented in Figure 1.

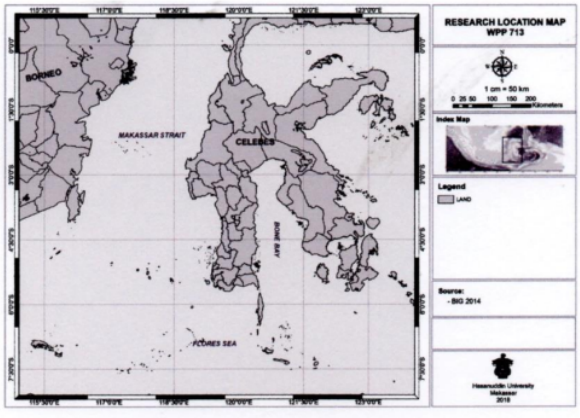

Figure 1. Research location

2.2. Materials and equipment

The materials and equipment used in this study were yellowfin tuna, traditional handline, and pole and line, traditional FADs ("*rumpon*"), digital camera, measuring board, computer and software such as SPPS, word excel, FISAT II.

2.3 Data collection

Fish length data (FL, cm) were collected on fishing vessels and fish landing places weekly in each study area using a stratified random sampling method. During the research, 2,638 specimens were measured that represent the catch of hand line and pole and line. In this study also carried out separate measurements of yellowfin tuna caught by pole and line-free school, and pole and line-associated school.

2.4. Data analysis

The structure of the size and number of age groups of yellowfin tuna caught by hand line and pole and line was analyzed using a Bhattacharya method [28,29], growth parameters by Ford and Walford method [29]. To differentiate the size distribution of yellowfin tuna between a hand line and pole and line catches, and pole and line-free school and pole and line-associated school, the Median Test [30] was used in the following equation,

$$T = \frac{(A/n) - (B/n)}{\sqrt{\hat{p}(1-\hat{p})[(1/n_1) + (1/n_2)]}}$$

Where A = number of samples that higher than the combined median, B = number of samples that lower than the combined median, n_1 = number of samples one, n_2 = number of samples two

$$n = n_1 + n_2 \text{ and } \hat{p} = (A+B)/n$$

Yellowfin maturity levels were analyzed using the gonad maturity stage (GMS) of these fish. Gonad maturity stages were analyzed using the morphological approach, according to ICCAT [24] as presented in Table 1.

Table 1. Maturity stage classification for visual examination of gonads for large pelagic

Stage	Criteria	
	Males	Females
I	Gonads small ribbon-like, not possible to determine sex by gross examination	Gonads small ribbon-like, not possible to determine sex by gross examination
I	Immature; testes extremely thin, flattened and ribbon-like, but sex determinable by gross examination	Immature; gonads elongated, slender, but sex determinable by gross examination
II	Enlarged testes, triangular in cross-section, no milt in the central canal	Early maturing; gonads enlarged but individual ova not visible to the naked eye
III	Maturing; milt flows freely if testes pinched or pressed	Late maturing; gonads enlarged, individual ova visible to the naked eye
IV	Ripe; testes large, milt flows freely From testes	Ripe; ovary greatly enlarged, ova translucent, easily dislodged from follicles or loose in the lumen of the ovary
V	Spent; testes flabby, bloodshot, surface dull red, little or no milt in the central canal	Spawned; includes recently spawned and post-spawning fish, mature ova remnants in various stages of resorption, and mature ova remnants about 1.0 mm in diameter

Furthermore, the catch composition according to the maturity level of yellowfin tuna for each technology used criteria, namely fish that have GMS I and II are classified as young fish, GMS III fish are classified pre-adult fish, and GMS IV and V fish are classified adult fish.

In this study, it is stated that fish eligible to be caught is fish that has spawned or has gonad maturity stages IV and V. The percentage of fish is eligible to catch using the equation [5] as follows:

$$S_E = (Ns/N_T) \times 100\%$$

Where : S_E = percentage of eligible size to catch
N_S = number of fish in catch predictive already spawned
N_S = number of fish in catches

3. Result and Discussion

3.1 Results

3.1.1 Comparison of the size structure of the hand line and pole and line caught.

The measurement result that the handline catch was measuring 39 to 111 cm, dominant Size 49 to 57 cm and 66 to 73 cm, average length 62.7859±14.58 cm while the pole and line caught measuring 34 to 87 cm and dominant size 35 to 37 cm, and average length 48.9021±15.45 cm (Figure 2). The results of the median test analysis showed that the size distribution of yellowfin tuna on the hand line and pole and line was significantly different (T 29.3513> T table 3.8415, $p \geq 0.05$).

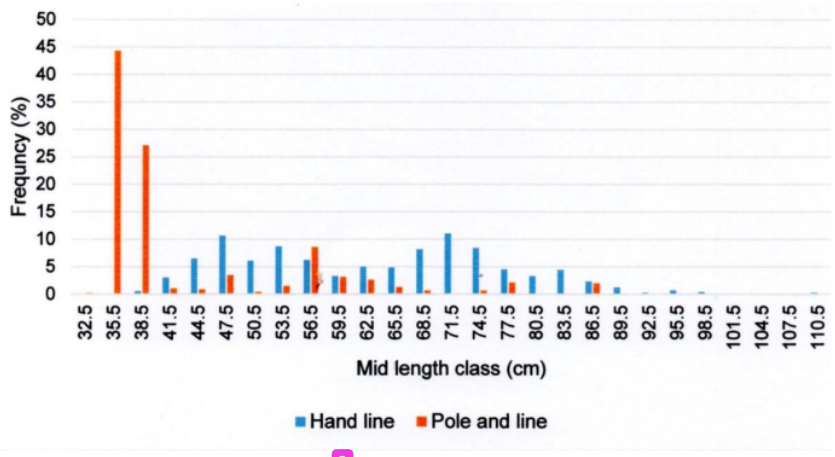

Figure 2. Size structure of yellowfin tuna caught by hand line and pole and line in Bone Bay

3.1.2. Comparison of the size structure of pole and line-free school and associated school.

The pole and line-associated school measuring 32 cm to 57 cm, dominant size 35 cm – 37 cm and average length 36.9921 ± 5.2367 cm while the pole and line-free school measuring 34 cm to 87 cm, dominant length 51 cm to 66 cm and average length 60.8121 ± 6.7189 cm (Figure 3). The results of the median

test analysis showed that the size distribution of yellowfin tuna caught by pole and line-free school and pole and line-associated school was significantly different (T 69.7042> T table 3.8415, $p \geq 0.05$)

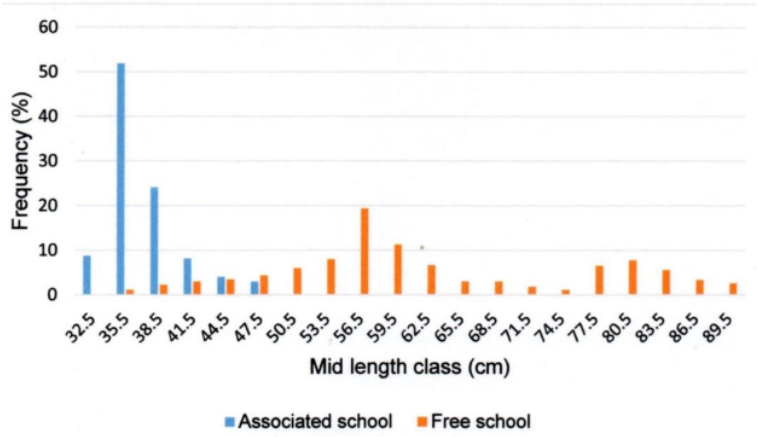

Figure 3. Size structure of yellowfin tuna caught by pole and line-associated and free school in Bone Bay

3.1.3. Comparison of age groups of hand line and pole and line catches.

The results of the analysis using FISAT software can determine the number of age groups caught by handline (Figure 4), and pole and line (Figure 5) in the Bone Bay waters. Based on this figure, it can be explained that the catch of the two fishing gear consists of three age groups, but from different age groups (Table 2).

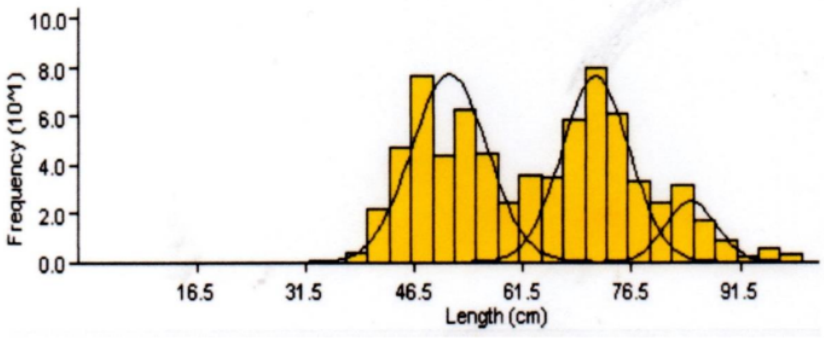

Figure 4. The age group of yellowfin tuna caught by handline in Bone Bay waters

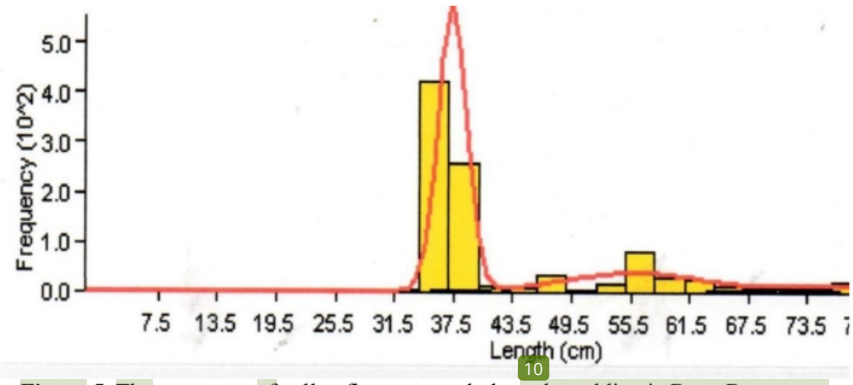

Figure 5. The age group of yellowfin tuna caught by pole and line in Bone Bay waters

Table 2. Age group and average length of yellowfin tuna according to age group and fishing gear

Ages groups	Hand Line			Pole and Line		
	Mean Length (FL cm)	SD	Population	Mean Length (FL cm)	SD	Population
1	-	-	-	37.37	±1.45	709
2	51.31	±5.20	336	55.91	±7.10	229
3	71.50	±4.55	298	78.56	±5.78	58
4	84.89	±3.51	72	-	-	-

3.1.4. Comparison of age groups in catches of pole and line-associated and free school.
The results of the analysis using FISAT II explained that the number of age groups of yellowfin tuna in pole and line-associated and free school was different. The catch of pole and line-free school consists of three age groups (Figure 6) while pole and line-associated school consist of only one age group (Figure 7).

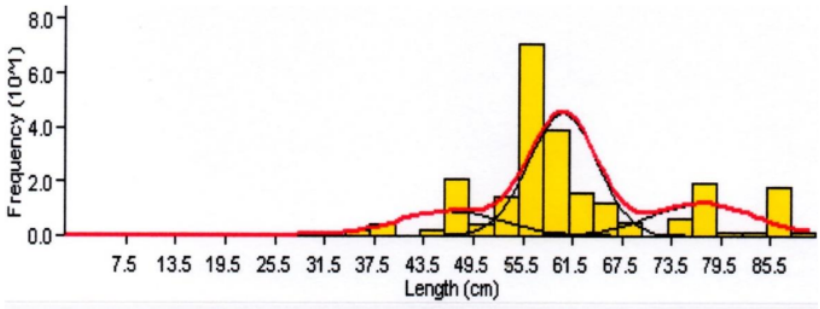

Figure 6. The age group of yellowfin tuna caught by pole and line-associated school in Bone Bay waters

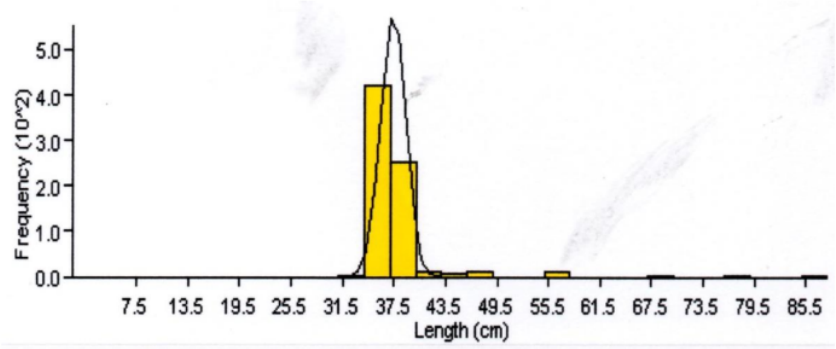

Figure 7. Age group of yellowfin tuna caught by pole and line free school in Bone Bay waters

The number of age groups according to fishing technologies and average length of yellowfin tuna according to age groups are presented in Table 3.

Table 3. Age group and average length of yellowfin tuna according to age group of pole and line catch

Age Group	Pole and Line Associated School			Pole and Line Free School		
	Mean Length (FL cm)	SD	Population	Mean Length (FL cm)	SD	Population
1	37.73	1.45	703	46.54	6.19	46
2	-	-	-	60.31	4.07	154
3	-	-	-	77.37	6.26	63

3.1.5. Comparison of catch composition based on the maturity level of yellowfin tuna.
Observation of yellowfin tuna gonad samples yellowfin tuna caught by handline explained that most of the yellowfin tuna observed were in gonad maturity stages I and II, and very few at GMS III and none had GMS IV or V. This situation occurs in pole and line catches, and even yellowfin tuna is not found in GMS III and above. These results indicate that yellowfin tuna caught both hand line and pole and line are young fish. The composition of the catch according to the maturity level of yellowfin tuna on hand and pole and line is presented in Figure 8. Observations of GMS yellowfin tuna in pole and line-associated and free school, also show the same thing. Pole and line-free school catch consisted of yellowfin tuna GMS I and II, while pole and line-associated school catches were all at GMS I. Comparison of catch composition based on the maturity level of yellowfin tuna between a hand line and pole and line, and between the pole and line-associated and free school is presented in Figure 8.

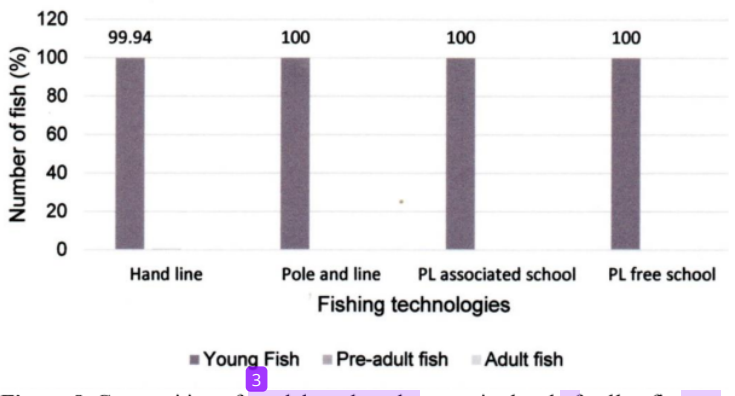

Figure 8. Composition of catch based on the maturity level of yellowfin tuna.

3.1.6. Comparison of the percentage of eligible fish to catch in catches.
Based on the size structure and maturity level of yellowfin tuna gonads, the catch both on the hand line and pole and line is biologically 100% unfit to catch or the percentage of eligible fish to catch is equal zero or very low.

3.2. Discussion
Yellowfin tuna caught in Bone Bay waters has a smaller average length and a narrow length range compared to yellowfin tuna caught in other Indonesian waters and outside Indonesian waters as presented in Table 4.

Table 4. Size structure of yellowfin tuna caught by types of fishing gears in several fishing grounds

Fishing Ground	Size Range (cm)	Dominant size (cm)	Average Size (cm)	Fishing Gear	References
Indian Ocean	94 – 178	-	136.00	Tuna Longline	[15]
	97 – 167	-	140.00		
Eastern Indian Ocean	54 – 162	140 - 150	136.00	-	[27]
Indian Ocean	112 – 160	-	141.50	Tuna long line	[13]
Banda Sea	88 – 178	-	134.71.	-	[14]
Oman Sea	44 – 156	68 – 117	82.00	Surface gill net	[20]
Eastern Atlantic Ocean	72.8 – 170.9M 76.4 – 166.2 F	-	-	Purse seine	[24]
Banda Sea	25 – 178	72 - 107	94.00	Hand line	[19]
Oman Sea	37 – 172	54 – 102	86.12	Drift gill net	[23]
Bengkulu waters, Indian Ocean	94 – 161	-	-	Handline – FAD	[17]
Bone Bay	32 – 111	35 – 35	55.84	Handline, pole and line	This study

These differences can be caused by the type of fishing gear used, oceanographic conditions, especially the depth of the waters, the use of FADs and the designation of waters by yellowfin tuna. Various types of large pelagic fish, including yellowfin tuna, use the Bone Bay waters as a rearing area and after reaching adult size migrate to the spawning ground such Indian Ocean, the west Pacific Ocean for spawning [4]. In addition, the size structure of yellowfin in the catch is also affected by season [18].

The difference in size structure between yellowfin tuna caught hand line, and yellowfin tuna caught pole and line is thought to be due to the FAD area as a fishing area having different depths. Generally, hand line uses deep-sea FADs while pole and line catch on shallow sea FADs. The size structure of tuna caught in FADs differs according to the depth of the FAD location, where the size of yellowfin tuna caught in deep FADs is relatively larger than the yellowfin caught in shallow sea FADs [19,31].

The differences in the size structure of yellowfin tuna caught on pole and line inside and outside FADs were also reported to occur in other large pelagic fish in the waters of Bone Bay. This phenomenon is caused by; first, that small tuna finds it easy to get food in the FAD area. Second, in the waters of Bone Bay, FADs are generally installed in shallow waters so that the tuna that comes to FADs are small tuna. Third, the tuna caught by the pole and line in FADs are those that cluster together with skipjack tuna and have a length almost the same as the skipjack tuna [9]. The existence of young tuna in the FAD area is due to various reasons, namely, first, tuna use floating object primarily for protection from predators, second, as a source of food availability, third, as a meeting location, which is a meeting place to form larger groups [32]. The use of FADs can increase the number of small tuna in the catch of fishermen [11,32,33,34,35,36,37].

The low number of adult yellowfin tuna and fit to catch in the catch of hand line and pole and line fishermen in the waters of Bone Bay is also related to the function of the waters which are only as a rearing area for these fish and the installation of FADs in shallow waters. Yellowfin tuna reaches maturity in size 110 – 170 cm [13], 140 – 170 cm [27], 125 – 175 cm [24]. The low levels of adult yellowfin tuna in fishermen's catches are reported to occur in the waters of the Makassar Strait [38], in the waters of the Banda Sea [14], the waters of the Indian Ocean [13,15]. On the other hand, it is reported that more than 50% of yellowfin tuna caught in the waters of the eastern Indian Ocean are adult fish [27].

4. Conclusion

The size structure of the yellowfin tuna caught by the hand line and pole line in the waters of Bone Bay is different, as are the pole and associated and free school catches. Yellowfin tuna caught in the waters of the Bone Bay has a relatively smaller size than other waters in Indonesia. Yellowfin tuna caught by hand line and pole and line each consisted of three age groups and came from different age groups. Yellowfin tuna caught by hand line and pole and line was dominated by young fish few pre-adult fish and no adult fish. Biologically, the percentage of eligible fish to be caught on both the hand-line and pole and line is low, where the phenomenon is caused by the use of FADs in both.

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