Comparison of handline tuna catches in Indian Ocean and Banda Sea waters

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Abstract. There are two essential landing sites for handline tuna in Indonesia: Palabuhanratu (in the Indian Ocean) and Kendari (in the Banda Sea). This paper analyzes handline catches from the Indian Ocean and Banda Sea waters as the main fishing ground. The catch composition of the handline tuna landed in Kendari is more varied than Palabuhanratu. Several species commonly caught are yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), bigeye tuna (*Thunnus obesus*) as a target species, and some billfish species as bycatch. Mean CPUE for handline tuna landed in Palabuhanratu is lower than Kendari. A significant difference is based on the monthly mean CPUE variation between Palabuhanratu and Kendari landing sites ($p < 0.001$). Handline catches in Palabuhanratu had a more comprehensive range of length sizes than Kendari, using a two-sample K-S test showed significant differences ($p < 0.001$). The fish size landed in Kendari is relatively smaller than Palabuhanratu. The average length of fish caught by handline is smaller than the length at first maturity (Lm) value in both landing sites. The use of large size hook for hand lines is recommended for catching tunas in this area.

1 Introduction

Tuna and tuna-like species are utilized by industrial and small-scale fisheries in Indonesia using several fishing gears such as longline, purse seine, handline, pole and line, gillnet, and troll line [1]. Tuna fishing activities by industrial-scale have been going on since the 1960s-1970s, along with the introduction of longline and purse seine [2]. The production of tuna fish resources in Indonesia in 2018 reached 670,000 tons, divided into tuna fisheries production in the Indian Ocean of 150.00 tons. The rest was produced in the waters of the Pacific Ocean [3, 4].

The handline tuna fishery in Indonesia has been developing for a long time and was only published in the 1990s [5]. Handline fisheries in Indonesia fall into small-scale fisheries with vessel sizes < 10 GT [6]. Tuna handline fisheries provide opportunities for economic sustainability through product certification and export markets [7], biological and social [8].

Based on the characteristics of the waters in Indonesia, tuna fishing activities are separated into the Indian Ocean (FMA 571-573) and the Pacific Ocean-which is divided into archipelagic waters (FMA 713-715) and ZEEI (FMA 716-715). The fishing gear for tuna fish

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resources is spread over several fishing areas, including the handline. Handline tuna landings were found in Kendari (Kendari Fishing Port and Sodohoa Fish Landing Site), which caught in the Banda Sea waters, and Palabuhanratu (Palabuhanratu Fishing Port), which caught in the Indian Ocean. This paper aims to analyze and compare the catch of handline tuna in these two areas, especially for catch composition, catch per unit effort (CPUE), and size of fish.

2 Methods

Enumerators collected daily landing data in Kendari (Kendari Fishing Port and Sodohoa Fish Landing Site) and Palabuhanratu (Palabuhanratu Fishing Port) (Fig. 1**).** The enumerators recorded tuna handline landing information, which consisted of the vessel's name, the number of days of operation, the composition and size of the catch. The catch composition is the proportion of the tuna catch species to the total catch. The catch rate of handline tuna was calculated by dividing catch and effort data, namely catch per unit effort (CPUE). Catch (in kg) was the number of fish of the target species (*Thunnus obesus*/Bigeye tuna/BET, *Katsuwonus pelamis*/Skipjack tuna/SKJ, and *Thunnus albacares*/Yellowfin tuna/YFT). Whilst effort divided into the number of trips and fishing day. The CPUE index was obtained by comparing the monthly CPUE with the mean annual CPUE of each target species. The fish measurement was carried out on the three tuna species (BET, SKJ, YFT) by measuring fork length (FL).

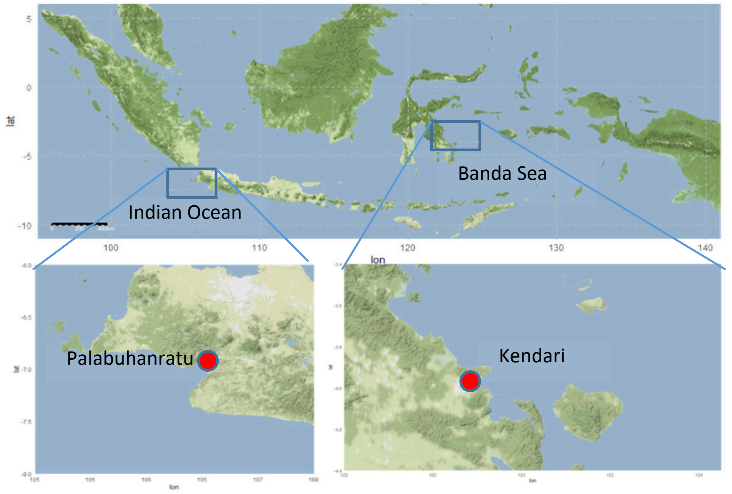

Fig. 1. Map showing landing site of hand line tuna in Kendari (Banda Sea) (3°59'02.3"S 122°34'21.9"E) and Palabuhanratu (Indian Ocean) (6°59'15.9"S 106°32'38.3"E).

T-test was used to identify the differences CPUE of handline tuna landed in Kendari and Palabuhanratu. ANOVA test used to distinct of CPUE index that represents the two areas' monthly fishing season. A Kolmogorov–Smirnov test was later conducted to compare the size distribution of fish caught by handline fishing gear from the two landing sites.

3 Results

3.1 Catch composition

In 2014-2016, twelve fish species were identified as handline catch landed in Kendari and seven fish species in Palabuhanratu. The catch composition in Kendari is more varied than Palabuhanratu. Yellowfin tuna (*Thunnus albacares*) most catch of the handline tuna in Kendari waters (47.8%), followed by skipjack tuna, *Katsuwonus pelamis* (39.81%), and bigeye tuna, *Thunnus obesus* (6.37%), with some bycatch species, which are little tuna *Auxis thazard* (2.69%), marlin *Makaira indica* (1.28%) and dolphin fish *Coryphaena hippurus* (0.18%). However, in Palabuhanratu dominated by yellowfin tuna *T. albacares* (48.58%), skipjack *K. pelamis* (32.97%), bigeye tuna *T. obesus* (6.12%), with the bycatch of sailfish *Tetrapturus audax* (9.8%) and dolphin fish *C. hippurus* (2.19%) (Fig. 2).

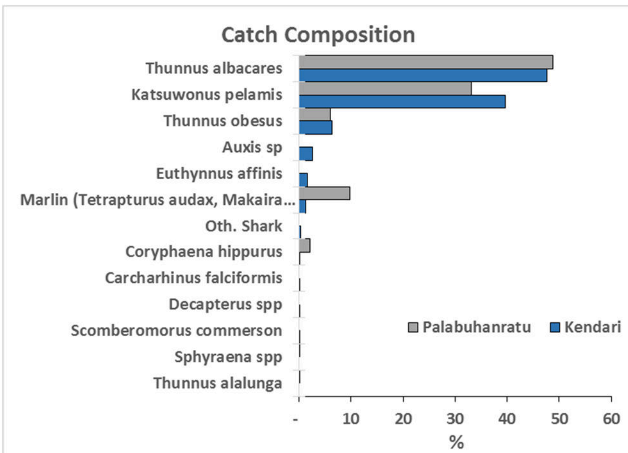

Fig. 2. Catch composition of handline tuna catches landed in Kendari and Palabuhanratu.

3.2 Catch rate

The total handline landed in Kendari in 2014-2016 was recorded 1,733 trips, and in Palabuhanratu was 4,373 trips. Mean catch rate for handline tuna in Kendari for bigeye tuna (BET) was 127 (±5,92) kg/trip and 17.1 (±0.77) kg/day, skipjack tuna (SKJ) was 404 (±8.83) kg/trip and 56.9 (±1.19) kg/day and yellowfin tuna (YFT) was 506 (±8.95) kg/trip and 73.4 (±1.27) kg/day. In Palabuhanratu mean catch rete for BET was 40,4 (±1,7) kg/trip and 5.29 (±0.22) kg/day, SKJ was 190 (±5.48) kg/trip and 25.2 (±0.71) kg/day and YFT was 275 (±5.57) kg/trip and 37 (±0.77) kg/day. The mean catch rate in Palabuhanratu was lower than in Kendari. There is a significant difference based on the monthly mean CPUE variation between Palabuhanratu and Kendari ($p < 0.001$) (Fig. 3, Table 1).

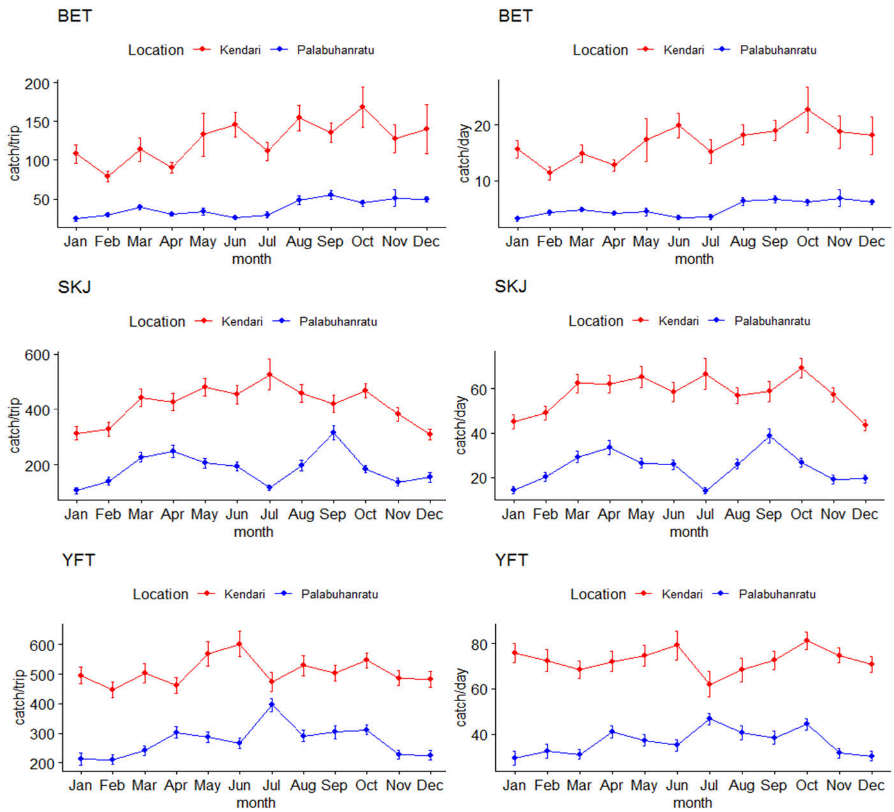

Fig. 3. Mean catch rate of Bigeye tuna (BET), Skipjack tuna (SKJ), and Yellowfin tuna (YFT), expressed as catch per trip (left) and catch per day (right), of Handline tuna in Kendari (n= 1733) and Palabuhanratu (n= 4373) (vertical bar are mean SE.).

Table 1. t-test result of HL catch per unit effort in Kendari and Palabuhanratu.

CPUE	Species	Result
catch.trip^{-1}	BET	t = 19.343, df = 1274, p-value < 2.2e-16***
	SKJ	t = 21.458, df = 1626, p-value < 2.2e-16***
	YFT	t = 22.659, df = 1675, p-value < 2.2e-16***
catch.day^{-1}	BET	t = 20.429, df = 1262, p-value < 2.2e-16***
	SKJ	t = 24.197, df = 1610, p-value < 2.2e-16***
	YFT	t = 25.735, df = 1658, p-value < 2.2e-16***

*** *p< 0.001*

Based on the fishing resource index that describes the fishing season, it can be seen that the BET fishing season between Palabuhanratu and Kendari did not differ (p > 0.5). The peak fishing season occurs from August to December, and the low season occurs from January to May. The index shows different things for SKJ, which are significantly different (p < 0.001). The peak of SKJ fishing season in Palabuhanratu occurred in April and September, while in Kendari, it was relatively consistent from March-October. The index for YFT resources tends to be different, although not significant (p<0.5). Peak fishing season occurs in July and October in Palabuhanratu and June and October in Kendari.

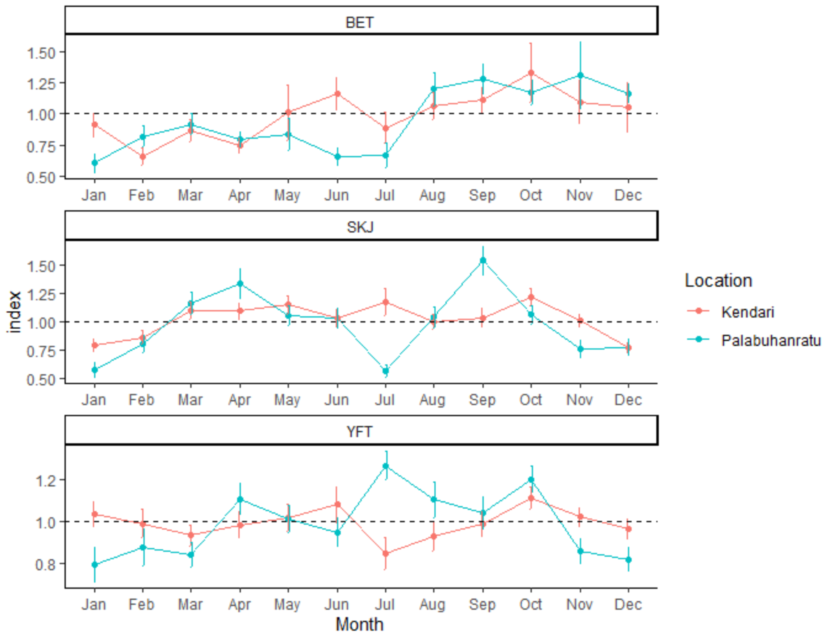

Fig. 4. CPUE Index represents seasonal fishing for BET, SKJ, and YFT in Kendari and Palabuhanratu (vertical bar mean SE).

Table 2. ANOVA test result of monthly index CPUE handline of BET, SKJ, and YFT in Kendari and Palabuhanratu.

Species	Result
BET	F value = 0.618, p-value = 0.815
SKJ	F value = 3.091, p-value = 0.000399***
YFT	F value = 2.246, p-value = 0.0105*

****p<0.001, * P<0.05*

3.3 Size composition

During the research periods, a total of 21,464 fish landed were recorded. There were 14,946 fish (SKJ = 7,842, YFT = 5,079, BET= 2,043) from Palabuhanratu, and 6,500 fish (SKJ = 3,400, YFT = 2,749, BET = 351) from Kendari. YFT in Palabuhanratu were distributed from 10-163 cmFL in length, with an average of about 63.3 cmFL, and mode 40 cmFL. Meanwhile, YFT in Kendari were distributed around 12-58 cmFL, with an average of approximately 34.4 cmFL, and mode 36 cmFL. Meanwhile, the size of SKJ in Palabuhanratu was about 24-60 cmFL, with mode 40 cmFL and an average of 41 cmFL. The SKJ that landed in Kendari was around 20-48 cmFL, with an average of 32.2 cmFL, and mode 30 cmFL, relatively more minor than in Palabuhanratu. Size distribution of BET in Palabuhanratu and Kendari is quite the same in mode and average size. BET size that landed in Palabuhanratu has intervals around 22-110 cmFL, with mode 40 cmFL and average 42.8 cmFL, whilst in Kendari was around 25-58 cmFL with 40 cmFL mode 40.6 cmFL average.

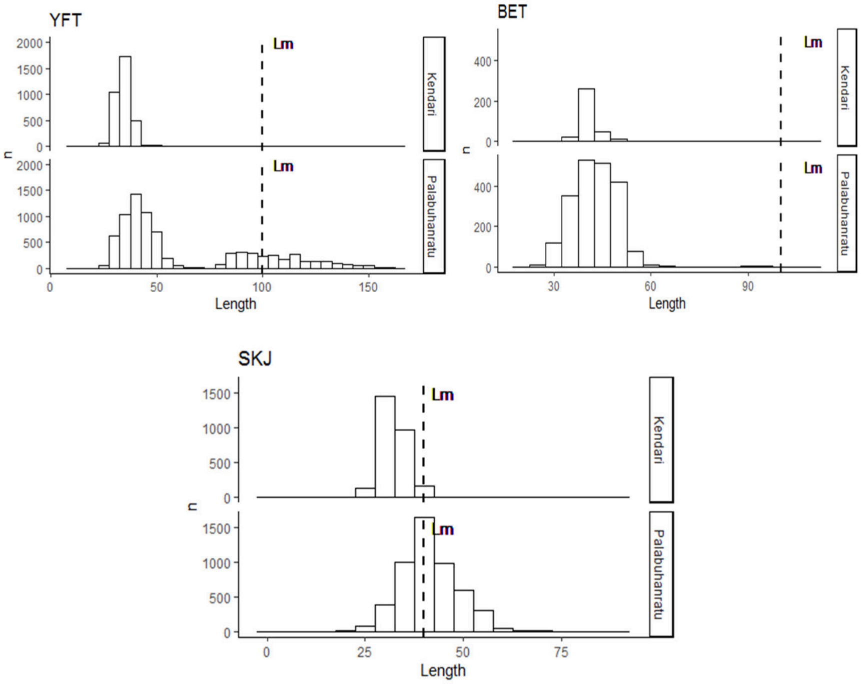

Fig. 5. Size frequency of YFT, BET, and SKJ caught by HL in Kendari and Palabuhanratu. Dash line represented the biomass-weighted mean length at first maturity (Lm).

Size distribution of the handline's catches from Palabuhanratu had a wider range than in Kendari. The result of the two-sample K-S test showed there was a significant difference for the three target species (D YFT = 0.66137, D BET= 0.31539, D SKJ = 0.65198, $p < 0.001$) (Fig 5. Table 3). The graph in Fig 5 showed that almost all the fish (70% WFT, 40% SKJ & 100% BET) landed in Palabuhanratu have a small size that is less than the size of the first maturity (Lm). Meanwhile, in Kendari, almost 100% of fish landed are below the length of the first maturity (Lm). The length of the first maturity of YFT tuna is ranged between 94.6-100.6 cmFL in Banda Sea, Tomini Bay, Eastern Indian Ocean, and Pacific Ocean [9-12]. The length at first maturity of BET tuna in the Banda Sea is 133.5 cmFL for males and 146.1 cmFL for females, in the Indian Ocean in range 91-170 cmFL, in the tropical waters Pacific Ocean is 107.8 cmFL [13-15]. Lm value for SKJ in Kendari is 47.73 cmFL, and in the Indian Ocean is range 39.92-40.2 cmFL [16-18].

Table 3. Two-sample Kolmogorov-Smirnov test result of size distribution of YFT, BET, & SKJ in Kendari and Palabuhanratu.

Species	Result
YFT	D = 0.66137, p-value < 2.2e-16***
BET	D = 0.31539, p-value < 2.2e-16***
SKJ	D = 0.65198, p-value < 2.2e-16***

*** *p< 0.001*

4 Discussion

Catch composition of hand line fishing landed in Kendari has more variety, but some species were found in Kendari and Palabuhanratu, particularly target species and billfish. That common thing also occurs in handline fisheries in Sendang Biru (Eastern part of the Indian Ocean), where billfish contributed around 5% of the total catch [19]. Billfish also contributed as the second-most fish caught by longline fisheries [20]. Several fish categorized as billfish are bycatch that has a substantial economic value other than the target species.

CPUE of handline in Kendari is higher than Palabuhanratu that several factors might cause. The total catch of tuna in FMA 713 & 715 (Indonesian Archipelagic Waters, IAW) has a very high catch, estimated at about 398,000 tons in 2018, greater than FMA 572 and 573 (Indian Ocean), only 151,000 tons [3,4]. The Banda Sea, which in FMA 715, has been one of the potential tuna fishing grounds since the 1970s [2]. Fishing activity in the Banda Sea is only granted for Indonesian fishing vessels because of its location, which is Indonesia's territorial waters. Meanwhile, tuna in the Indian Ocean were managed by Regional Fisheries Management Organization (RFMO) – IOTC, where IOTCs members carry out the utilization. However, the size composition of tuna caught in the Banda Sea is smaller than in the Indian Ocean. It cannot be used as an indicator of the number of juvenile fish caught in the waters of the Banda Sea, which is the spawning ground area for tuna fisheries resources. Of course, it must be with other supporting data, such as the abundance of tuna larvae.

The size of the SKJ, YFT, and BET tuna caught by handline, which landed in Kendari, has not yet reached the first stage of gonadal maturity. In Palabuhanratu, a small proportion of YFT and half SKJ have experienced gonadal maturity, while BET is still below the value at first gonadal maturity. This condition could be caused by using several types of hook and line gear and Fish Aggregating Devices (FADs) by fishers who catch tuna. More than four fishing gears are operated with different sizes in one handline fishing unit that fish in FADs [21, 22]. The operation of Purse Seine vessels in FADs produces more undersized and juvenile tuna than Purse Seine that catches free school tuna [23]. Likewise, the average tuna caught by handline is still below the length of the first capture (Lm) [21, 24].

One of the management efforts that can be done is to manage catch selectivity for all fishing gear. Selectivity is defined as the ability of each method or type of fishing gear to capture fish in a certain fraction or part of the population by grouping them based on species, age, size, or behavior of certain fish and removing others [25]. Knowledge of fishing selectivity can be used in fisheries management, primarily regulating the size of the nets and hooks of a fishing vessel to provide the minimum size of fish that can be caught [26]. One of the efforts in fisheries management is to reduce juvenile fish resources that have less than the size at the first maturity of the gonads [27]. Handline operated in FADs is categorized as fishing gear with moderate selectivity compared to Purse Seine [25]. Tuna fisheries management in the Indian Ocean will refer to RFMOs' regulation, IOTC's resolutions, and CMMs. Meanwhile, the Indonesian Government manages tuna fisheries in the Banda Sea by developing a harvest strategy in Indonesian waters, including open-close season and management of FADs.

5 Conclusion

The catch composition caught by handline landed in Kendari is more varied than that in Palabuhanratu. However, they have the same species composition, especially tuna as the target species and billfish as the bycatch caught by handline landed in both fish landing sites. The CPUE of tuna caught by handline landed in Kendari is higher than in Palabuhanratu's CPUE. The size of the tuna landed in Kendari is smaller than the Palabuhanratu catch. The average length of tuna caught in these two areas is smaller size compared to the first maturity length (Lm), excepted for skipjack landed in Palabuhanratu. This condition could be an indication of high fishing pressure on tuna fish resources in both fishing areas.

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7 Statement

Main contributors this paper are all authors. The authors have equal contributions to this paper.

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