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Comparison of Catches of Skipjack Tuna *(Katsuwonus pelamis* Linnaeus 1758) Purse Seines Inside and Outside of the FADs Areas

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ABSTRACT

Skipjack tuna is a potential fish resource in the Makassar Strait, Bone Bay, and the Flores Sea waters, Indonesia. This fish is captured by fishermen using many kinds of fishing gear, and the most widely used is purse seine. The study was conducted from January to December 2018, aimed to compare the size structure of skipjack, productivity, and by-catch of purse seine inside and outside of Fish Aggregation Devices (FADs) areas. Fish length (cm, FL), annual production and trips data were collected from 10 ship owners in each fishing area, The main catch and by-catch weight data were obtained through direct observation of 30 trips each for 10 units, both of purse seines inside and outside of FADs areas in each study area. Comparative analysis of the catches of purse seines inside and outside of FADs areas included size structures using the Median Test (T test), productivity and by-catch using Mann-Whitney Test (T test). The results of the study explained that purse seiners inside FADs areas could increase business productivity, but caused an increase in small-sized skipjack and by-catch while purse seines outside of FADs areas caught less small size skipjack, low by-catch but low productivity.

Keywords: By-catch, FAD, productivity, size structure, skipjack purse seiner

INTRODUCTION

Indonesia divides its sea waters into eleven Fisheries Management Regions, and one of them was Indonesian Fisheries Management Region 713 (WPP RI 713). The WPP RI 713 consists of the waters of the Bone Bay, Makassar Strait and the Flores Sea, which are directly adjacent to the Indian Ocean

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waters. The WPP RI 713 waters have high potential for big pelagic fish, especially the skipjack tuna. These fishes are exploited by fishermen using several types of fishing gear including drift surface gill net, purse seine, pole and line, trolling line, hand line, vertical long line, traditional seine net, and boat lift net. Purse seines are most widely used by fishermen, where they operate both inside and outside of the Fish Aggregation Devices (FADs) areas. The operation of skipjack purse seines inside of the FADs areas has positive and negative impacts. The positive impacts include improving business performance, increase catch per unit effort and fishing efficiency, and reduction fishing cost (Menard et al., 2000; Beverly et al., 2012; Dagorn et al., 2012; Davies et al., 2014; Yusfiandayani et al., 2015). In terms of negative impacts, such operation of purse seine may cause tuna fish stocks to be less healthy. Besides, it may also mislead tunas to make an inappropriate habitat selection, the dominant small size tunas in the catch, recruitment overfishing occurrence, changes in school movement pattern, catches of juvenile tunas (Hallier & Gaertner, 2008; Morgan, 2011; Wang et al., 2012; Leroy et al., 2013; Susaniati, 2014; Scot & Lopez, 2014; Hare et al., 2015; Wilantara, 2016; Talakana et al., 2017; Murua et al., 2017). The negative impact on the environment such as disturbing delicate ecosystems, increases the amount of by-catch and discard catch (Amande et al., 2010; Beverly et al., 2012; Dagorn et al., 2013; Davies et al., 2014; Scott & Lopez, 2014; Murua et al., 2017).

Based on the description above, the question arises whether the operation of purse seines in the area of FADs in the waters of the Gulf of Bone, Makassar Strait, and the Flores Sea can increase productivity or catch per unit of effort, can lead to the capture of small size skipjack tuna and increase the number of by-catch.

This study aimed to compare the size structure of skipjack tuna, productivity, and by-catch of purse seines operated inside and outside of the FADs areas in the waters of Bone Bay, Makassar Strait and the Flores Sea. The results of the study are useful as baseline information in managing the skipjack fisheries in WPP RI 713 waters, and Indonesian waters specifically related to the use of the FADs in the skipjack purse seine fisheries.

MATERIALS AND METHODS

Time and Place

The study was conducted for one year, from January to December 2018 in the WPP RI 713 which included the waters of the Gulf of Bone, the Makassar Strait and the Flores Sea, South Sulawesi, Indonesia. The area of the research is presented in Figure 1.

Material and Equipment

The materials and equipment used in this study were skipjack, small purse seiners, traditional FADs ("*rumpon*"), digital camera, measuring board, digital weight, computer, and software.

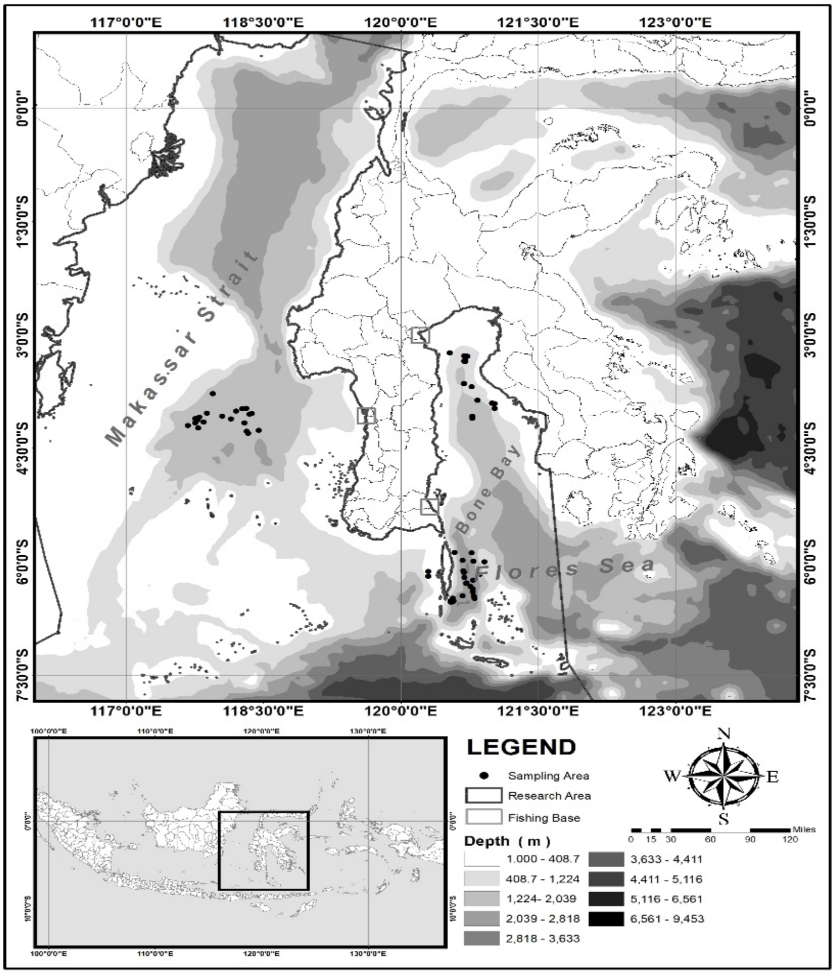

Figure 1. Study area (Bone Bay, Makassar Strait and Flores Sea waters)

Data Collection

Fish Length Data. Fish length data (FL, cm) were collected on fishing vessels and fish landing places two to three times per month in each study area using a stratified random method. In this study, skipjack length data were obtained from purse seines inside and the outside of the FADs areas of 3852 and 5554 specimens respectively in Bone Bay waters, 3362 and 3098 specimens respectively in Makassar Strait waters, and 4670 and 4469 specimens respectively in the Flores Sea waters.

Production and Number Trip Data. Annual production and the number of trips (one day trip) data were obtained from the daily logbooks of 10 skipjack fishing business owners in each study area.

Main Catch and By-catch Weight Data. The main catch and by-catch weight data were obtained through direct observation of 30 trips each for 10 units, both of purse seines inside and outside of the FADs areas in each study area. The weight of skipjacks tuna (main catch) and the by-catch were obtained by weighing directly on the sample ships. The kinds of the by-catch were known through identification at the genus and/or species level whenever possible.

Data Analysis

To achieve the research objectives, several methods of data analysis were used as follows:

Catch Size Structure. To know the smallest size, the largest, and the dominant size of skipjack caught in the purse seines inside and outsides of the FADs areas, a mapping between the length frequency (%) and the length of the middle class was carried out and displayed in the form of histograms. The mean length value and standard deviation (Sparre et al., 1989) was calculated using the following Equation 1a and 1b:

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{m} F(j)\bar{L}(j) \qquad (1a)$$

$$s^2 = \frac{1}{n}\sum_{j=1}^{m} F(j)\,(\bar{L}(j) - \bar{x})^2 \qquad (1b)$$

Where $\bar{L}(j)$ = midpoint class, $F(j)$ = frequency, $\bar{x}$ = mean length, s^2 = variance
$s = \sqrt{s^2}$

In order to know the difference in the size of skipjack fish caught inside and outside the FAD areas, the Median Test (Mangkuatmodjo, 2004) was used in the following Equation 2:

$$T = \frac{(A/n) - (B/n)}{\sqrt{\hat{p}(1-\hat{p})[(1/n_1) + (1/n_2)]}} \qquad (2)$$

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

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

Productivity. The productivity of purse seines inside and outside of the FADs areas was calculated using the following Equation 3 (Mallawa et al., 2017):

$$\mathrm{CPUE} = \frac{\mathrm{C}}{\mathrm{n}} \quad (3)$$

Where, CPUE = Catch per Unit Effort or productivity, C = Amounts of catch per per unit per year, n = Number of the trip of fishing unit per year

By-catch. The by catch was analyzed based on the appearance of fish which were classified as by-catch or not target species in both technologies. The percentage of by-catch (Mallawa et al., 2014) was calculated by the Equation 4 as follows:

$$B_C = \left[\frac{\mathrm{FN}}{\mathrm{FT+FN}}\right] \times 100\% \quad (4)$$

Where B_C = By-catch (%), FN = weight of non-target fish, FT = weight of target fish.

Then Mann Whitney Test was carried out to determine the difference in the productivity and by-catch of purse seines inside and outside of the FAD areas. The Mann Whitney test formula (Mangkuatmodjo, 2004) is as in Equation 5:

$$\mathrm{T} = \mathrm{S} - \frac{\mathrm{n(n+1)}}{2} \quad (5)$$

Where S = Number of ranks from population 1, n = total population sample 1 or sample 2.

RESULTS AND DISCUSSION

Fish Size Structure

The bar graph of middle class length provides an overview of the size of the smallest skipjack, the largest fish, the dominant fish in the catches of purse seine inside and outside of the FADs areas in the waters of Bone Bay, Makassar Strait and Flores Sea as shown in Figure 2, 3 and 4, and Table 1.

Based on Figures 2, 3 and 4 and Table 1, it can explain three things. First, skipjack caught by purse seines outside of the FADs areas had a wider size distribution than skipjack caught purse seines inside of the FADs areas, second, the skipjacks which was found in the catch of purse seines outside of the FADs areas had a relatively larger size compared to

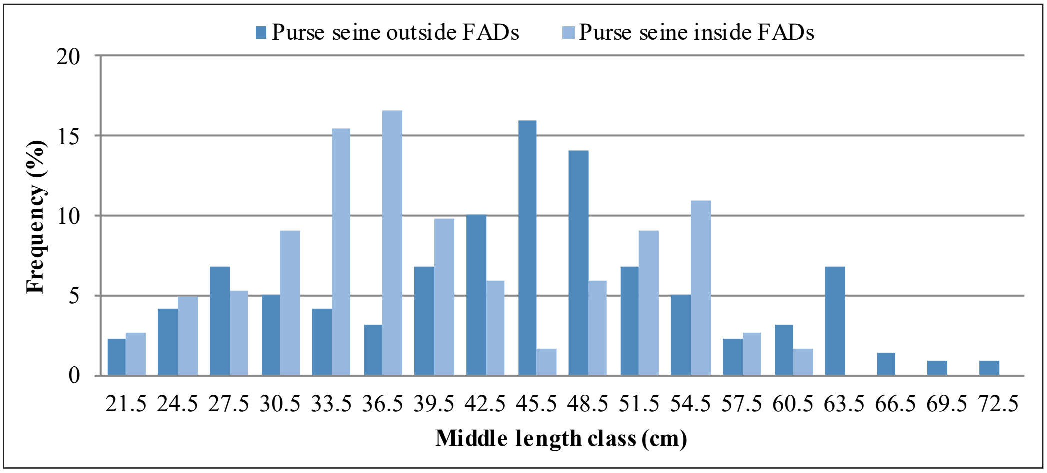

Figure 2. Size structures of skipjack captured by purse seines inside and outside of the FADs areas in Bone Bay waters

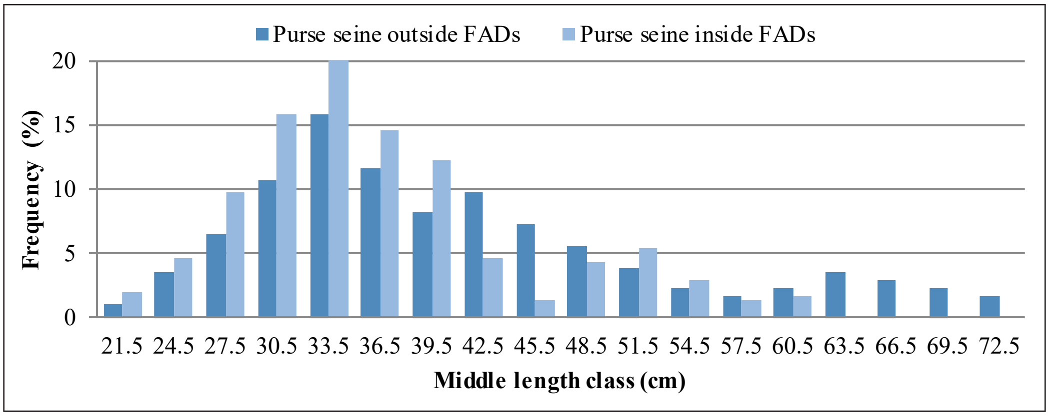

Figure 3. Size structures of skipjack captured by purse seines inside and outside of the FADs areas in Makassar Strait waters

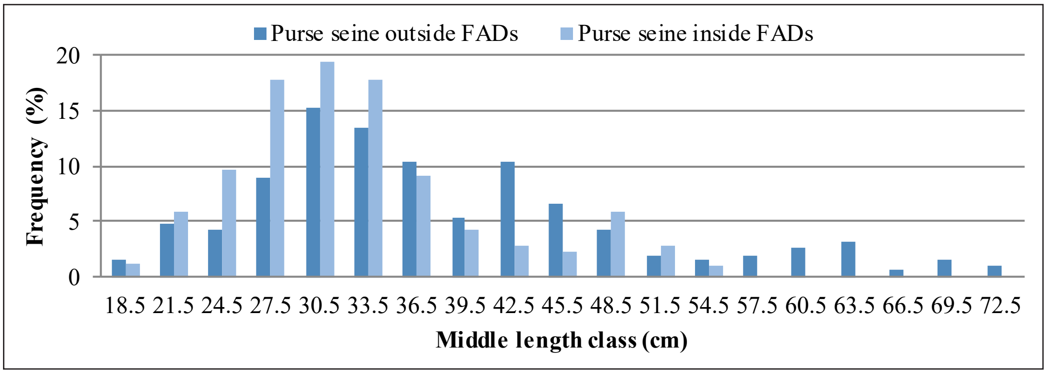

Figure 4. Size structures of skipjack captured by purse seine inside and outside of the FADs areas in Flores Sea waters

Table 1
Size structure of skipjack caught purse seines inside and outside of the FADs areas in Bone Bay, Makassar Strait and the Flores Sea waters

Fishing Areas	Purse Seine Inside FADs areas			Purse seine outside FADs areas		
	Length Range (cm)	Dominant Length (cm)	Average Length (cm)	Length Range (cm)	Dominant Length (cm)	Average Length (cm)
Bone Bay	20.75-60.65	30.50-39.50	40.39±10.07	28.50-73.15	39.50-51.50	44.64±11.60
Makassar Strait	20.10-61.50	27.50-39.50	37.46±8.53	20.50-73.50	30.50-42.50	45.86±12.78
Flores Sea	18.10-55.90	24.50-36.50	32.74±7.83	17.90-72.90	24.50-39.50	38.33±11.90

those caught in purse seines inside of the FADs areas, third the average length of skipjack caught by purse seines outside of the FADs areas was greater than that caught in purse seines inside of FADs area.

The results of statistical tests using the Median Test can be explained that there are differences significantly in the size distribution of the skipjacks captured by purse seines inside and the outside of the FADs areas in Bone Bay waters (*T* count 29.37 > z ±1.96, α = 0.05) and in the Makassar Strait waters (*T* count 13.20 > z ±1.96, α = 0.05) and in the Flores Sea waters (*T* count 16.29 > z ±1.96, α = 0.05). The difference in the size structure of skipjack caught by purse seines inside and outside of the FADs areas is thought to be caused by, firstly, small-sized skipjack feel comfortable in floating objects in the sea. The other possibility was skipjack migrated onshore and offshore depending on size or known as size-dependent migration where small fish tended to be in shallow waters and large fish tended to be in deep waters. The case in the study area shows that the purse seine outside of the FADs areas was operated in deeper waters whereas purse seine inside of the FADs areas was operated in shallow waters where FADs are located. In the WPP RI 713, the FADs were generally installed in shallow waters, depths ranging from 70 to 200 meters and few installed in deep waters (Mallawa et al., 2017). The wider size distributions and relatively larger sizes of skipjack tuna caught outside the FADs areas than inside the FADs areas have also been previously reported by other studies, namely in the Makassar Strait waters (Wilantara, 2016), in the Flores Sea waters (Susaniati, 2014), and in the Bone Bay waters (Alamsjah et al., 2014; Mallawa, 2016). This is also supported by what was stated by Leroy et al. (2013) that the FADs had been shown to influence the behavior and movement pattern of the three species of tuna such as skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacores*) and bigeye (*T. obesus*) with juveniles of each species occupying shallower habitat when associated with FADs. Furthermore, that the aggregation of tunas around drifting objects increases their vulnerability to purse seine gear, particularly for juvenile and small size classes. Koya et al. (2012) described that the different size range of skipjack in catch might be due to the change in the distribution pattern of fishes in a different area, the fishing gear or fishing technology employed and another environment parameter. Others study results also showed differences in the size structure and the average length of skipjack caught by purse seines inside and outside of the FAD areas is presented in Table 2.

Table 2
Size structure of skipjack captured by purse seines inside and the outside of FADs areas in several fishing areas in the world

Fishing Area	Purse Seine Inside FAD area		Purse Seine Outside FAD area		References
	Length Range (cm, FL)	Average Length (cm, FL)	Length Range (cm, FL)	Average Length (cm, FL)	
Moro Gulf	19.0-52.0	25.0	14.0-66.0	25.0	Barbaran (2006)
Flores Sea	13.0-63.0	26.3±4.9	18.0-73.0	52.4±8.8	Susaniati (2014)
Makassar Strait	16.0-26.0	19.6 ±2.43	34.0-49.o	42.7±3.11	Wilantara (2016)
Indian Ocean	26.6-62.0	40.0±5.0	nd	Nd	Nurdin and Panjaitan (2017)
Western & Central Pacific Ocean	26.4-73.3	43.37±7.59	33.1-74.8	51.09±6.87	Wang et al. (2012)
Pacific Ocean	nd	49.6	nd	54.6	Hare et al. (2015)
Western & Central Pacific Ocean	26.4-73.3	37.0±7.59	33.1-74.0	51.09±6.87	Leroy et al. (2013)

nd = data not available

Purse Seine Productivity

Productivity or Catch Per Unit Effort (CPUE) of purse seines inside and the outside of FADs areas were analyzed using annual production or annual yield and annual efforts or number of trip per year data from the records of ship owners of each study areas as presented in Tables 3, 4 and 5.

Test results using the Mann-Whitney method showed that the productivity of purse seines inside and the outsides of FADs areas in Bone Bay waters was significantly different (T count 79 > $W_{1-\alpha}$ 77, $\alpha = 0.05$), as well as in the Makassar Strait waters (T count 78 > $W_{1-\alpha}$ 77, $\alpha = 0.05$) and in the Flores Sea waters (T count 88 > $W_{1-\alpha}$ 77, $\alpha = 0.05$). Apart from that, it can also be explained that the productivity of purse seines inside and outside of the FADs areas varied within the same location and among different locations. The high productivity of purse seines inside FADs areas in this study might be due to, the first, the availability of fish in FADs at any time, second, the greater number of FADs installed had resulted in a reduction in the number of fish school outside the FADs areas or free-swimming fish school, third, differences in environmental parameters as a result of differences in the depth of the fishing area. The high productivity of purse seines inside FADs areas waters also reported by others study. Olii and Iwan (2018) reported that the productivity of the skipjack purse seines associated FADs in Tomini Bay waters in 2011-2015 ranged from 1.5 to 9.83 tons per trip and an average of 3.694 tons per trip. In Sulawesi Sea, the productivity of purse seines inside FADs areas ranged from 0.967 to 5.761 tons per trip with an average value

Table 3
The yield, effort and productivity (CPUE) of purse seiners inside and outside of the FADs areas in the Bone Bay waters

Boat sample	Purse seine inside FAD			Purse seine outside FAD		
	Yield (ton/year)	Effort (trip/year)	CPUE (ton/trip)	Yield (ton/year)	Effort (trip/year)	CPUE (ton/trip)
I	252.16	128	1.97	148.50	110	1.35
II	243.75	125	1.95	102.00	120	0.85
III	192.00	128	1.50	186.50	115	1.01
IV	181.25	125	1,45	187.50	123	1.52
V	192.50	125	1.54	220.50	110	2.01
VI	239.36	128	1.87	133.65	110	1.21
VII	318.72	128	2.49	155.00	115	1.35
VIII	210.50	128	1.64	201.50	115	1.75
IX	198.50	124	1.60	110.00	110	1.00
X	208.75	125	1.67	115.50	110	1.05
Average	223.75	126.4	1.77	156.07	156.07	1.12
SD	±41.23	±1,71	±0,31	±41.38	±4.71	±0.37

Table 4
The yield, effort and productivity (CPUE) of purse seiners inside and outside of the FAD in the Makassar Strait waters

Fishing Boat Sample	Purse seine inside FAD			Purse seine outside FAD		
	Yield (ton/year)	Effort (trip/year)	CPUE (ton/trip)	Yield (ton/year)	Effort (trip/year)	CPUE (ton/trip)
I	212.40	120	1.77	148.50	110	1.35
II	218.75	125	1.75	102.00	120	0.85
III	194.56	128	1.52	196.15	115	1.71
IV	195.00	125	1.56	195.60	113	1.73
V	188.16	128	1.47	144.50	120	1.21
VI	248.75	125	1.99	110.75	115	0.96
VII	199.08	126	1.58	115.65	110	1.05
VIII	192.78	126	1.53	193.55	110	1.76
IX	194.40	120	1.62	119.75	115	1.04
X	209.92	128	1.64	138.50	115	1.18
Average	205.38	125.10	1.64	146.50	114.30	1.28
SD	±18.17	±1.71	±0.16	±36.65	±3.71	±0.34

Table 5
The yield, effort and productivity (CPUE) of purse seiners inside and outside of the FADs areas in the Flores Sea waters

Fishing Boat Sample	Purse seine inside FAD			Purse seine outside FAD		
	Yield (ton/year)	Effort (trip/ year)	CPUE (ton/trip)	Yield (ton/ year)	Effort (trip/ year)	CPUE (ton/ trip)
I	177.50	125	1.42	138.50	110	1.26
II	248.75	125	1.99	112.00	120	0.93
III	192.00	128	1.50	126.15	115	1.10
IV	161.25	125	1.29	168.50	123	1.11
V	169.20	120	1.41	171.50	115	1.37
VI	218.75	125	1.75	126.75	115	1.10
VII	186.00	128	1.45	118.50	118	1.00
VIII	188.50	128	1.47	134.50	118	1.14
IX	219.60	120	1.83	133.50	115	1.16
X	192.00	128	1.50	201.50	115	1.03
Average	195.36	125.20	1.56	143.14	116.4	1.23
SD	±26.47	±3.08	±0.22	±28.24	±3.53	±0.25

of 2.925 tons per trip (Prasetyo et al., 2018). The productivity of purse seines inside FADs areas that landed their catch at the Fishery Port of Lampulo Beach, Banda Aceh, Sumatra Island ranged from 0.405 to 2,368 tons per trip (Affan, 2015). Scott and Lopez (2014) described that across the oceans, floating object purse seine fishing was about 50% more productive (in ton per set) than free-school fishing for tropical tunas in combination and about twice as effective for skipjack.

Factors that cause higher productivity of purse seines operating inside than outside of the FADs areas are explained by several previous studies. Cabral et al. (2014) explained that in using FADs enhanced catch per boat when total fishing pressure was low but could exacerbate fishery collapse when the fishing effort was high. In Indian Ocean, the productivity of purse seines inside of the FADs areas was higher than that of purse seines outside of the FAD areas where this phenomenon was caused by a decrease in skipjack free-swimming school as a result of an increase in the number of FADs installed in the waters (Fonteneau et al., 2015). The decrease in the number of catches per unit effort in purse seines outside FADs areas in the Eastern Atlantic Sea and Western Indian Ocean due to the increasing number of FADs installed in the area (Fonteneau, 2015). In the Bone Bay waters, the productivity of purse seines inside FADs areas could be different due to differences in the depth of location of the FADs where the fishermen who carried out fishing in deeper waters FADs provided higher yields compared to shallow water FADs (Nurwahidin et al., 2016).

Types and Percentage of By-Catch

The results of this study show that, firstly, the kinds of by-catch in purse seines operated inside FADs areas included sharks, dolphins, turtles, ray, and kinds of small-sized fish such as anchovy (*Stelophorus* spp), sardine (*Sardinella* spp), Indian mackerel (*Rastrelliger* sp), juvenile of yellowfin tuna (*Thunnus labacares*), and frigate tuna (*Thunnus alexis*) while in purse seines operated the outside of FADs areas included dolphins, sharks and kinds of small pelagic fishes. Secondly, both in purse seines inside and outside of the FADs areas, the by-catch was dominated by small pelagic fish, which ranged from 58.4 to 75.03% of total by-catch in purse seines inside FADs areas and 59.7 to 73.22% in purse seines outside FADs areas. The third, the percentage of mammals, turtles, stingrays and sharks in the purse seines inside FADs areas were higher compared to the purse seines outside the FADs areas, this is due to the large number of small pelagic fish in the FADs as food of these organisms (Figure 5), and forth, in plain view, the percentage of by-catch on the purse seines inside the FADs areas was higher than the purse seines outside the FADs areas (Table 6).

The types of by-catch of the present study were found to be not difference with other studies. Hartaty et al. (2012) reported that purse seines operated in the FADs areas, besides catching skipjack tuna as the main catch also caught juvenile both of yellowfin tuna and bigeye tuna, and the other fishes. Romanov (2008) reported that the types of by-catch from purse seine associated FAD in North Equatorial Area of the western Indian Ocean consists of tuna by-catch which included juvenile bigeye tuna (*Thunnus obesus*), albacore (*Thunnus alalunga*), frigate tuna (*Auxis thazard*) and bullet tuna (*Auxis rohei*), and non-tuna by-catch

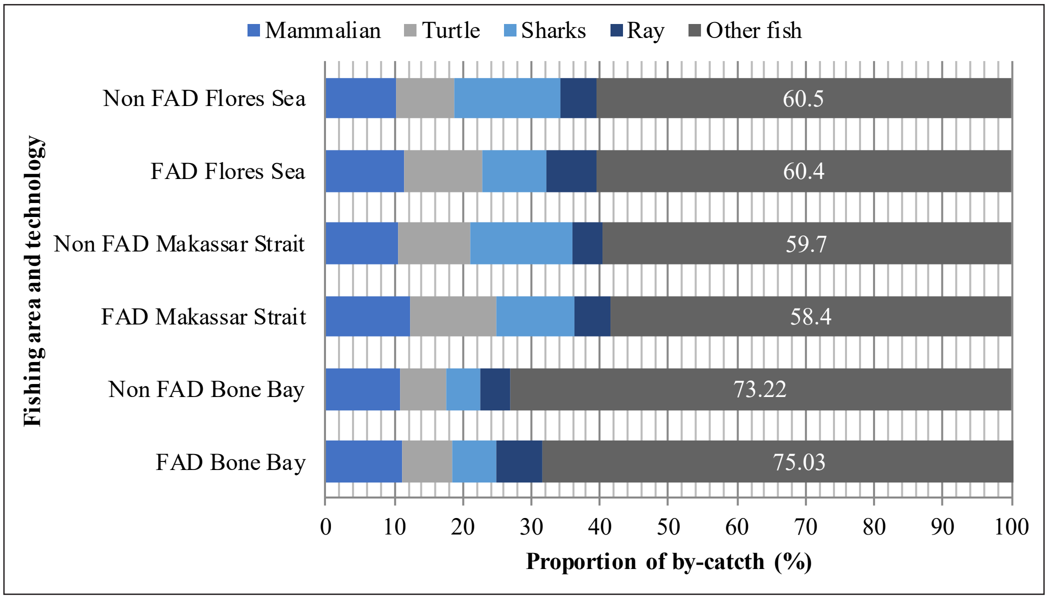

Figure 5. By-catch of purse seines inside and outside of the FADs areas in Bone Bay, Makassar Strait and the Flores Sea waters

including sharks (*Carcharhinus* spp and *Sphyrna* spp), rays (*Dasyatis* spp and *Mobula* spp), marlin (*Makaira* spp), sword fish (*Xiphias gladius*), sea turtles (Cheloniidae) and others. For purse seiners, by-catch species are usually divided in to six categories such as tunas other than target species, miscellaneous bony fishes, billfishes, sharks, rays and sea turtles (Dagorn et al., 2013). The major species associated to FADs are skipjack, young bigeye tuna, young yellowfin tuna, bullet tuna, wahoo (*Acanthocybium solandri*), dolphin fish or mahi-mahi (*Coryphaena hippurus*), sharks, billfishes, some small pelagic fishes, and carangids (Fonteneau et al., 2015). In Atlantic Ocean waters, the by-catch of skipjack tuna purse seines consists of marine mammals, sea turtles, coastal sharks, pelagic sharks, skates and rays, *Scombridae* and billfish, and other teleosts as by-products (Gaertner et al., 2015). Indian Ocean Tuna Commission (2018) reported that purse seines operated inside FADs areas besides catching kinds of tuna also sea mammalian, turtles and sharks. The by-catch on purse seine could include several species of sharks, rays, marine mammals, marine turtles and bony fishes but can differ according to the fishing areas (Garcia & Herera, 2018). The by-catch of purse seines inside FADs areas in the eastern tropical Atlantic waters consisted of discarding tunas such as frigates and little tuna and other fish dominated by wahoo, billfish, triggerfish, sharks and dolphin fish (Menard et al., 2000). In West Central Pacific Ocean, by-catch in FAD-associated consists of small tuna (98%), sharks (0.20%), billfish (0.06%), tuna-like (0.13%), other fish (1.13%) while in FAD-unassociated consists of small tuna fish (99.86%), sharks (0.05%), tuna-like (0.03%) and other fish (0.08%) (Morgan, 2011). Murua et al. (2017) explained that the tropical purse seines that operated in the FADs areas caused an increase in the number of sharks caught.

Table 6
By-catch (%) of purse seiners inside and the outside of FADs areas in the waters of Bone Bay, Makassar Strait and the Flores Sea

Fishing Boat Samples	Bone Bay		Makassar Strait		Flores Sea	
	Inside FAD	Outside FAD	Inside FAD	Outside FAD	Inside FAD	Outside FAD
I	6.50	3.54	7.50	2.50	6.50	4.75
II	4.54	5.88	5.55	5.55	4.85	1.50
III	5.58	1.59	5.50	1.50	6.10	3.50
IV	5.52	6.28	5.50	1.50	4.56	5.65
V	5.73	2.65	4.50	5.20	4.45	1.35
VI	5.49	1.00	5.30	6.95	4.50	1.60
VII	5.94	1.01	6.50	1.25	4.15	5.56
VIII	4.98	5.40	7.50	0.89	6.95	1.10
IX	5.46	5.50	7.85	4.11	5.65	0.50
X	6.76	1.36	5.54	6.15	4.45	4.75
Average	4.59	3.42	5.68	3.56	4.52	3.03
SD	±1.41	±2.17	±1.27	±2.29	±1.05	±2.02

Based on Table 6, the by-catch of purse seine operated inside FADs areas are higher than purse seines operated outside of the FADs areas. The test results using the Mann-Whitney method show that the by-catch of purse seines inside and the outsides of FADs areas in Bone Bay waters was significantly different (T count 79 > $W_{1-\alpha}$ 77, $\alpha = 0.05$), as well as in the Makassar Strait waters (T count 81 > $W_{1-\alpha}$ 77, $\alpha = 0.05$) and in the Flores Sea waters (T count 77.5 > $W_{1-\alpha}$ 77, $\alpha = 0.05$).

The high percentage of by-catch in purse seines operated inside FADs areas in this study is due to firstly, the large number of marine organisms associated with FADs, and secondly, because many prey fish, especially small pelagic fish can stimulate predatory organisms such as sharks, dolphins, sea turtles to find food in FADs. The high percentage of by-catch in purse seine operating in the FAD area has also been reported by several previous studies. The by-catch of purse seine associated FADs school in the western Indian ocean was 9.68 ± 4.8% consisting of by-catch tuna of 5.07 ± 4.38% and by-catch non tunas of 4.61 ± 2,18% (Romanov, 2008). Dagorn et al. (2012) described that fishing on free swimming schools was comparatively more selective, with by-catch 2.8 – 6.7 times lower than set on floating objects. Furthermore, Dagorn et al. (2013) explained that the ratio of by-catch purse seines inside and outside of the FADs areas varied according to the waters, namely in the western Pacific Ocean 1.7% and 0.3%, in the eastern Pacific Ocean 2.4% and 0.8%, in the Indian Ocean 3.6% and 0.8%, in the Atlantic Ocean 8.9% and 2.8%. Hall and Roman (2013) reported that in skipjack tuna purse seine fisheries in the Eastern Pacific Ocean the percentage of by-catch of floating object sets (11.7%) was higher than in free school sets (3.8%) and dolphin sets (3.9%). The by-catch value of purse seine inside FADs in eastern tropical Pacific was 9.9% of total catch (Menard et al., 2000). The by-catch of tuna purse seines inside and outside of the FADs areas in the Atlantic Ocean was 15.03% and 2.84% respectively (Amande et al., 2010). Bourjea et al. (2014) based on observations from 2003 to 2011 explained that in the Atlantic Ocean as many as 415 sea turtles was a purse seine by-catch, 201 turtles (48.4%) caught on DFAD and 214 turtles (51.6%) on free swimming school, on the contrary in the Indian Ocean as many as 182 turtles as by-catch, 148 turtles (81.3%) were caught in the DFAD and 34 turtles (18.7%) in the free swimming school. Escalle et al. (2016) described that the reduction in the number of FAD used could reduce the number of small tunas in purse seine catches in the Indian Ocean and Atlantic Ocean waters and could reduce the number of by-catches of purse seines in the Indian Ocean waters.

CONCLUSION

Based on the results of the study, it can be concluded that the length distribution of skipjack caught by purse seine outside of the FADs areas was wider than those caught inside FADs, and the average length of skipjack caught outside of the FADs was greater than those caught inside FADs. The operation of purse seine in FADs areas has a positive impact through increasing fishing gear productivity but has a negative impact such as an increase in the number of by-catches and protected marine organisms.

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