



## INVESTIGATION ON TUNA FISHERIES ASSOCIATED WITH FISH AGGREGATING DEVICES (FADs) IN INDONESIA FMA 572 AND 573

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### ABSTRACT

The use of anchored fish aggregating devices (a-FADs) in the Indonesia-Indian Ocean has increased rapidly. Since 2004, the Government of Indonesia has issued various FAD related fisheries regulations; however, its implementation was difficult, largely due to the lack of such information. As an endeavor to improve the management of tuna fisheries associated with FADs in this area, an Indonesia–Australia research collaboration project conducted a port sampling program from November 2013 to December 2015 in three key fishing ports in the western Indonesia, i.e., Pelabuhanratu (West Jawa), Muara Padang (West Sumatera), and Bungus (West Sumatera). Data were collected through daily enumeration and interviews with skippers, which consisted of catch, trip duration, biological data, and number of FADs visited. These data were analyzed to estimate catch rate, success rate, and length frequency distribution. The success rate of hand line/trolling line (HL/TR) at Muara Padang showed much lower than that at Pelabuhanratu. This may be due to more a-FADs or higher density in the Padang region, competing with purse seine (PS) boats operating in the same area, than those in the Pelabuhanratu region. The species composition caught by HL/TR and PS associated a-FADs in Indonesian FMA 572 and 573 include skipjack (SKJ, *Katsuwonus pelamis*), yellowfin (YFT, *Thunnus albacares*) and bigeye tuna (BET, *T. obesus*). A large proportion of the SKJ, YFT and BET caught at both Indonesian FMA 572 and 573 were juvenile fish, below the reported length at maturity ( $L_m$ ) for those species.

**Keywords:** Tuna Fisheries; FAD; Indonesia FMA 572-573

### INTRODUCTION

Utilization of floating objects (logs, seaweed, etc.) as known attractors of fish has been a feature of artisanal and coastal fishing in the waters of the Western and Central Pacific Ocean (WCPO) for hundreds of years (Kakuma 2000, Morales-Nin *et al.* 2000). The 1970s marked the beginning of fishers deploying floating *fish aggregating devices* (FADs) in deep-water in the eastern Indonesian waters to attract and catch tunas. Anchored FADs (called as *a-FADs*) in waters as deep as 2000 – 2500 m have since become a dominant practice for tuna fishing in Indonesia's archipelagic waters, including those in the western Indonesia. With the aim of increasing the efficiency of catch by purse seine (PS) boats in Prigi Bay, East Java (FMA 573), Indonesia's (RIMF) conducted a trial research with deployment of *a-FADs* in 1986. In 1992, with similar purposes, the RIMF deployed two *a-FADs* in Binuangen Cape waters (FMA

573) at the depth of 500-600 m for hand line (HL) and troll-line (TR) or HL/TR fisheries, two *a-FADs* in Cempi Bay, Nusa Tenggara Barat (FMA 573), for PS fisheries, and two *a-FADs* in Semangka Bay, Lampung, and Pesisir Selatan waters in West Sumatera (FMA 572), for HL/TR fisheries (Linting *et al.*, 1992). Unfortunately RIMF did not monitor the results of the *a-FAD* after deploying but obtained information that some fishers subsequently tried to develop similar *a-FADs* in the trial areas. Since the early 2000s, the use of *a-FADs* has been developed rapidly in the FMAs 572 and 573, including in the waters near Pacitan, East Java (FMA 573) (Nuraini *et al.*, 2014). The *a-FADs* in deep-water have become an integral component of tuna fishing in Indonesian waters. Figure 1 shows a map of the FMAs 572 and 573. Since 2004, the Government of Indonesia has issued various FAD related fisheries regulations: PER.30/MEN/2004; PER.08/MEN/2011 and PERMEN No. 26/PERMEN-KP/2014, and the relevant plans: National FAD Management Plan for 2015-2017

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issued by DGCF in 2014 and Ministry Decree No. 107/KEPMEN-KP/2015 about National Tuna Management Plan. Effective fisheries regulations for management of FADs require quality data and information on the Indonesian fisheries including: numbers and locations of FADs, types of FAD ownership, types of fishing gears deploying FADs, catch rates, catch species compositions per gear type, fish size by species (target tunas and bycatch species). Until now, implementation of FAD regulations

has been difficult, largely due to the lack of such information as listed above. To address the information gaps, in 2012 Indonesia's Agency for Marine and Fisheries Research and Development (AMFRAD) joined by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australia, conducted a four-year collaborative research that included *a-FAD* fisheries study. This paper provides results from the study with particular reference to the FMAs 572 and 573.

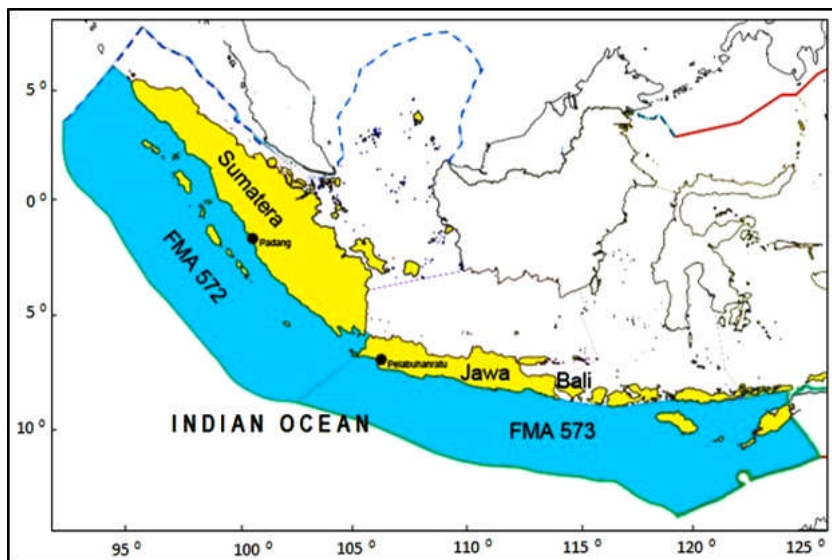


Figure 1. Indonesian Fisheries Management Areas 572 and 573 (modified from Wilayah Pengelolaan Perikanan, KOMNAS KAJISKAN 2010).

## MATERIALS AND METHODS

Fishery data were obtained through daily enumeration including interviews with skippers at the earliest opportunity right after their catches were unloaded, and also by direct observations and biological sampling during November 2013 to December 2015. Fishery information on numbers and positions of *a-FADs* were obtained from local port authorities, fisheries offices, fishing companies and fishing association representatives. The enumeration carried out at three key tuna fishery bases where the fishers fish in FMAs 572 and 573, i.e., Muara Padang in Padang City, Bungus Fishing Port in West Sumatra, and Pelabuhanratu Fishing Port in West Java. The primary tuna fisheries associated with *a-FADs* based at both Pelabuhanratu Fishing Port and Muara Padang included HL and TR. On occasion, the HL and TR boats from Muara Padang also unload their catch at Bungus Fishing Port as did PS boats from Fishing Port of Sibolga (North Sumatra). At the three key tuna fishery bases, it is generally found that one boat switches both HL and TR fishing gears subject to season, prevailing sea conditions and catch

success, and such boat is registered as a *kapal tonda* (TR boat).

The types of data and information collected from interviews with boat skippers include technical aspects of *a-FADs*, number and positions of *a-FADs*, tuna fisheries associated with *a-FADs*, operational aspects of the fisheries using *a-FADs* includes *a-FAD* visit success rate and catch rate (*nominal catch per unit effort* or *CPUE*) as well. The types of data collected from biological sampling include catch composition and individual tuna species size (*cm-fork length* or *cm-FL*). The sampling was done on a subsample of the catch at time of catch unloading or at point of auction or sale. The tuna species include skipjack or SKJ (*Katsuwonus pelamis*), yellowfin tuna or YFT (*Thunnus albacares*) and bigeye tuna or BET (*T. obesus*). Data were first recorded onto hard-copy *Landings and Biological Samplings Forms* and later entered into a project specific database (Oracle/Apex), *FAD Fisheries Database*.

The *a-FAD* visit success rate is defined as the number of successful *a-FAD* visits, with respect to

fish caught or not caught during the visit, expressed as a percentage (%) of total number of *a*-FADs visited during the fishing trip. Catch rate (*nominal catch per unit effort* or *CPUE*) is calculated to indicate the productivity of each boat of fisheries associated with *a*-FAD/s using the following equation:

$$CPUE = C/E \dots\dots\dots (1)$$

Where;

C = total catch of tuna (kg)

E = effort (day-fishing).

Length distribution of each tuna species was compared with length at first matured ( $L_m$ ) to investigate the tuna fishing activities are still applying the sustainable practices (comparing the proportion of tuna catch relative to its  $L_m$ ).

## RESULTS AND DISCUSSION

### Results

#### Technical Aspects of Indonesian Anchored FADs

The common fish aggregating devices (FADs) deployed by tuna fisheries in Indonesia are anchored FADs (*a*-FADs). The Indonesian *a*-FADs have four key components: i) the surface float (bamboo raft, steel pontoon or polystyrene block), ii) the mainline to

seafloor (polypropylene rope), iii) a subsurface attractor (*nypa* or coconut leaf), and iv) the anchor (Figure 2). In general, the *a*-FAD surface floats are not equipped with navigation aids (no radio signal emitters or radar reflectors), but in some cases the surface floats are attached to a superstructure such as a flag to make the *a*-FAD more visible.

In the eastern Indonesia, the most sophisticated type of *a*-FAD, which is relatively common, is made of bamboo raft with a bungalow (*rakit*) in which the fishers and/or caretakers of the *a*-FAD reside for weeks or even months. Supply of fresh food and water and other necessities for the persons staying at the *rakit* of *a*-FAD is made by fishing boats or carrier boats. The bamboo raft *a*-FADs with *rakit* have not yet extended to the western Indonesia, where *a*-FADs are commonly of the steel (pontoon) or polystyrene types. The pontoon is a steel cylinder of 2 – 3 m length and approximately 0.8 m diameter, with generally one end conical. Previously, this was the most common type of *a*-FAD float in the western and eastern Indonesia. The *a*-FADs with polystyrene (commonly called *gabus*) are large cylinders or blocks of styrene foam, encased in cloth and often bound by rope and used-motorcycle tires, and strengthened by a wooden frame. This type of *a*-FAD has replaced the pontoon as the most common *a*-FAD type, due to its lower cost.

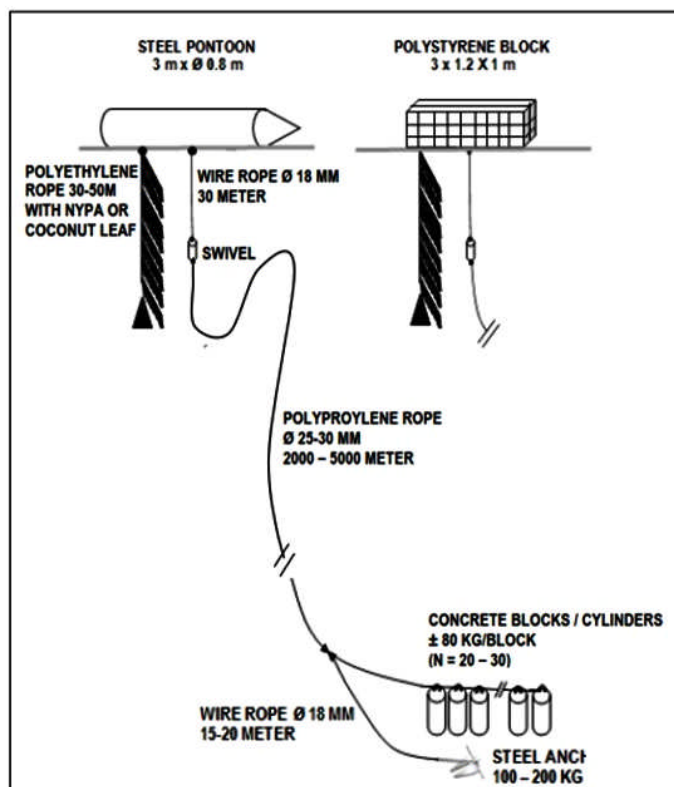


Figure 2. Common construction of *a*-FADs deployed by fishers based at Pelabuhanratu and Padang (modified from Hargiyatno *et al*, 2013 and re-drawn by Widodo, 2015).

### Total Numbers and Positions of a-FADs

It is difficult to estimate the total number and position of tuna *a-FADs* in Indonesia's FMAs 572 – and 573 due to the lack of effective systems of *a-FAD* registration and monitoring, and the desire of fishing companies and boat skippers to keep *a-FAD* position confidential. However, the current fisheries laws require the registration of *a-FADs*, and owners of *a-FADs* should provide information on the position and the use of their boats for each *a-FAD* installed in the Directorate General of Capture Fisheries in Jakarta. These laws have not yet been effectively implemented and complied with. In general, National, Provincial, Regency and District offices of Ministry of Marine Affairs and Fisheries (MMAF) were unable to provide information on numbers and locations of *a-FADs*. Port Authorities are primarily concerned with monitoring of boat traffic into and out of ports and boat activity in their ports, and do not in general maintain records of *a-FAD* locations. Some fishing companies, boat owners, and skippers interviewed for this study provided positional information for their *a-FADs*, whereas others were reluctant to do so because they want to keep their fishing locations confidential. Information obtained by this enumeration program, combined with that from other sources, suggested

that the total number of *a-FADs* in FMAs 572 and 573 ranged from several hundreds to several thousands.

Figure 3 shows the positional information of *a-FADs* in FMAs 572 and 573 based on some of the enumeration done for this study. The current Indonesian fisheries regulations for *a-FADs* require that *a-FADs* should be apart at a minimum of 10 nm. There is strong evidence to suggest that this requirement is not being complied with, and in many cases *a-FADs* are deployed significantly less than 10 nm apart. Achieving the effective enforcement of this regulation is undoubtedly one of the biggest challenges faced by Indonesia's management agencies, and requires improved education to fishing companies, fishing boat owners, and fishers about the proven benefits that are likely to come from a reduction in density of FADs in any given area (Cayré 1991; Marsac and Cayré 1998). The main fishing areas for HL and TR boats based at Pelabuhanratu Fishing Port are in the Indonesian EEZ waters, 20 - 200 nm from port, but some of the *a-FADs* are located in the high seas, about 350 nm from Pelabuhanratu. The main fishing areas for HL and TR boats based at Muara Padang and Bungus are on the western side of the Mentawai Islands, approximately 70 - 300 nm from Padang (Figure 3).

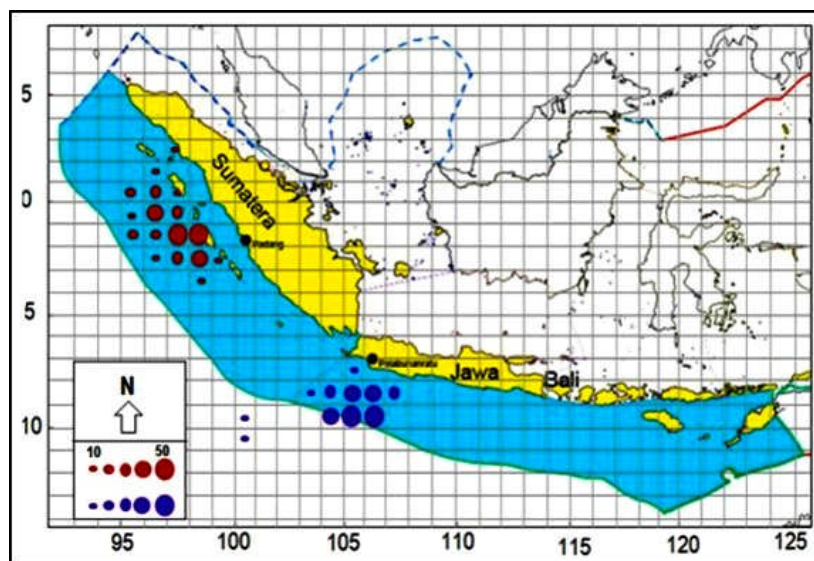


Figure 3. Estimation FAD numbers and positions in the FMAs 572 and 573, from information collected during enumeration in Padang in 2013 and Pelabuhanratu in 2014. FADs in Pelabuhanratu region are used by HL and TR boats and FADs in Padang region are used by HL, TR and PS boats.

### Tuna Fisheries Associated with a-FADs

Fishers based at Muara Padang and Pelabuhanratu Fishing Port use multi-gear boats, commonly called '*kapal tonda*', to catch tuna in the vicinity of the *a-FADs*. The *kapal tonda* (TR boats) normally use HL and TR, which switches gears

depending on season, prevailing seas conditions, and catch success. The boats are commonly wooden-hulls of size 6 – 10 GT. The *kapal tonda* and their fishing methods originated in southern Sulawesi (Bugis fishermen). Fishers based at Bungus Fishing Port use TR and PS boats to catch tuna around *a-FADs*. The PS boats have two types: catcher boat



and carrier boat (called *group purse seiner*, consists of one catcher boat, two to three carrier boats and several light boats). Both the TR and PS boats are commonly of wooden-hull structure. The size of TR boats ranged 6-10 GT and the size of PS boats ranged 30 – 150 GT.

### Operational Aspects of the Fisheries Using *a*-FADs

The success rate of *a*-FAD visit

The *a*-FADs visit success rate of boats of HL and TR fisheries based at Muara Padang during the 2013 – 2014 survey periods was 34.5%, and that of the PS boats based at Bungus Fishing Port was 48.3%. The HL and TR boats based at Pelabuhanratu Fishing Port

were significantly higher, at 87.7%, than those at Muara Padang and Bungus (Table 1). The significantly lower *a*-FAD visit success rate of HL/TR boats based at Muara Padang may be due to more *a*-FADs in the Padang region with a higher *a*-FAD density (see Figure 3) or due to competition with PS boats operating on similar fishing grounds or due to both. Widodo *et al.* (2016) noted that skippers of PL boats based at Kendari (Southeast Sulawesi) and Sorong (West Papua) often expressed their frustration that the deployed FADs were found '*empty of fish*' after sets by PS boats. In the FMAs 713-717, the PS, PL, and HL/TR fleets have significant overlapping in their fishing grounds. Information provided by the PL skippers indicated that it normally takes at least 1 – 2 weeks before fish re-aggregated at the FADs after a PS set.

Table 1. Summary of trip lengths (fishing days) and FAD visit success for HL/TR and PS boats at Muara Padang, Bungus, and Pelabuhanratu, based on information collected by this study during 2013 – 2015.

Location	Gear Type	No. of Boat Trip	Avg. of Fishing Days	Avg. number of FADs visited	Avg. number of FADs with success	FADs visit success rate (%)
Pelabuhanratu	HL and TR	976	7.6	1.3	1.0	87.7
Muara Padang	HL and TR	133	12.6	12.9	3.3	34.5
Bungus	PS	5	35.5	8.8	4.0	48.3

Catch Rates

At Pelabuhanratu Fishing Port, the average catch rates (or nominal catch per unit effort, CPUE) of all total catch (all species combined) for HL and TR boats in October – December in 2013, 2014, and 2015 were 486 kg, 517 kg, and 680 kg (avg. 561 kg) per boat per trip, respectively (Table 2). The trip days were about 5 - 8 days with an average of 6 actual fishing days per trip. The average catch rates per day per HL and TR boat based on total catch per number of actual fishing days) per fishing trip for 2013 (165 fishing trips), 2014 (548 fishing trips), 2015 (263 fishing trips) were 81 kg, 86 kg, and 113 kg per boat and per actual fishing day, respectively.

At Muara Padang landing place, Padang City, where the majority of HL/TR boats unload catch, the average catch rates of all total catch (all species combined) per boat per trip in October – December in 2013, 2014, and January – April in 2015 were 750 kg, 914 kg, and 1,112 kg, respectively (Table 3). The trip days were about 12-16 days, with an average of 10 actual fishing days per trip. The average catch rates per day per HL and TR boat based on total catch per number of actual fishing days per fishing trip in 2013

(one fishing trip only), 2014 (59 fishing trips) and 2015 (73 fishing trips) were 150 kg, 91 kg, and 111 kg per boat and per actual fishing day, respectively.

Limited data and information were obtained for PS boats during the enumeration (5 fishing trips surveyed only). The PS boats based at Bungus Fishing Port operate in a group, which consists of a PS catcher boat, 2 to 3 PS carrier boats, and several light boats. The pattern of fishing operations of the group is that the PS catcher boats have fishing trips for more than 6 months; catches are transferred directly to the PS carrier boats because the catcher boats generally do not have fish-holds of sufficient size to hold the catch; and one setting of a net per day or per night is normal. The amount of fish that is transported to Bungus Fishing Port by a PS carrier boat is mostly the catch from 3 to 4 sets by a catcher boat. The unloaded catch by PS carrier boats in the Bungus Fishing Port showed that five carrier boats surveyed during 2013 (3 boats) and 2014 (2 boats) were between 1,530 kg and 43,500 kg with an average of 15,406 kg per carrier boat per landing (Table 3). If these landings were from catches from 3 - 4 sets of the PS net, the estimated average catch per set was 3,191 kg to 5,722 kg.

Table 3. Catch rate of HL and TR based in Pelabuhanratu and Muara Padang, and PS based in Bungus for years 2013-2015.

Location	Gear	Year	No. of Month	No. of Landing	Total Catch (KG)	Avg. Catch/Boat/Trip (KG/Boat/Trip)
Pelabuhanratu (West Java)	HL-TR	2013	3	165	80,204	486
		2014	12	548	283,166	517
		2015	12	263	178,858	680
		<b>Total</b>	<b>3</b>	<b>27</b>	<b>976</b>	<b>542,264</b>
Muara Padang (West Sumatera)	HL-TR	2013	3	1	1,500	1,500
		2014	12	59	53,923	914
		2015	4	73	81,140	1,112
		<b>Total</b>	<b>3</b>	<b>19</b>	<b>973</b>	<b>136,563</b>
Muara Padang (West Sumatera)	PS	2013	3	3	51,500	17,167
		2014	5	2	25,530	12,765
		<b>Total</b>	<b>2</b>	<b>8</b>	<b>5</b>	<b>77,030</b>

**Biological Aspects of the Tuna Fisheries Operating on a-FADs**

Catch Composition

The enumeration results in Pelabuhanratu Fishing Port showed that at least nine species were identified from about 180,751 kg of sampled fish that were caught by the HL and TR boats, with adult (big) yellowfin tuna (a-YFT, *Thunnus albacares*) (49.2%) and skipjack tuna (SKJ, *Katsuwonus pelamis*) (32.9%) making up a large proportion of the catch. Common dolphin fish (DOL, *Coryphaena hippurus*) and striped marlin (MLS, *Kajikia audax*) were key bycatch species (Figure 4A). During 2013-2015, the enumeration results at Muara Padang showed that at least 10 species from 136,563 kg of sampled fish were caught

by the HL/TR boats. The highest catch proportion among the overall catch during the study period was SKJ at 37.7% by volume, followed by the mixed juvenile and adult yellowfin tuna catch (j-a-YFT, *Thunnus albacares*) at 24.7% and mixed juvenile and adult bigeye tuna catch (j-a-BET, *Thunnus obesus*) at 13.1%. Mixed juvenile yellowfin and bigeye tuna catch (j-YFT-BET) also comprised a significant portion of the total volume (8.0%). Black marlin (BLM, *Makaira indica*) and various sharks (*Carcharhinus spp.*) only made up of 0.1% and 0.01% of the catch by volume, respectively (Figure 4B). Catch composition of the 77,030 kg landed fish by PS carrier boats at Bungus was SKJ at 29.9%, j-YFT at 19.5%, j-BET at 4.5%, neritic tuna or *tongkol* (BLT-FRI, *Euthynnus affinis*, *Auxis rochei*, and *A.thazard*) at 27.3%, and scads at 18.8% (Figure 4C).

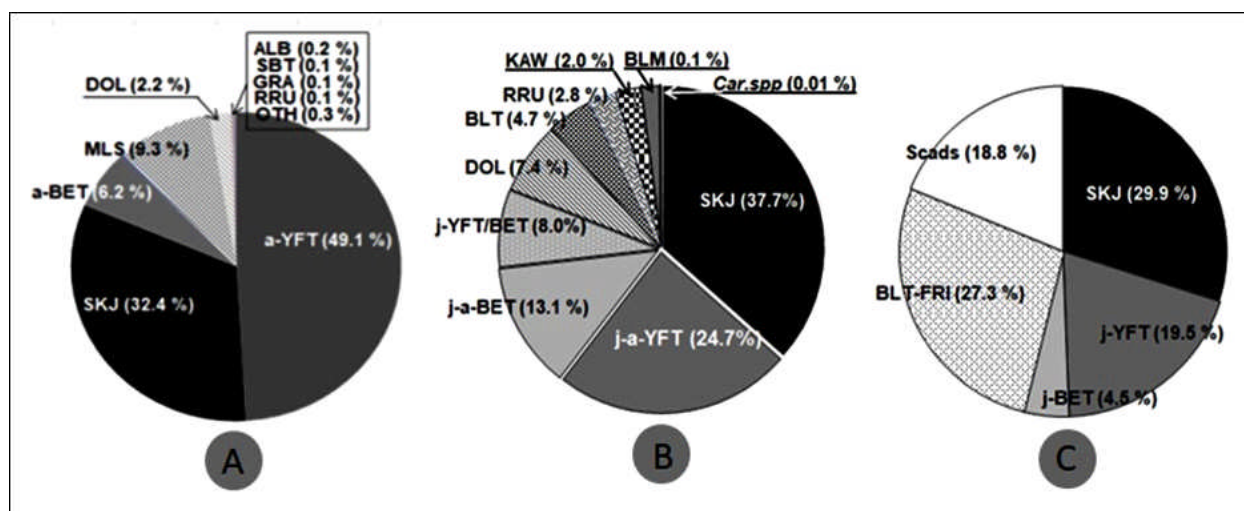


Figure 4. Catch composition of HL and TR in Pelabuhanratu (A), HL and TR in Muara Padang (B) and PS in Bungus (C).

## Fish Size

The result of the *port sampling program* at Pelabuhanratu showed that the average size (cm fork length or cm-FL) of SKJ caught by HL and TR in 2013, 2014, and 2015 were 42.5 cm, 41.3 cm, and 42.1 cm, respectively. The results in the three study areas showed that the average sizes of most YFT and BET caught by HL and TR vessels and PS vessels were below the reported *Lengths of Maturity* ( $L_m$ ): 103 cm FL for YFT (Mardijah *et al.*, 2012) and 102 – 105 cm

FL for bigeye tuna (Schaefer *et al.*, 2005). The majority of SKJ size landed by HL and TL vessels at Muara Padang were also below their reported  $L_m$  of 40 – 42 cm FL (Tandog-Edralin *et al.* 1990). In contrast, the average size of SKJ caught by PS vessels based at Bungus Fishing Port and by HL and TL vessels based at Pelabuhanratu were larger than the  $L_m$ . The average size of most SKJ caught by HL, TR and PS boats in Muara Padang and Bungus was that of juvenile fish, and YFT and BET caught by HL, TR and PS boats in the three landing locations were also small (Table 4).

Table 4. The size of SKJ, YFT, and BET caught by HL-TR and PS based in Pelabuhanratu, Muara Padang and Bungus during 2013-2015

Location	Gear	Species	Year	Min. Length (cmFL)	Max. Length (cmFL)	Avg. Length (cmFL)	n Sample (fish)
Pelabuhanratu (West Java)	HL-TR	SKJ	2013	29	58	42.5	292
			2014	20	88	41.3	1,337
			2015	23	63	42.1	1,520
	YFT	2013	28	56	39.1	520	
		2014	21	72	40.7	1,451	
		2015	26	66	42.3	1,383	
	BET	2013	30	53	41.1	226	
		2014	26	66	44.6	424	
		2015	26	57	43.2	595	
Muara Padang (West Sumatera)	HL-TR	SKJ	2013	24	60	37.9	288
			2014	16	58	35.0	887
			2015	26	47	35.9	1,023
	YFT	2013	26	56	40.6	250	
		2014	16	90	37.2	884	
		2015	25	45	36.4	971	
	BET	2013	27	52	40.8	258	
		2014	22	49	37.2	649	
		2015	27	44	35.9	764	
Bungus (West Sumatera)	PS	SKJ	2013	26	50	38.6	32
			2014	70	90	79.2	18
		YFT	2013	27	50	38.5	44
			BET	2013	30	59	39.2

## Discussion

Among the two types of *FADs*, i.e., drifting and anchored *FADs* in the Pacific region, *a-FADs* have been used since the late 1970s by both industrial and artisanal sectors. Fonteneau *et al.* (2013) noted that tuna *FADs* were first introduced in the Indian Ocean in the early 90s. Among the two, only *a-FADs* have been used in the Indonesian tuna fisheries where *drifting FADs* (*d-FADs*) were not used even by PS boats. Developments in Indonesian *a-FADs*, including region specific designs, were first detailed by Subani *et al.* (1989). Monintja (1993) described ten different types of *a-FADs* in Indonesia. In general, *a-FADs* in Indonesia use biodegradable material such as *nypa* or *coconut* leaf as a subsurface attractor of *a-FADs*.

Dagorn *et al.* (2012) mentioned that currently most *FADs* deployed are made of synthetic materials such as nylon ropes or small pelagic fishing nets. Synthetic materials were not recommended because of its contribution to the marine litter and other potential negative impacts on the ecosystem, such as *FAD* beaching (Maufroy *et al.*, 2015, Zudaire *et al.*, 2018).

Anderson *et al.* (1996) defined at least 10 benefits of *FADs* and three of them are related to the increase of fishery production, reduced fuel consumption and reduced pressure on reef resources, but the use of *FADs* including *a-FAD* results in a lot of juvenile tuna catch at a size below the reported  $L_m$ . The exact reasons for the association of juvenile tuna and *FADs* are still not known (Dagorn *et al.*, 2007). However,

Castro *et al.* (2002) stated that FADs provide protection to juvenile tuna while also providing them with a good food supply. The floating objects are also believed primarily for protection from predators, as a source of food availability and increasing survival of eggs, larvae, and juveniles (Gooding & Magnuson, 1967). Juvenile bigeye may also use FADs as a meeting point to develop larger schools (Fréon *et al.*, 2000). Majority of YFT and BET landed by HL/TR and PS in Pelabuhanratu, Muara Padang and Bungus were at juvenile stage, and the majority of SKJ landed by HL/TL vessels at Muara Padang were also at juvenile stage. Harvesting juvenile fish before they reach their socially optimal size generated *growth overfishing* (Diekert, 2012).

The significantly lower *a-FAD* visit success rate of HL/TR boats based at Muara Padang may be due to more *a-FADs* in the Padang with a higher *a-FAD* density, competition with PS boats operating on similar fishing grounds, or both. Natsir *et al.* (2017) said lower value of technical efficiency of fishing gear associated with FADs could be resulted by the increasing number of FADs that can result in a higher *a-FAD* density in certain areas or waters.

## CONCLUSIONS

FADs employed by tuna fisheries in Indonesia are *a-FADs* with biodegradable attractors such as *nypa* or *coconut leaf*. Two principal tuna fisheries associated with *a-FADs* in Indonesian FMA 572 and 573 were i) HL and TR, and ii) PS. The lack of effective registration and monitoring system of *a-FADs* and confidentiality issues of fishing companies and boat skippers made it hard to estimate the total number and position of tuna *a-FADs* in Indonesian FMAs 572 and 573. Higher *a-FADs* density in certain fishing grounds and fishing competition among PS and HL and TR have resulted in a lower *a-FAD* visit success rate for HL/TR boats in the fishing grounds. Large portions of small-sized ( $< L_m$ ) SKJ, YFT and BET were caught by HL/TR and PS boats associated with *a-FADs*. Therefore, further studies to determine the maximum proportion of small-sized tuna catch need to be done to ensure the sustainability of tuna fisheries. The use of *a-FADs* in tuna fisheries is considered to be an important part in their fishing operation. The use of *a-FADs* with biodegradable materials such as *nypa* and *coconut leaf* in Indonesia is considered to be environment-friendly *a-FADs*, and should be maintained. As the Government has issued regulations for the use of *a-FADs*, an increased awareness of all stakeholders is required for the effectiveness management of *a-FADs* in Indonesia. Further research on the *a-FAD* fisheries is required to

determine 'realistic' and effective *a-FAD* management options and to identify the likely impacts of *a-FAD*-based management measures on both industrial scale and small-scale fishers, e.g., restrictions on *a-FAD* numbers by region, regulated *a-FAD* sharing within and between gear-types, seasonal closures, etc. There is a need to address the question of whether a free school (i.e. FAD-free) tuna fishing by 'one by one fishing gears' (hand-line or troll-line) and by purse seine is likely to achieve the operational efficiencies, sufficient catch, and sustainable incomes for the communities and industries associated with those gears.

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