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CHARACTERIZING OF TUNA FISHERIES ASSOCIATED WITH FADS IN INDONESIA FMA 713-717

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ABSTRACT

To support improving fisheries management on tuna fisheries in Indonesia FMA (I-FMA) 713-717, an Indonesia - Australia research collaboration conducted a study during November 2013 – December 2015 at two key tuna fishing bases including Kendari (Southeast Sulawesi) and Sorong (West Papua). This study involved an enumeration program with skipper interviews, direct observations and biological sampling. The study showed that all fish aggregating devices (FADs) in Indonesian waters are *anchored fish aggregating devices* (aFADs). Three main fisheries associated with aFADs include purse-seine (PS), pole and line (PL) and hand-line (HL). The PL fishery based in Sorong had the highest *FAD-success rate*-FSR (84.9 %) compared to other fisheries including PL and HL based in Kendari. The average catch rates of PL and PS boats based in Sorong 2013-2015 were 10,352 and 33,854 kg/trip/boat respectively. The average catch rates of PL and HL boats based in Kendari were 2,819 and 1,135 kg/trip/boat respectively. Apart from the catch of HL based in Kendari, the largest proportion of the catch was juvenile yellowfin tuna (j-YFT) and juvenile bigeye tuna (j-BET). The proportion of sharks and billfish as by-catch species, in the landings of HL and PL boats based in Kendari and Sorong was extremely low.

Keywords: Tuna; Fisheries; FADs; Indonesia FMA 713-717

INTRODUCTION

Artisanal fishers in Pacific Islands have used floating objects or *flotsam* including logs and seaweed as fish attractors in their fishing practices for hundreds of years (Kakuma, 2000; Morales *et al*., 2000; Reuter, 1938; Nasution *et al*., 1986). These natural floating objects were subsequently developed and elaborated as *fish aggregating devices* (FADs). There are two general types of FADs i.e. *anchored* FADs and *free drifting* FADs (Fréon *et al.*, 2000). The *anchored* FADs are hereinafter referred to as aFADs and the *free drifting* FADs are written as dFADs, fishers in Indonesia only use aFADs. The early 1980s marked the beginning of deploying aFADs by the tuna industry in eastern Indonesia (Tuasamu, 1985). Itano *et al*. (2004) mentioned that FADs support thousands of fishing boats in the Philippines and Indonesia. Currently reliance on aFADs has become a dominant practice for tuna fishing in Indonesia including in Indonesia Fisheries Management Areas or I-FMA 713-717 waters. These areas are included in the Western and Central Pacific Fisheries Commission (WCPFC) statistical area.

The Indonesian government has issued several regulations regarding the use of FADs since 2004, such as PER.30/MEN/2004, PER.08/MEN/2011, and PERMEN No. 26/PERMEN-KP/2014. In addition, the use of FADs is also regulated in the National FAD Management Plan for 2015–2017 (DGCF, 2014) and the National Tuna Management Plan (MMAF, 2015). Effective fisheries regulations for the management of FADs require a range of quality data and information.

These regulations include the numbers and locations of aFADs, types of aFAD ownership, types of fishing gear and boat operations associated with aFADs, catch rates and catch compositions for each gear type, by species and size of fish (target tunas and by-catch species). The implementation of aFAD management has proven challenging, in large part due to the lack of such operational data. An aFAD fisheries study was conducted as part of a four-year

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research cooperation between CSIRO Australia and Indonesia's Agency for Marine and Fisheries Research and Development (AMAFRAD) to fill in the data and information gaps. The findings of this study are summarized in this paper.

MATERIAL AND METHODS

The results from an enumeration program carried out between November 2012 and November 2016 in Kendari, southeast Sulawesi, and Sorong, west Papua, are reported. Kendari and Sorong are landing ports for tuna hand line (HL), pole and line (PL), and purse seine (PS) boats operating at aFADs in I-FMAs 713–717 (Figure 1).

Data and information were obtained daily by two enumerators in each port through direct observation of the catch as well as interviews with skippers as soon as possible after their boats unloaded their catches. Technical aspects of aFADs (design and construction), boat type (HL, PL, or PS), length of trip (number of days), number of aFADs visited, number of aFADs visited that produced fish (called FAD success), amount of total catch, and effort are the types of data and information that were collected in the interviews (per day of trip or per fishing operation). A subsample of the catch was used for the direct observations, which were made during the unloading process or at the auction or sale location. The kinds of data and information gathered included measurements of the target species' (tuna's) fork length (FL) and bycatch species' (other species') catch composition (tuna). Data were entered into a project-specific database (Oracle/Apex), *the FAD Fisheries Database*, after being written down on paper landings and biological sampling forms.

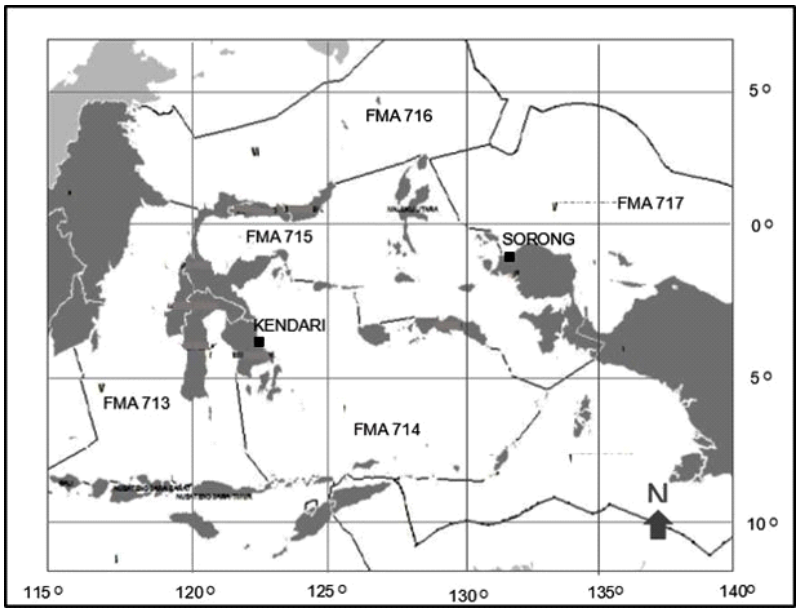

Figure 1. Research locations (Kendari and Sorong) which are the bases for tuna fishing at I-FMA 713-717.

Data Analysis

Fishers informed that not all $_a$FADs visited had fish around them - if fishers find an aFAD without fish (*empty*), then they will move to visit another aFAD which is thought to have fish and hopefully catch successfully. The ratio of total $_a$FADs visited that produced fish and total aFADs visited both empty and found with fish during the fishing trip, is defined as FAD *success rate* (FSR) as shown in equation 1.

$$FSR = \frac{TFS}{TFV}(\%) \quad \text{..... (1)}$$

Where FSR = FAD *Success Rate* which is expressed as percentage (%), TFS = Total FADs successfully fished and TFV = Total FADs visited.

The nominal catch per unit effort (CPUE) or catch rate of HL, PL and PS is calculated using equation as presented by Petrere *et al.* (2010) as equation 2 below:

$$CPUE\frac{\sum ci}{\sum fi} = \frac{c}{f} \quad \text{..... (2)}$$

Where: C_i is volume of catch (tonnes), f_i is respective fishing effort (trip). Other relevant data and information were analyzed descriptively with the results of the analyses presented in the form of tables and graphs.

RESULT AND DISCUSSION
Result

Technical aspects of Indonesian aFADs

The surface float (bamboo "rakit," steel pontoon, or "gabus"), the main anchor line to the bottom, a subsurface attractor, and the anchor are the four essential parts of an Indonesian tuna aFAD (Figure 2). The aFAD surface floats typically lack navigational aids, such as radio signal transmitters or radar reflectors, although occasionally they have an attached superstructure that increases their visibility. The three primary types of aFAD surface floats are:

1. A pontoon is a steel cylinder with one conical end that is typically 2-3 meters long and 0.8 meters in diameter.
2. The most complex version of the bamboo raft includes a bungalow called a "rakit," where the fishers and/or keepers of the aFADs spend weeks or even months. Fishing boats or carrier boats bring fresh supplies of food, water, and other requirements for the fishers or caretakers staying at the aFAD.
3. "Gabus" are large styrene foam cylinders or blocks that are covered in cloth, reinforced with a wooden structure, bound with rope and/or old motorcycle tires. Due of its reduced price, this kind of "gabus" float has replaced the "pontoon" as the most popular float type.

The aFAD mainline, up to 4000 meters in length for aFAD deployment in water depths of 2000–3000 meters (but sometimes as deep as 6000 meters), is most typically a 2.5–4.0 cm diameter synthetic rope, sometimes with a wire core; however, other types of synthetic rope of shorter diameter and lower cost are not uncommon, especially with the lighter gabus aFADs. The most common subsurface attractants are typically dangling clusters of Nipa palm (Nypa fruticans) or coconut palm (Cocos nucifera) branches that are attached to the underside of the surface float. The most popular aFAD anchors are made of 25–40 concrete blocks, each weighing 60–80 kg, joined together to make an anchor weighing 2-3 t. Each block has attachment points for ropes or motorcycle tires (Figures 2 and 3).

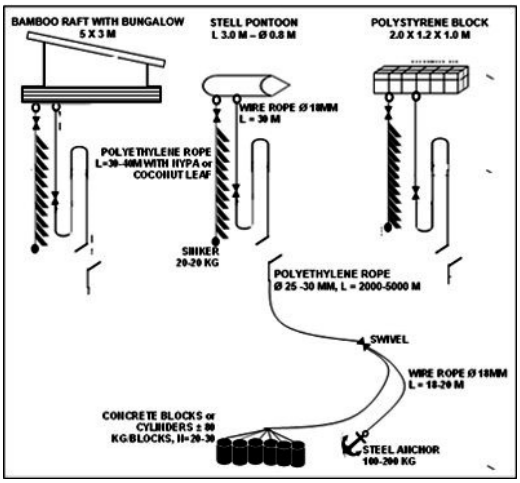

Figure 2. Common typical aFAD construction for bamboo '*rakit*', steel *pontoon* type and '*gabus*' polystyrene block type aFADs (drawn by A.A. Widodo, 2015).

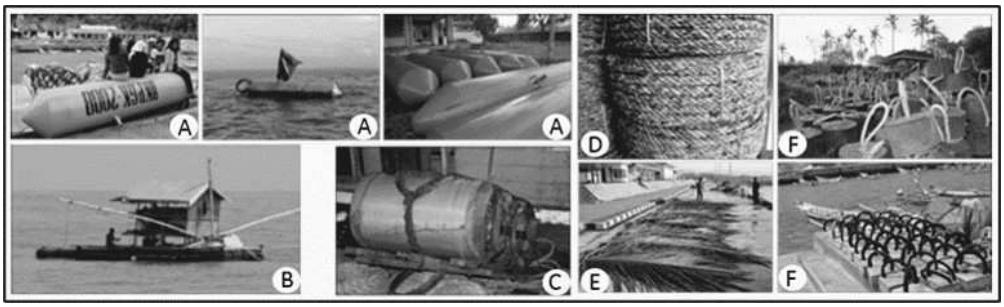

Figure 3. Various types of aFAD floats in Indonesia (A) steel '*pontoon*', (B) bamboo raft with '*rakit*', (C) styrene foam '*gabus*', and another components (D) coils of rope used for aFAD mainline, (E) coconut palm branches attached to mainline as subsurface attractor and (F) 60-80 kg cement weights which are linked together to form the aFAD anchor, (photos by Proctor, 2013).

Number and positions of aFADs

Estimating the total number of tuna aFADs in Indonesia proved challenging. The Directorate General of Capture Fisheries in Jakarta is required by the present fisheries regulations to register aFADs and receive positioning and boat use information from their owners for each aFAD installed; however, these regulations have not been properly followed. In general, the Ministry of Marine Affairs and Fisheries' (MoMAF) national, provincial, regional, and district offices were unable to give information on the number and location of aFADs. Port authorities generally do not keep records of aFAD locations because their major priority is observing boat traffic into and out of ports as well as boat activities within their ports. In order to protect the privacy of their fishing areas, some fishing companies, boat owners, and skippers interviewed for this study did disclose positional information for their aFADs. The information gathered by the study's enumeration tool, when supplemented with data from other sources and GPS coordinates that are accessible onboard the boats, indicates that there are at least several hundreds and maybe thousands of aFADs in I-FMAs 713–717. The distribution of aFADs placements used by fishermen in Kendari and Sorong and provided to the study is shown in Figure 4.

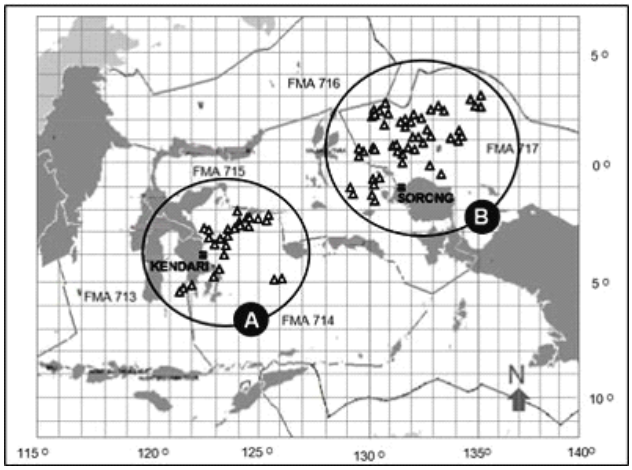

Figure 4. Estimation of some aFAD positions deployed by HL and PL fishers based in Kendari (A) and aFADs deployed by PL and PS fishers based in Sorong (B) as determined from GPS coordinates obtained during interviews with boat owner / skippers in the study.

Tuna fisheries associated with aFADs

Purse seine (PS), pole and line (PL), and handline (HL) gear are used in tuna fisheries that are associated with aFADs in FMAs 713–717. In the waters of FMA 713–717, there are two sizes of PS boats in use: smaller boats, known as "mini purse seines" or "pajeko" in the local language, and larger PS boats, known as "kapal pukat cincin" and exceeding 30 GT. The two primary categories of PL boats that operate near aFADs are small boats under 20 GT, or "funae," and larger boats over 20 GT, or "huhate." The number of funae boats is not growing, although they are still in use in a number of northern Sulawesi locations, such as Belang and Gangga Island. A handline (HL) boat often uses several gears, such as a deep handline (dHL), a surface handline (sHL), a trolling line (TR), and kite lines (KL). The gears are switched based on the time of year, the sea conditions, and the success of the catch. The HL boats are typically wooden-hulled vessels between 6 and 10 GT in size, and they go by many regional names, such as "penongkol" in northern and southern Sulawesi and "long-boat" in Sorong. The HL boats and their fishing techniques started with the Bugis fishermen in southern Sulawesi and have since migrated to numerous other islands in the Indonesian archipelago. Some Indonesian HL boats, mainly in Bone (Southern Sulawesi) and Kendari (Southeast Sulawesi), have adapted a different kind of fishing. These boats usually carry six to eight sampans (referred to as "pakura"), from which both large (up to 100 kg yellowfin tuna) and small tunas are caught. Figure 5 presents as an example the types of boats associated with aFADs based in Eastern Indonesia, including Kendari and Sorong.

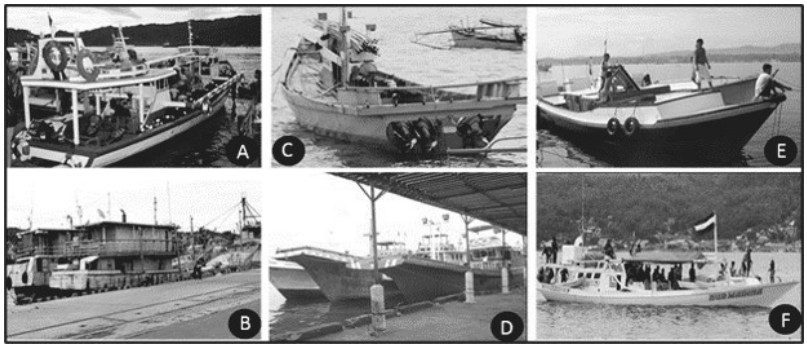

Figure 5. Examples of Indonesian boat types that fish on a-FADs: (A) mini PS (pajeko) and (B) PS based in Kendari; (C) smaller PL (called *funae*) in Belang, North Sulawesi; (D) larger PL (called *huhate*) in Sorong; (E) HL (called *penongkol*) and (F) HL 'mother-boat' carrying several small catcher boats (called *sampan* or *pakura*) in Kendari (Photos by Proctor, 2014).

Operational aspects of the fisheries using aFADs

Fishing strategy

The HL boats from Kendari has a fishing ground in aFADs around Manui Island, which is about 36 nautical miles from Kendari. The trip duration ranged from 7 to 10 days, and the catches were landed at PPS Kendari and PPP Sodohoa. Meanwhile, the fishing grounds for a PL boats are around Umbele Island, which is about 58 nm from Kendari, so it takes 7-8 hours from Kendari. PL boats catch bait and tuna in one fishing day and land the catch on a transport boats at Umbele Island to be transhipped to Kendari. The boats use the Umbele islands as the base for fishing activity. Figure 6 illustrates the general fishing strategy of PL boats based on Kendari, both for fishing boats and carrier boats.

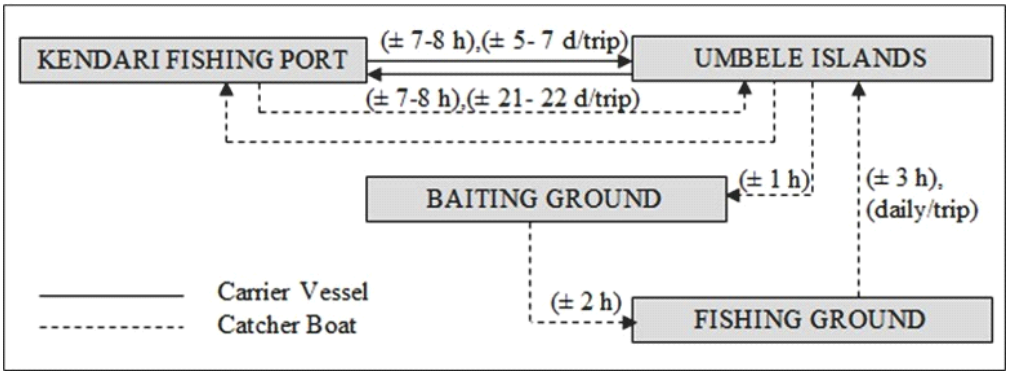

Figure 6. An illustration fishing strategy of PL boats based in Kendari.

PS boats located in Sorong typically operate as a group consisting of a PS catcher boat, 3–4 PS carrier boats (CBs), and 3–4 light boats (LBs). The group's fishing operation pattern is as follows:

1. The PS catcher boat goes on fishing trips that last longer than six months. The fish caught by the PS catcher boat are sent straight to CBs because the PS catcher boat can't hold all of the fish it catches.
2. Most of the time, the net is only set once over the course of a day or night. The tuna that a CB catches in Sorong is usually the result of three or four sets by a PS catcher boat.

aFAD success rate

The FAD success rate (FSR), i.e., successful FAD visits expressed as a percentage of the total number of FADs visited, The majority of the enumeration of FSR at Kendari and Sorong fishing ports focused on HL and PL boat activity. Table 1 summarizes some of the fishing trip characteristics and displays the results from 372 trips surveyed for HL boats and 112 trips surveyed for PL boats. According to interviews with skippers in Kendari, HL-TR boats had an average length of 7 fishing days (excluding days traveling to and from fishing grounds and any days lost to bad weather or gear issues, etc.). HL-TR visited 12 aFADs

on average throughout fishing trips, with a successful fish catch taking place after an average of eight aFAD visits (FSR = 64.9%). The Kendari PL fleet had a success percentage of roughly 65.9% for fishing operations lasting an average of two to three fishing days. The success rate for PL boats based in Sorong was much higher for excursions with an average length of six fishing days, at about 84.9%. The fact that aFADs were found to be "empty of fish" after sets by PS boats during the surveys in Kendari and Sorong frequently upset the captains of PL boats. The PS, PL, and HL-TR fleets' fishing grounds in I-FMAs 713–717 substantially overlap. The PL skippers in Kendari reported that it frequently takes at least 1 to 2 weeks for fish counts at the aFADs to "recover" following a successful PS set (Pers. comm. 2013).

Table 1. Summary of trip length (fishing days) and FSR, for HL and PL boats in Kendari and Sorong, based on information collected by this study during 2013 – 2014.

Location	Gear Type	No. Boat Trips	Average Number of Fishing Days	Average Number of FADs Visited	Average Number of FADs with Success	FSR (%)
Kendari	HL	372	7.2	12.1	7.5	64.9
	PL	21	2.4	2.1	1.0	65.9
Sorong	PL	91	5.8	4.5	3.9	84.9

Catch productivity

The average catch productivity of HL, PL Kendari, PL Sorong, and PS Sorong boats over 27 months (October 2013 to December 2015) fluctuated. The average catch productivity of HL Kendari boats is 1,135 kg per trip, or 160 kg per day. The average catch productivity of PL Kendari vessels is 2,819 kg/trip/boat. Estimating the total catch per trip for Kendari PL boats is difficult because the measurement is done on the carrier boats (CB) that land the catch in PPS Kendari, which may come from two or more fishing boats. Productivity estimation was only conducted on PL boats that landed catches on the last few trips directly at PPS Kendari without using carrier boats.

The catch productivity of PL vessels in Sorong during the same period (10,352 kg/trip/boat, or around 1900–2000 kg/day/boat) was higher than that in Kendari. The average number of days of a fishing trip for PL vessels in Sorong is 10 (the maximum is 27), with an average of 6 days spent actually fishing and an average of 4 days spent traveling to and from fishing grounds, looking for bait, or doing other non-fishing activities like boat engine repairs. The counting of CBs revealed that from 2013 to 2015, the average amount of fish that each CB in Sorong landed was 38,805 kg, 32,035 kg, and 30,721 kg (Table 2). If these landings are the result of captures from three to four sets of the PS net, the average catch per set was estimated to be between nine and twelve tonnes in 2013, eight to ten tonnes in 2014, and seven to nine tonnes in 2015.

Table 2. Summary of fishing trip, catch and catch productivity of HL, PL and PS boats based in Kendari and Sorong surveyed during the 27 month period (October 2013 to December 2015).

Port Sampling Program (Enumeration) Location								
Year	Kendari				Sorong			
	Gear : HL		Gear : PL		Gear : PL		Gear : PS	
	No . of trip surveyed	Catch rate (kg/trip/boat)	No . of trip surveyed	Catch rate (kg/trip/boat)	No . of trip surveyed	Catch rate (kg/trip/boat)	No . of trip surveyed	Catch rate (kg/trip/boat)
2013	76	1,078	7	1,694	9	6,388	5	38,805
2014	144	1,225	15	2,503	59	11,855	16	32,035
2015	144	1,102	3	4,260	24	12,813	23	30,721
Total	364	3,405	25	8,457	92	31,056	44	101,561
Average	121	1,135	8	2,819	31	10,352	15	33,854

Biological aspects of the tuna fisheries operating on aFADs

Catch composition

The results of the Kendari enumeration showed that at least 18 different species of fish were caught by the HL boats in the landings that were surveyed. *Thunnus albacares*, also known as yellowfin tuna (YFT), was the dominant species, accounting for 47.6% of the total catch (416,995 kg). During the study period, bigeye tuna-BET (*T. obesus*) made up 5.4% of the composition, while skipjack tuna-SKJ (*Katsuwonus pelamis*) made up 41.0%. Other species

only made up 6.0 percent by volume of the total catch, consisting of frigate tuna - FRI (*Auxis thazard*) 2.7%, black marlin- BLM (*Makaira indica*) 1.46%, kawakawa-KAW (*Euthynnus affinis*) 0.53%, bullet tuna-BLT (*Auxis rochei*) 0.43%, common dolphin fish-DOL (*Coryphaena* sp.) 0.24%, tiger shark-TIG (*Galeocerdo cuvier*) 0.17%, various sharks (*Carcharhinidae*) 0.16%, various billfish (*Istiophoridae*) 0.06%, blue marlin-BUM (*Makaira nigricans*) 0.06%, silky shark-FAL (*Carcharhinus falciformis*) 0.03%, scads-SDX (*Decapterus* spp.) 0.02%, blue sharks-BSH (*Prionace glauca*) 0.02%, striped marlins-MLS (*Tetrapturus audax*) 0.02%, narrow-barred Spanish mackerel -COM (*Scomberomorus commerson*) 0.01, and barracuda-BAR (*Sphyraena* spp.) 0.01%. The tuna catch volume of PL boats that were surveyed in Kendari was 62,193 kg over the study period. The catch volume was dominated by SKJ (73.2%) by volume and YFT (26.7%), while BET were recorded at only 0.1% of the landings.

About 1,064,424 kg of PL catches that landed in Sorong were surveyed over the study period. From the survey, 9 species of fish were identified - SKJ made up 75.6% by volume, YFT (19.6%), BET (3.5%) and the rest was other species with only 1.3% by volume of catch. The others species consisted of small tuna-indistinguishable as YFT or BET (0.6%), FRI (0.3%), KAW (0.2%), rainbow runner-RRU (*Elagatis bipinnulata*) 0.1%, casper-BRA (*Brama* spp.) 0.05% and DOL (0.05%). The tuna catch volume of CBs of PS boats landed that were surveyed in Sorong was 101,561 kg dominated by SKJ (81.0%) YFT (14.1%), BET (2.1%), with the rest of catches indicated as others recorded at about 2.7%, consisting of FRI (1.3%), KAW (0.9%), RRU (0.3%), and DOL (0.2%).

Fish size

There was a total sample of 10,522 SKJ, 7,513 YFT, and 2,435 SKJ measured during the research period from HL, PL, and PS fishing gear. Based on the characteristics of HL fishing operations in Kendari, they were divided into sHL-TR and dHL. In the years 2013–2015, the average FL of the subsample YFT caught by dHL in Kendari was 119 cm FL, 123 cm FL, and 121 cm FL, respectively. The average FL of subsample BET caught by dHL based in Kendari in 2013–2015 was 130 cm FL, 129 cm FL, and 131 cm FL, respectively. The size of skj caught by sHL-TR, PL, and PS ranged from 15–87 cmCL with an average of 38.9 cmCL. The average size of skj caught by PL in Kendari was higher when compared to other fishing gears. Table 3 presents a summary of the size distribution of SKJ, YFT, and BET tuna in Kendari and Sorong.

Table 3. The FL of SKJ, YFT, and BET caught by sHL-TR, dHL, PL and PS boats based in Kendari and Sorong, surveyed during October 2013 to December 2015.

Location	Gear Type	Species	Year	Min. Length (cm)	Max Length (cm)	Average Length (cm)	Number of sample measured (Fish)
Kendari	sHL-TR	SKJ	2013	21	41	31.5	456
			2014	20	48	32.3	1,235
			2015	24	41	32.6	1,543
		YFT	2013	29	41	34.0	718
			2014	22	41	34.5	1,240
			2015	22	45	33.7	830
		BET	2013	25	42	37.8	128
			2014	31	46	40.1	150
			2015	32	48	39.8	193
	dHL	YFT	2013	73	151	119	97
			2014	71	166	123	182
			2015	68	160	121	201
		BET	2013	70	165	130	55
			2014	78	159	129	73
			2015	75	163	131	71
	PL	SKJ	2013	30	46	37.3	651
			2014	30	87	42.2	855

Location	Gear Type	Species	Year	Min. Length (cm)	Max Length (cm)	Average Length (cm)	Number of sample measured (Fish)
			2015	26	73	49.9	580
		YFT	2013	34	47	40.8	332
			2014	30	82	41.0	514
			2015	29	82	50.0	629
		BET	2013	48	52	49.7	93
			2014	31	57	46.2	130
			2015	58	63	60.5	142
Sorong	PL	SKJ	2013	15	65	36.5	435
			2014	15	83	38.7	2,388
			2015	25	59	43.9	205
		YFT	2013	15	66	42.7	151
			2014	15	65	43.6	528
			2015	29	59	43.1	335
		BET	2013	27	65	48.0	170
			2014	18	85	46.5	221
			2015	25	58	44.5	215
	PS	SKJ	2013	21	52	41	311
			2014	28	49	40	964
			2015	26	51	42	899
		YFT	2013	29	60	48	221
			2014	27	53	46	714
			2015	28	56	43	821
		BET	2013	31	54	46	134
			2014	29	51	42	346
			2015	27	61	41	314

DISCUSSION

The design and construction of FADs in Indonesia is relatively similar to the design of FADs in general in Pacific Ocean waters, consisting of buoys, attractors, main ropes, and weights (Subani *et al.,* 1989; Itano *et al.,* 2004). FADs used in Indonesia are achored FADs. Monintja (1993) wrote about more than ten different types of FADs in Indonesia. Generally, they are only separated by the buoys they use, which are called “pontoon,” “rakit,” and “gabus.” The attractants used were generally made from natural materials, but some attractors made from pieces of plastic (synthetic raffia) were also found on FADs during this study. Based on current regulations (PERMEN No. 26/PERMEN-KP/2014), the use of non-biodegradable materials is prohibited. The Indonesian tuna aFADs provide little risk of turtle or other marine animal entanglement since nets and netting-like materials are not used as subsurface attractants on the aFADs.

The exact number and position of FAD deployments in Indonesia are currently unknown. Several FAD-related regulations have been published; however, they have not yet been implemented. Among these is the current requirement that the distance between FADs be at least 10 nm. There is substantial evidence to indicate that this condition is not being satisfied, as FADs have been observed in a number of instances to be considerably less than 10 nm. The Directorate General of Capture Fisheries (DJPT) of the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia faces one of its greatest obstacles in enforcing this policy effectively. It is clear that better communication between DJPT and fishing

companies, boat owners, and fishers is required, as is a focus on the benefits of reducing FAD density in certain locations (Cayré, 1991; Marsac *et al.,* 1998).

Based on the catch composition, the BET in the PL fishery in Kendari is lower than in Sorong and the previous study from 2007 to 2013 (2.9%) (Widodo *et al.,* 2016), and is therefore being handled with care at this point in the data analysis. It might be completely or partially explained by the enumerators' lack of expertise in estimating YFT and BET in small sizes. Bycatch of sharks and billfish by HL and PL boats in Kendari and Sorong was very low. Sharks and billfish only made up 1.9% of the total amount of fish brought in by HL and PL boats. There were no sharks or marlins landed by PL boats in Kendari or Sorong, nor by PS catcher boats (landed by CBs) in Sorong. Fishing vessels frequently discard prohibited fish species at sea, including sharks, but this is not documented, so capture is thought to be very low, if not negligible. In this situation, an observer program is necessary. This latter finding stands in stark contrast to the substantial quantity of shark—particularly silky sharks, Carcharhinus falciformis—reported as bycatch in the Papua New Guinea (PNG) PS fishery (Nicol *et al.,* 2009).

The majority of YFT and BET caught by the Kendari-based sHL, TR, and PL as well as the Sorong-based PL and PS were smaller on average than those whose initial gonadal maturity was reported (Lm). According to Mardlijah *et al.* (2012), the Lm of YFT is roughly 103 cm FL, while the Lm of BET is 102–105 cm FL (Schaefer *et al.,* 2005). However, the HL in Kendari caught YFT and BET fish that were bigger than Lm. Most of the SKJ caught by sHL, TR, and PL vessels based in Kendari, as well as PL and PS vessels based in Sorong, were below the reported SKJ Lm (40–42 cm FL) (Tandog-Edralin *et al.,* 1990).

FADs, especially anchor-FADs, could affect the ecosystem if they are used as tuna-towing equipment. Numerous earlier studies have been done on this topic, including those by Bromhead et al. (2000), Sokimi (2008), Ménard *et al.* (2000), and Freon and Dagorn (2000). These researchers' key finding is that purse seine fishing operations near FADs produce significant quantities of juvenile fish (YFT and BET) and pose a significant risk of overfishing. Another finding of this study was that in the waters of the eastern Indonesian archipelago, YFT and BET from the catches of SHL, TR, and PL also contained large numbers of juvenile fish.

CONCLUSION

Only aFADs are used in Indonesian waters, including in the eastern Indonesia tuna fisheries studied here, including purse seine (PS) fisheries. Three main fisheries were associated with aFADs i.e., PS, PL, and HL (including dHL, sHL, and TR). The PL based in Sorong had the highest FSR (84.9%) compared to other fisheries, including the PL and HL based in Kendari. Excepting the dHL, the fisheries associated with aFADs in eastern Indonesian FMA 713–717 include PS, PL, and s-HL–TR and have been shown to catch a large proportion of juvenile yellowfin tuna (j-YFT) and juvenile bigeye tuna (j-BET), which are below the reported lengths at first maturity (Lm). Overall, the proportion of by catch species (sharks and billfish) caught by PS, PL, and HL boats based in Kendari and Sorong was extremely low.

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