ISSF Technical Report 2018-06

CHARACTERIZING SMALL AND MEDIUM SCALE TUNA PURSE SEINE AND RING NET VESSELS IN INDONESIA

Photo: David Itano & Jefferson Murua

Jefferson Murua[1], David Itano[2], Anung Widodo[3] / **March 2018**

Suggested citation:
Murua, J., Itano, D., Widodo, A. (2018). Characterizing small and medium scale tuna purse seine and ring net vessels in Indonesia. ISSF Technical Report 2018-06. International Seafood Sustainability Foundation, Washington, D.C., USA

Topic Categories: Small-scale purse seiners; Indonesia; aFADs; bycatch; fishing technology

Abstract

The majority of tropical tuna landings result from free school or drifting fish aggregating devices (dFAD) fishing effort by fleets operating high-tech industrial-scale vessels in Exclusive Economic Zones (EEZs) of tuna-rich countries and the high seas. One notable exception is Indonesia, which is one of the principal tuna producers worldwide despite having primarily an artisanal and semi-industrial fleet that utilizes anchored FADs (aFADs) within its Western Pacific and Eastern Indian Ocean EEZs. Purse seine is the principal gear type for tuna catches in Indonesia, consisting of a variety of sizes and types of ringnet and surround net vessels that operate in Indonesian waters for which little literature exists. Understanding the technical characteristics, target species and fishing operations for each seine vessel class is necessary for better evaluation of fisheries impacts, more precise stock assessment and development of relevant harvest and bycatch mitigation practices. This document provides insight into the technical and operational details of the diverse range of Indonesian tuna purse seine boats and fisheries operating in the Indian and Western Pacific Ocean.

Author Information

Jefferson Murua | AZTI-Tecnalia, Marine Research Division
Txatxarramendi Ugartea z/g, 48395, Sukarrieta, Spain

David Itano | Fisheries Consultant
689 Kaumakani Street, Honolulu, Hawaii, USA

Augustinus Anung Widodo | Center for Fisheries Research
Ministry of Marine Affairs and Fisheries Republic of Indonesia

March 2018

The research reported in the present Technical Report was funded by the International Seafood Sustainability Foundation (ISSF) and conducted independently by the author(s). The report and its results, professional opinions, and conclusions are solely the work of the author(s). There are no contractual obligations between ISSF and the author(s) that might be used to influence the report's results, professional opinions, and conclusions.

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Executive Summary

Some East Asian tuna purse seine fleets that are primarily composed by large numbers of artisanal and semi-industrial vessels fishing on fish schools aggregated to anchored FADs (aFADs) make a significant contribution to global catches. The Indonesian fleet is a prime example, yet there is little information available on gear and technology, operational details and type of catches for these small-sized purse seine vessels and fleets.

Based on a series of collaborative ISSF workshops between scientists and Indonesian skippers from 2012 to 2017, including vessel visits to the principal Indonesian tuna ports in the Western Pacific Ocean and Indian Ocean, first-hand information on vessel characteristics and fishing practices has been collected for ringnet and purse seiner gears. Vessel categories are divided for descriptive purposes in the report by capacity size into <30 GT, 30-100 GT and > 100 GT.

General construction of anchored FADs (aFADs) are shown with different types of rafts (e.g. house rafts, pontoons, foam blocks), all being classed as non-entangling. Catch pre-estimation methods for aFADs such as divers, handlines or echo-sounder is documented. The operation of setting on an aFAD is similar for most small-purse seine types, beginning the set a few hours before sunrise in the dark with the help of auxiliary vessels with lights to attract and concentrate tunas. Very small net vessels ("payangs") with small storage capacity operate closer to the coast and tend to return frequently to port while larger purse seine vessels fish in the outer EEZ and remain at sea for several months at a time, with carrier vessels delivering the catch to port. Recent Indonesian government regulations have limited to some extent the operations of larger semi-industrial sized vessels.

Catches are mostly composed of skipjack, small-size yellowfin and bigeye tuna, neritic tunas (e.g. bullet tuna (*Auxis rochei*), frigate tuna (*Auxix thazard*) and scads. As most aFAD attracted finfishes are also retained (e.g. rainbow runner, mahi-mahi, etc.) and locally consumed, bycatch only comprise Endangered, Threatened and Protected (ETP) species that have non-retention regulations such as sharks, manta rays or marine turtles, which are encountered less frequently. Due to technological and size limitations, bycatch mitigation measures in these smaller vessels require a different approach to super-seiner fleets.

Improving knowledge on fishing technology and operational practices for small-vessel gears is the first step in trying to find efficient ways to improve bycatch mitigation and to assess the real scale of impacts of these fisheries on stocks, ETP species and ecosystems.

A short description of small purse seine tuna vessels in the Vietnamese fleet is also included (Appendix I).

Key Findings:

1. The Indonesian purse seine fleet is composed of a variety of wooden-hull small-scale vessels ranging from 5 to 250 GT fishing with lights on anchored FADs for tunas and associated finfish species. All of these vessels are built in Indonesia of locally sourced tropical woods.
2. Specific characteristics of fishing gear, technology and operations are illustrated for the various surround net vessel sizes described.
3. Due to limited technology and net and deck size restrictions, bycatch mitigation solutions for small-scale purse seiners need to be specifically designed and tested.

Research Questions

- What are the characteristics (e.g. vessel size, net size, well storage, hauling system, etc.) of tuna purse seiners in the Indonesian fleet?
- What kind of fish aggregating devices (FADs) are used by the Indonesian tuna fleet?
- How do Indonesian small-scale purse seiners pre-estimate catches before setting on FADs?
- What is the composition of the tuna and FAD-associated species in the catch for each vessel category?
- Which species are considered bycatch in the Indonesian fishery?
- What bycatch mitigation options are best suited for small-scale tuna purse-seiners?

I. Introduction

Currently in most regions worldwide large-scale purse seiners (> 335 m3 fish hold volume) are the principal source of tropical tuna catches (Miyake et al., 2010), with around 725 vessels having a combined fish hold volume which can be taken as a proxy for fishing capacity of 880,000 m^3 (Justel-Rubio and Restrepo, 2016). The largest vessels, known as “super-seiners” have over 1000 metric ton fish-hold capacity and utilize state-of-the-art sonar, radar, echo sounders and echo-sounder buoys to locate and efficiently exploit large tuna schools (Itano, 2002). While Philippines, a primarily artisanal tuna fleet, also flags some large scale and super-seiner class vessels that fish in the archipelagic waters of Papua New Guinea and open waters of the Western Pacific (Justel-Rubio and Restrepo, 2016), Indonesia have few or no large-scale tuna fishing vessels currently in operation. This trend was emphasized when the Indonesian government banned all fishing vessels with foreign-built hulls in 2015 and prohibited new licenses to vessels over 150 GT. Vietnam is another example of an east Asian country with a tuna purse seine fleet composed of small to medium-scale vessels. Compared to super-seiner standards, these fleets consist of small rudimentary wooden hulled vessels equipped with few or no technological aids. Many small surround net boats are “artisanal” and family owned, with the captain usually being the ship-owner as well. Despite having fleets primarily composed of small (e.g. < 30 GT) and medium (e.g. 30-100 GT) size vessels, countries like Indonesia, Philippines and Vietnam make considerable contributions to global catches of tropical tunas and tuna-like species. For example. Eastern Indonesian reported catches alone account for 15 percent of the skipjack, yellowfin and bigeye catch in the Western and Central Pacific Ocean (WCPO), the largest tuna fishery in the world (Williams, 2009).

The number of artisanal and medium-sized tuna boats operating in the Southeast and East Asian region is very large. Outboard and inboard motorized fishing vessels in Indonesia range between 160,000-180,000 and 80,000-90,000, respectively (Williams, 2009). Indonesia has over 3000 small and medium size tuna vessels registered (http://rvia.kkp.go.id/data-kapal) and Vietnam has more than 700 tuna purse seiners in this size range (WCPFC, 2013). Based on tuna catch volume, surround net boats (e.g. purse seine, lampara net and ringnet) are the principal gears in these regions, but neritic and large tuna are also caught by many other gears including pole and line, longline, handline, liftnet, gillnet, bag net or troll line.

These smaller vessels are widely distributed across numerous ports, and fishing trips range from day trips in coastal waters by the smaller boats, to several months in the outer areas of their EEZs for the medium sized purse seiners with operation in both the WCPO and the eastern Indian Ocean. Fishing strategies also vary from vessels working alone to group seine operations consisting of catcher vessels supported by multiple auxiliary and carrier vessels. Some information on small tuna vessel operational strategies has been published for the Philippines (e.g. Macusi et al., 2015), and little information, except for some recent work like that of Widodo et al. (2016), is currently available on the Indonesian fleet. A common feature among these artisanal and commercial tuna vessels is their strong reliance on anchored fish aggregating devices (aFADs); known as “rumpons” in Indonesia or “payaos” in the Philippines. The general implementation of purse seining on aFADs by the 1970’s in Philippines and Indonesia dramatically increased catch rates of tuna and small pelagics (Kawamura et al., 1983; Dickson and Natividad, 2000; Indonesia, 2016). Increased catches of undesirable sizes of juvenile bigeye tuna and incidental bycatch of species of concern like sharks and turtles have been linked to the use of FADs (Fonteneau et al., 2013). Occasional opportunistic sets on natural floating objects (e.g. logs, dead whales) or drifting FADs that have broken loose from their mooring or industrial drifting FADs (dFADs) occur in Indonesian waters but are rare.

Despite recent programs to improve tuna fishery catch and effort data collection in East Asian small-vessel fleets, such as the Western Pacific and East Asian Sustainable Management (Vietnam, 2013; Gillett, 2013), there are still significant information gaps needed to accurately assess their impacts. One critical missing element is the lack of literature on the technological characteristics, fishing operations and targeting characteristics of the diverse types of small and medium sized seiners in East Asian fleets. This basic data is necessary for reliable catch-per-unit effort (CPUE) indices and better-informed stock assessments. Furthermore, understanding the fishing and storage capabilities of each kind of vessel, catch efficiency, effort creep and impacts on target and bycatch species, is essential for developing relevant management measures and bycatch mitigation solutions. Species targeted by each vessel class in small-sized seiners can vary from small coastal pelagic species like scads (*Decapterus spp.*) and neritic tuna (*Auxis spp.*, *Euthynnus affinis*, *Thunnus tonggol*) to skipjack tuna (*Katsuwonus pelamis*) and potentially larger species like bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*). However, most of the *Thunnus* species taken by these fleets are very small juveniles. Other aFAD-associated finfish species such as dolphin fish (*Coryphaena hippurus*), rainbow runner (*Elagatis bipinnulata*) and wahoo (*Acanthocybium solandri*) are also harvested. In fact, except for turtles, sharks, and manta rays there is full utilization of most aFAD non-tuna species that are consumed by the crew or are locally marketed.

Promising FAD bycatch mitigation approaches like acoustic selectivity (e.g. bigeye, bycatch and small tuna discrimination with echo sounders and echo-sounder buoys) or net modifications (e.g. shark release panels, sorting grids) focus on large-scale purse-seiners which use sophisticated acoustic instrumentation and large nets (e.g. >1500 m length and > 150 m depth) (Restrepo et al., 2016). Due to their small size, low level of technology and high utilization rates, small-scale vessels require different custom-designed bycatch reduction solutions (Murua et al., 2017). The FAO reports on small-scale boat fisheries highlight the need for more technical details to solve bycatch issues (Gillett, 2011). The first step to design efficient bycatch solutions is to understand specifics on equipment used in these boats (e.g. net size, mesh size, deck space, acoustic equipment, fish storage) and operational characteristics (timing of setting, trip duration, use of auxiliary vessels, etc.).

This document attempts to provide an overview of the kinds of tuna and other finfish species surround net boats harvest in Indonesia and describe their fishing practices based on information collected during port visits and ISSF Skippers Workshops between 2012 and 2017. This information can be of use to fisheries scientists and managers who can benefit from a better understanding of the technical and operational characteristics of the small and medium purse seine vessels used in tuna aFAD fisheries to address bycatch and capacity issues.

II. Methods

Between 2012 and 2017 the International Seafood Sustainability Foundation (ISSF) sponsored a series of participatory approach bycatch reduction workshops with tuna purse seine skippers in Indonesia and Vietnam. A total of 18 workshops covered Indonesia's Indian Ocean ports (e.g. Banda Aceh, Sibolga, Benoa) and Western Pacific ports (e.g. Jakarta, Kendari, Bitung, Ambon, Makassar, Manado) (Murua et al., 2018; Table 1). Over 600 participants attended these workshops, 65% (n=395) being vessel captains, and the rest relevant stake holders like other fishing crew, fleet managers, port managers, or national fisheries scientists. Throughout the workshops semi-structured questions on type of vessels, fishing gear, aFAD use, fishing strategy and bycatch release practices were discussed openly with fishers.

Table 1. ISSF Skippers' Workshops in Indonesia by locations and participation by work group category (2012-2017).

Year	Location	Skippers	Crew	Fleet Managers	Fleet reps	Officials	Scientists
2012	Bitung (Sulawesi)	20	0	0	0	25	3
	Jakarta (Java)	13	1	0	0	10	3
2014	Jakarta (Java)	21	2	0	1	1	3
2015	Jakarta (Java)	8	14	0	5	0	4
	Bitung (Sulawesi)	21	13	0	1	1	2
	Sibolga (Sumatra)	22	15	0	0	1	1
2016	Bitung (Sulawesi)	27	1	0	0	1	10
	Kendari (Sulawesi)	32	0	3	1	3	10
	Benoa (Bali)	21	0	0	6	0	0
	Sibolga (Sumatra)	15	0	7	1	2	0
	Lampulo (Banda Aceh)	23	0	0	8	0	0
2017	Kendari (Sulawesi)	23	9	0	0	4	0
	Makassar (Sulawesi)	20	8	0	0	3	0
	Manado (Sulawesi)	35	6	0	0	1	0
	Ambon (Molucas)	22	1	0	0	4	0
	Sibolga (Sumatra)	16	19	3	0	0	0
	Lampulo (Banda Aceh)	23	4	1	0	2	0
	Jakarta (Java)	33	3	0	0	0	0
Total		395	96	14	23	58	36

Immediately following the conclusion of the workshops, multiple vessels were visited at key ports to examine first-hand the vessels, gear, fishing methods and aFAD materials and support used in each region. Even within a single port, a variety of small and medium scale tuna vessels could be observed. In addition, meetings with government fisheries managers were held to better understand the operation of each fishery and current conservation measures. Local markets were also inspected to learn more about fish species utilization.

III. Discussion

1. Anchored FADs

FADs are used by many fisheries around the world not only to attract tuna but also to aggregate other coastal and pelagic species exhibiting associative behavior (Castro et al., 2002). Two types of FADs exist depending on if they can freely move in the water, drifting FADs (dFADs), or are moored in a fixed location, anchored FADs (aFADs). Artisanal aFADs have been used for centuries in Eastern Asia, but in the last four decades their use has increased exponentially in conjunction with purse seine fishing, greatly increasing fish catches (Monintja, 1993). Gershman et al. (2015) estimated there are about 30,000 dFADs in the WCPO but did not include data for aFADs in the Philippines and Indonesia due to the lack of reliable data on their abundance. Scott and Lopez (2014) calculated about 12,700 aFADs in tuna fisheries worldwide, with Indonesia and Philippines being the top FAD-using countries. Meanwhile, small and medium commercial purse seine landings in Eastern Asia derive exclusively from floating object sets, primarily on aFADs but occasionally on encountered natural floating objects like logs, seaweed mats, marine debris or even encountered dFADs. Floating objects are known to strongly improve tuna catchability as fish schools collect around them and are less likely to display escape responses before the set, particularly if the set is made before dawn (Fonteneau et al., 2000). Use of aFADs is especially useful to small purse seine vessels that are slow (e.g. 6-8 knots) with relatively small and shallow nets compared to super-seiners. Attempts by these vessels to catch fast-moving free schools of tuna will usually result in a failed or null set. Not only purse seiners, but other fishing gears have greatly benefited from reduced search time and higher fish concentrations afforded by aFADs. For example, Monintja and Mathews (1999) estimated that the introduction of aFADs, in conjunction with carrier vessels, in Indonesia in the 1980’s increased CPUE of pole and line vessels by 41% and reduced their fuel consumption by 46%.

There are four main components of an aFAD: (1) a surface float, (2) a subsurface attractor, (3) a mainline to the seafloor and (4) an anchor weight. In Indonesia aFADs, generally known as “rumpons” (other regional names including “tendak” in West Java, “uncang” in Sumatera or “rompong” in Sulawesi) have been utilized for centuries to attract tuna (Monintja, 1976). Early traditional aFADs were constructed using large bamboo rafts. Some bamboo rafts have a small hut on top, these house aFADs are known as “rakit” in Indonesia. The purpose of the man living on a house aFAD is to notify his company by radio when a good aggregation is present for purse seining and to discourage unauthorized vessels from fishing on it (Fig 1). Currently, the use of bamboo rafts as a float has lost prevalence and more durable modern synthetic materials are replacing them. Two float types are primarily used East Asian countries. One type is made with polystyrene foam filled cylinders or pontoons (“ponton” in Indonesia) which are either encased in a solid steel structure with a conical shape, often built by welding several metallic drums (Fig. 2), or more commonly composed of fiberglass (Fig.3). The cylinders are about 3 m long and 0.8 m in diameter with a pointed end that faces into the current. Pontoons have two metallic rings, that attach to the mooring rope and the fish attractor rope, often with rings made from automobile tires for shock absorption. The other type of float which has been observed increasingly in recent years in Indonesia is a cylindrical styrofoam block encased in a weather-resistant plastic cover, known as “gabus”. This float is much wider (e.g. 2 m diameter) and shorter (e.g. 1.5-2 m length) than the pontoons and has rope around it to hold the attractor and anchor line. The gabus floats observed in port visits since 2012 have been mostly pre-fabricated, often encased with red or orange colored plastic (Fig.4). Other more rudimentary gabus models have been described by Widodo et al. (2016) in which foam blocks are wrapped in cloth and bound by rope and motorcycle tires and have a wooden frame for structural support. Some benefits of the gabus float are lower price, much lighter weight for transport and can also prevent damage to the vessel and FAD float if it is accidentally struck while maneuvering during fishing operations. Some floats might carry a small flag attached on top to increase visibility when searching for the aFAD.

Figure 1. *Bamboo-built aFAD house, called "rakit" in Indonesia*

Figure 2. *Steel aFAD pontoon or "ponton" in Bitung (Sulawesi)*

Figure 3. *Fiber glass aFAD pontoon or "ponton" with a steel plate fastened to the fiberglass to which the steel ring is welded in Benoa (Bali)*

Figure 4. *Plastic encased foam block or "gabus" aFAD in Jakarta (Java)*

Underneath the float are the submerged anchorage line and attractor structures. The longest element is a 2.5-4.0 cm diameter polypropylene or polystyrene rope which holds the raft to the sea bottom. Sometimes the top section of the rope has a metal core to prevent aFAD sabotage by rival vessels or shark damage. The rope can be a few dozen to several thousand meters long depending on the depth of the sea floor. Anchorage depths can reach even 6000 m, but depths of 2000-4000 m are more common. The length of the mooring line is usually 1.3 to 1.5 times the depth to the seabed, to account for variation in tidal changes and swell effect. At the end of the mooring rope there are weights to hold the aFAD securely in place. Traditionally rumpons used stones as sinkers, but these days most are made by linking several concrete-filled steel petroleum drums with a motorcycle tire for attachment, each weighing around 60-100 kg (Fig.5). Sometimes small counter weights (e.g. 20-30 kg) might be hung half-way down the mooring rope to keep it vertical. Swivels may be included in the mooring to add weight but mostly to reduce pulling and twisting force stress that can result in anchorage rope failure.

Figure 5. *Anchorage rope and concrete weights for aFAD construction onboard purse seiner in Jakarta (Java)*

The second submerged structure is a shorter rope reaching down vertically 20 to 50 m below the float. This rope has suspended palm leaves attached, often nipa palm (*Nypa fruticans*; Fig. 6) or coconut palm (*Cocos nucifera*). Note that current Indonesian regulations prohibit the use of non-biodegradable attractor materials (e.g. plastics). Due to natural decomposition and degradation of the submerged palm leaves, they are replaced on a regular basis every one or two months. These appendages are believed to help attract small fish and tuna to the aFAD by creating a favorable micro-habitat with shade, food and sheltering spaces. Visual and sound stimuli produced by leaf movement and even perhaps odors emanating from the fronds' oil could help with location by the first colonizing species, and other fish follow. Many species show aggregative behavior under floating objects, and surveys in the Indian Ocean have identified more than 30 fish species under FADs (Taquet et al., 2007). Individuals of the larger tuna species, like bigeye and yellowfin tuna, are predominantly juvenile specimens below their reproductive size, whereas larger adult specimens tend to forage in free schools or individually at greater depths (Fonteneau et al., 2013; Hall and Roman, 2013).

Figure 6. *Nipa palm and coconut frond aFAD subsurface attractor material in Sibolga (Sumatra)*

Unlike traditional dFADs which use old netting to cover the raft or build the submerged appendage, there is virtually no netting material in aFAD construction. These aFADs belong to the non-entangling category, meaning they do not ghost fish FAD-associated species of concern like sharks or turtles through entanglement. Another difference with dFADs is that they do not require a tethered GPS buoy to locate the floating object, as their position is stationary and known to the owner vessels. Only one account of echo-sounder buoy use in aFADs was reported by a Jakarta port-based company in 2016. Buoys fitted with echo-sounder can offer hourly or on request remote estimations of fish biomass under a floating object and send this information via satellite to the owner vessel. The ship-owner found the information provided by the echo-sounder buoys useful to avoid inspection trip costs to empty aFADs (e.g. wasted time, fuel) but stopped using them due to their cost (e.g. > US $1000 per echo-sounder buoy) and most were quickly stolen. Capacity for an aFAD to replenish with fish after a successful set can vary between a few days to several months (Monintja and Mathews, 1999), so fishers usually will not inspect an aFADs until at least 4-5 days have passed since the last successful set.

The Indonesian government has passed several FAD-related regulations and legislation in recent years, including a National FAD Management Plan for 2015-2017 (DGCF, 2014) and National Tuna Management Plan (MMAF, 2015). Although regulation No. 26/Permen-KP/2014 states that all aFADs must be registered and establishes limits on their numbers (e.g. 3 aFADs per vessel) and densities (e.g. minimum 10 nm separation between aFADs) (Table 2), control and enforcement of these rules has generally been lacking. Based on Indonesian skippers' feedback, the number of aFADs per vessel can vary depending on the fishing company's resources from one or two units for very small vessels up to a dozen aFADs for the larger boats. This number of aFADs per vessel is still lower than that reported in the Philippines (20-50 aFADs per vessel; Dickson and Natividad, 2000) and much lower than super-seiner class vessels in the Western and Central Pacific which can deploy hundreds of dFADs per year (Scott and Lopez, 2014).

Many small and medium scale boats generally carry materials onboard for one or two aFADs in case they need to repair or replace heavily damaged or lost aFADs (Fig 5). Fishers in Sulawesi (Indonesia) estimated that each medium-scale vessel on average may lose 4 to 6 FADs a year. Monintja and Mathews (1999) reported losing over 50 per cent of aFADs spread across Indonesian islands after two years. Regarding aFAD densities, at recent workshops fishers estimated distance between aFADs to be more likely between 3 to 5 nm. Despite a general lack of enforcement of FAD regulations by

Indonesian governmental authorites due to the challenges of monitoring an EEZ that covers 5.8 million km2, local fishers' associations or "sasi" practice some forms of self-management of marine resources, including rules on FAD distribution and use (McLean, 2017). For example, there is an unwritten consensus among fishers that unless an aFAD has been abandoned for 3 months, another vessel is not allowed to fish there or deploy a new aFAD nearby.

Note that often many of the aFADs in non-Asian Indian Ocean and WCPO islands are set up by public funds in small numbers to support community-based artisanal fishers that use fishing methods that do not use netting or surround net techniques. These aFADs are in general structurally more complex, built to last longer, and are more expensive (Leproux, 1998; Desurmont and Chapman, 2000) designed and deployed to support troll, handline and vertical longline fisheries. On the other hand, the strategy of commercial fishing companies with higher numbers of aFADs is to build simpler and cheaper units to reduce costs, even if life span is shorter on average (e.g. 6 months to 1 year).

Many small and medium sized vessels in Vietnam and in specific regions of Indonesia, like Ambon, do not use traditional aFADs for fishing. Instead they just utilize a light source to attract fish schools and make a set on them. The light source is provided by a lamp hanging from a small auxiliary vessel. Technically speaking the use of any artificial object with the intention of attracting fish under it is considered a FAD by the WCPFC, so this kind of fishing would still be considered "FAD associated" and not free-school effort.

Table 2. Indonesian regulations relating to tuna purse seine fisheries.

INDONESIAN FISHING REGULATIONS	
No.26/2014	FAD registration and management
No.56/2014	Moratorium fishing permits vessels greater than 150 GT
No. 57/2014	Prohibition of transshipment at-sea in EEZ
No. 4/2015	Closure of Banda Sea
No. 2/2015	Prohibition on trawling net ban and other gears like *payan* (small PS)

2. General description of FAD fishing operation

Before conducting a set the captain must decide if the aggregation of fish under the floating object is large enough to be worth deploying the net. Currently, super-seiners receive remote information on fish biomass under dFADs through satellite linked GPS buoys equipped with echo-sounders that allows them to concentrate effort on larger tuna aggregations. On the other hand, aFADs are not fitted with echo-sounder buoys and need to be checked in situ by auxiliary ranger vessels, other fishing vessels of the same company or the catcher vessel itself. Pre-estimation of catch to assess the quantity and quality of fish in an aFAD is done by several low technology methods which include: (1) deploying skin divers (called "buceros" in Philippines), (2) fishing with a line, and (3) use of a basic echo-sounders on the vessel. These pre-assessment methods are not exclusive and may all be used in combination to obtain more information. If fishers have made a set on an aFAD, they usually will not revisit that aFAD for several days to allow some time for the fish aggregation to replenish. As aFAD sets in the WCPO occur early in the morning, fishers may inspect the floating object on arrival the day before to check for fish presence. The aFAD will be inspected again by divers assisted by light and with the vessels' echo-sounder during the nighttime before the final decision to make a set.

Sets on aFADs are somewhat different from sets on free-floating objects like logs or dFAD. In the later, the catcher boat can set the fishing net around the floating object, which stays in the center of the net circle until the purse cable is closed. The log or dFAD can then be towed out over the net cork-line with an auxiliary vessel or lifted out of the water onto the vessel's deck with a crane. In this way, the pursing and net hauling process can proceed without risk of the boat's net becoming entangled with the encircled floating object. With aFADs the presence of a fixed mooring line under the raft prevents this form of setting operation. The fixed mooring line must be excluded as otherwise it would tangle in the net or purse cable, thus jeopardizing the fishing operation. The following section describes how the aFAD setting operation is carried out.

Preparations for a typical aFAD set by a small or medium sized vessel in the WCPO starts the night before or at least several hours before dawn (e.g. 3 am), when a small auxiliary vessel equipped with a diesel-powered generator ties up to the aFAD and illuminates the water with a powerful artificial light either suspended just above the water surface or an underwater setting using a special water-resistant light source. Originally kerosene or pressure gas lamps where used to light an aFAD prior to setting. In the dark, light sources are believed to enhance fish attraction closer to the sea surface. It also enables divers to make visual inspection to pre-estimate the type and quantity of fish in the aggregation. In addition to the light, the auxiliary vessel will either carry underneath its own "attractor" line with palm fronds like those of the aFAD or detach the palm attractor line from the aFAD and tie it to itself. The objective is to lure the fish aggregation away from the aFAD and keep it under the auxiliary vessel. For this, the auxiliary vessel with the light and palm leave attractors will slowly drift away down current from the aFAD. The auxiliary boat with the fish aggregation must travel far enough (e.g. > 500 m) so that the catcher vessel can set the purse seine around the light boat without risk of tangling with the aFAD's mooring line. Another tow boat may be utilized in some cases to tow the aFAD and mooring line up current, to separate it as much as possible from the catcher vessel.

Approximately one to one and a half hours before sunrise the set will commence and the catcher vessel will set its net surrounding the auxiliary vessel with the fish. Once the purse seine net has been set around the aggregation, the pursing operation commences. Large purse seiners have a dedicated purse winch that draws in cable running through rings at the chainline from the stern and bow directions to fully close the bottom of the net (Fig.7). The smaller surround net and ring net vessels of East Asia use a variety of winches or mechanical systems to close the net. A typical arrangement will have two horizontal capstans that are used to manually haul a purse rope turned around the capstan drums (Fig. 8). On smaller vessels, motorized haulers are used to assist the pursing operation. The pursing operation should be well advanced while in the dark, to prevent fish being able to see any opening in the net that may trigger an escape response and result in loss of catch. The setting and pursing is timed so that once pursing is complete, the rising sun makes the net visible to the encircled tuna which prevents excessive gilling and tangling in the purse seine.

***Figure** 7. Typical hydraulically powered purse winch on the deck of a super-seiner vessel to close the purse and haul in the net's cable*

***Figure** 8. Two horizontal capstans to manually haul the purse rope in Bitung (Sulawesi)*

Once the pursing operation is complete and the net fully closed, the net hauling can begin. Net retrieval methods vary from manual pulling and lifting to mechanical assistance with rope slings taking one section of net at a time. More sophisticated vessels haul net with hydraulic power blocks of varying size depending on vessel type and configuration. Power blocks can be small deck mounted gear or the typical power block arrangement at the end of a long boom that extends over the stern area of the vessel (see examples in sections 3.2 and 3.3). Crew in medium sized boats can range from 20 to 35 fishers depending on the amount of mechanical equipment onboard. On these small and medium scale vessels, the net is usually piled on one side of the vessel, rather than at the stern as for larger purse seine boats. Pursing and hauling of the net can take between 30 to 120 minutes or more depending on net size and environmental conditions (e.g. bad weather, current), tonnes caught, size of the net and method of net retrieval.

Once net hauling is nearly complete the catch must be concentrated near the vessel in an operation commonly called "sacking up". This is accomplished by taking bights of the netting that is hauled up with hydraulic winches until the catch is raised close to the surface in a pocket of heavy netting. Once this operation is complete the catch can be scooped or brailed onboard. Maximum set catches can range between 15-25 tonnes for larger medium-sized vessels, but generally catches are much smaller, even below 1 tonne/set for smaller vessels. For very small vessels, sacking up can be done manually if the catch is not too large. However, for most operations, sacking up can only be accomplished by lifting heavy bights of the net with rope slings and hydraulic winches or pullers. Repeated operations concentrate the catch and brings the fish close enough to the surface to allow brailing or loading of the catch to iced or refrigerated fish holds. Brailers are basically round scoop nets that can be closed and opened much like a miniature purse seine to facilitate efficient catch loading. Brail capacity varies between vessels of different size, but the largest brails for Indonesian purse seiners can accommodate up to 3 tonnes per operation. Brails are either unloaded to the catcher vessel's wells located below the center of the top deck (single seiner operation), or in other instances catch is brailed directly to an accompanying carrier vessel (group seine operation) (see section 3.2). Some of the larger boats can have wells with a refrigeration system, although many are just cooled with ice blocks and seawater brine. The catch can be stored in ice in the wells or can be sorted by species and sizes in small metallic trays (e.g. 3-5 kg holding capacity) that are then frozen in blast freezers (Fig. 9).

Figure 9. *Trays with blast frozen tunas at Jakarta market port (Java)*

3. Overview of Indonesian surround net boats by size class

According to the online Indonesian fisheries agency database R-VIA (http://rvia.kkp.go.id/data-kapal) in 2017 there were 3,400 records of authorized vessels fishing for tuna. Registered small and medium scale vessels are divided into three categories according to gross tonnage: vessels under 10 GT (684 or 20%), between 10-30 GT (587 or 17%) and > 30 GT (2130 or 63%). The target species, fishing gear and operations conducted in each size category differs and better understanding of these characteristics is required to improve tuna fisheries management. Table 3 shows a simple classification by gross tonnage based on types of boats, gear used, fishing area and fishing operation characteristics.

Table 3. Indonesian tuna purse seine vessel general attributes by size category.

	Vessels under 30 GT	Vessels 30–100 GT	Vessels over 100 GT
GT	5-30	30-100	100-250
LOA (M)	5-24	20-35	> 30
TARGET FISH	Scad, SKJ and neritic tuna	SKJ, YFT and BET	SKJ, YFT and BET
HULL	Wooden beam	Fiberglass over wooden beam	Fiberglass over wooden beam
NET	Size: 100-400 m length; 20-60 m depth Small mesh size	Size: 350-650 m length; 80-100 m depth	Size: 800-1200 m length; 80-150 m depth
ENGINE (HP)	1-4 small outboards	In board	In board
TECHNOLOGY AND FISHING OPERATION	No or few technological aids. Sets on aFAD at dawn. No powerblock.	Radio and simple echo-sounder. Some powerblock. Sets on aFAD at dawn.	Radio and high-tech echo-sounder. Powerblock. Sets on aFAD at dawn.
FISH HOLD	Storage using ice in wells onboard	Storage using trays with ice in wells, others refrigeration coils. Often unload to carrier vessels	Storage in refrigerated wells. Often unload to carrier vessels
ASSISTING VESSELS	Small lightboat. Sometimes work in pairs	Small lightboat, tender vessel, skiff	Small lightboat, tender vessel, skiff
FAD TYPE	aFAD	aFAD	aFAD
FISHING AREA	Coastal (0-100 nm)	Offshore within EEZ (100-200 nm)	Offshore within EEZ (100-200 nm) and international waters
FLEET (PORT)	Indonesia (most ports)	Indonesia (most ports)	Indonesia (few ports like Bitung)

The following paragraphs will describe an overview of some artisanal to semi-industrial tuna seiner types currently operating in Indonesia.

3.1. VESSELS UNDER 30 GT

3.1.1. General description < 30 GT

In Indonesia 1270 tuna vessels in this size category were registered in R-VIA (as of June 2017). Vessels between 5 GT and 30 GT are register at province rather than national level. Those under 5 GT, which by number constitute most of fishing boats (e.g. 1-2 fishermen operated tuna hand liners), should be licensed at the district level but many are likely to be unregistered. The small-scale tuna boats could be classed as “artisanal” and use a small number of aFADs. These smaller purse seine vessels operate close to the coast, with aFADs being near shore, usually within 20 km from the coastline and in shallow waters (50-200 m depth). In Indonesia the local government, through Law No.23/2014, manage marine resources within 12 nm of the coastline, and are the principal authority dealing with small scale vessels and near-shore fisheries.

The lampara net boats or “payangs” are the smallest Indonesian size of surround net vessel, of 3 to 5 GT (Fig. 10) The lampara or Danish net is considered the precursor of purse seining, and the nets are smaller and lighter than purse seines. The lampara still surrounds the shoal of pelagic fish but does not have a purse line like purse seiners to drawn the bottom of the net together to prevent catch losses of diving fish trying to escape. The footrope is fixed to the bottom of the netting by short ropes instead. Another significant difference is that lampara have the bunt or sack in the middle of the net and both net ends or “wings” are hauled in at the same time, whereas purse seiners have the sack or bunt in the end section and the net is hauled in from opposite end only. As the leadline is shorter than the floatline when the wings are hauled together the net forms a characteristic “spoon” shape that traps the catch. The lampara net consists of three parts: wings, body, bag/sack, with mesh size decreasing in the same order from 10-35 cm, 0.4 cm, to 0.1 cm while increasing in twine diameter and strength (Rochmaniah, 2015). Up to 12 fishers crew the boat to deploy and haul the net manually. Most payangs target small coastal or pelagic fish such as scads, mackerels, sardines, herrings, trevallies, Spanish mackerel, anchovies, small tunas and hairtails (*Trichiurus spp.*). These vessels use coastal rumpons and kerosene lights at nigh to attract fish. The recent fishing prohibition of trawlers by Indonesian law also included some gears like the payang. It is unknown if this regulation has been strictly implemented and has seriously reduced the number of these vessels.

Figure 10*. Lampara or “payang” vessel at Pelabuhanratu port (Java)*

A more advanced form of surround net is the ringnet, which is the precursor of the purse seine. Like the lampara, the ring net has wings and a central bunt but also includes rings on the lower edge of the net through which a pursing line passes to close the bottom. In Indonesia, these ring boats are known as mini-purse seiners or "pajekos", which are 10-15 m long, which are powered by one or several outboard engines (Fig. 11, 12, 13). Fish hold capacity can vary but usually ranges between 10 and just under 30 GRT. Most are wooden hull boats, some with a fiberglass coating on top. Nets have a very small mesh size (e.g. < 2.5 cm; Fig. 14) and are no longer than 200 m corkline length and shallow with less than 50 m depth. Due to the shallowness, the net only catches fish closer to the surface.

Figure 11*. Small pelagic purse seiner or "pajeko" vessels at the port of Bitung (Sulawesi)*

Figure 12*. Pajeko or mini purse seiner at Kendari (Sulawesi)*

Figure 13. Outboard engines in pajeko vessel at Bitung (Sulawesi)

Figure 14. Detail of pajeko net for small pelagics and tuna in Bitung (Sulawesi)

Typical pajekos in Bitung or Kendari (Sulawesi) have a small wheelhouse towards the bow equipped with a radio and in some cases, carry a basic echo-sounder. Under the working deck located in the center of the vessels, are two or three small wells for fish storage. The net is piled and deployed from the middle section of the vessel and retrieved by hand with the help of a basic net roller (Fig. 15) constructed out of a bamboo cane on the port side and some also have capstans (Fig. 16). Many ring net boats work on a two-boat system which makes deploying the net easier.

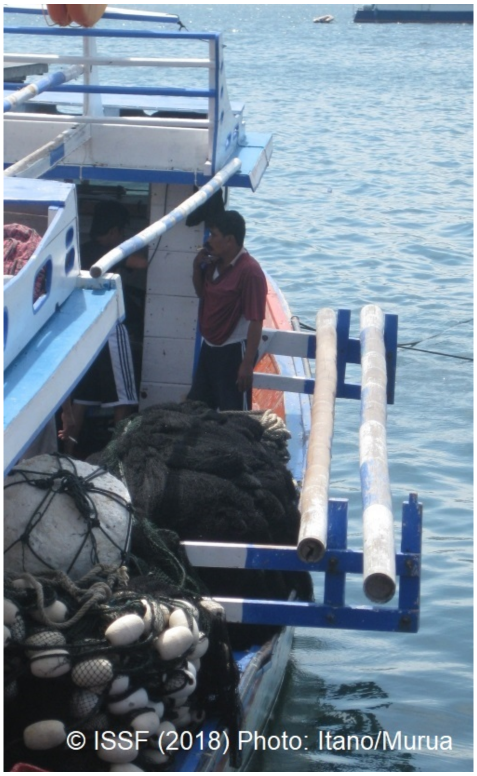

Figure 15. *Stacked net and corks and net roller in pajeko mini purse seiner in Bitung (Sulawesi)*

Figure 16. *Net, capstan and net roller powered by dedicated engine on in pajeko mini purse seiner in Bitung (Sulawesi)*

3.1.2. Fishing operation < 30 GT

The number of aFADs used by smaller-sized vessel is relatively small (e.g. 1-5 units), mostly operating in shallower waters less than 30 nm from the coastline. Some of the payangs and pajekos in Indonesia still use aFAD rafts made from traditional materials like bamboo rather than steel or plastic pontoons (Shomura et al., 1996). Some small vessels in Indonesia even work without aFADs, only with the aid of lights to attract fish at night and in the early morning hours. These vessels make one or two sets in one night; while aFAD vessels only make the one set shortly before dawn. Small payangs will do short day trips, leaving early in the morning (e.g. 3 am) and returning in the afternoon to port. During this time, the lampara net will be set numerous times (e.g. 6-8 sets). Catches are generally small in volume, averaging under 500 kg.

Many of the < 30 GT purse seine vessels operate individually, without assistance of carrier vessels to transport catches back to port or ranger vessels to monitor aFADs. However, it is not infrequent to associate with other catcher boats to conduct fishing. Others will have a small auxiliary light boat to attract fish away from the aFAD before the set. Average catches of pajekos just under 30 GT are between 1-5 tonnes per set as informed by skippers in Kendari, Paulete and Ambon in the Western Pacific.

Small non-fishing boats inspect their aFADs for fish at least every 5-7 days. For this reason, they like to have more than 3 aFADs, because after a set it takes some time to replenish the floating object with a large enough school of fish. Some fishers indicate that it can take more than two weeks for an aFAD to aggregate again a sizable group of tuna worth fishing. During the day time or while waiting for aFADs to accumulate enough fish for a set, these small vessels will spend time handline fishing near floating objects to complement their catches.

3.1.3. Catch composition, onboard storage and utilization < 30 GT

Given the proximity to coastal zones and the shallowness of the nets, catches mostly consist of small pelagics like scads (*Decapterus* spp.) and neritic tunas (e.g. bullet tuna *Auxis rochei*, frigate tuna *Auxis thazard*, mackerel tuna *Euthynnus affinis*, longtail tuna *Thunnus tonggol*), etc. often referred to generally in Indonesia as “tonkgol” (Fig. 17, 18); with less than a third of the catch composed of the main tropical tuna species, primarily skipjack. The catch species composition can vary strongly between regions and seasons. A wide variety of small filter feeding tropical sardines, herring, sprats and anchovy species are also harvested (Fig. 19).

Figure 17. Unloading of small pelagics catch of pajeko purse seiner at Bitung (Sulawesi)

Figure 18. Mixed sample of neritic tuna species (e.g. frigate tuna and bullet tuna) from a pajeko purse seiner at Bitung (Sulawesi)

Figure 19. *Variety of small pelagic fish caught in small purse seines sold at market in Bitung (Sulawesi)*

Fish are loaded in ice-cooled brine in small holds located under the central deck floor. Trips are short and return on a regular basis to port to unload and collect ice for fish storage. Most of the catches are sold at local markets and full utilization of species is common. Many of the so called "bycatch" species in industrial-scale FAD fisheries, are target or at least desirable retained species in the small scale aFAD fisheries and sold at local markets (Fig. 20). For example, in Sulawesi the price of rainbow runners (e.g. 2-3 USD kg^{-1}) can be twice that of skipjack tuna (e.g. 1-1.5 USD kg^{-1}) and dolphin fish reach up to 5-6 USD kg^{-1}. Thus, all aFAD bony fish species are highly regarded in Indonesia and there is no discarding. This is also true for vessels larger than 30 GT.

Design of bycatch mitigation activities in small pajekos is probably limited to best release practices from deck of species of special concern that have mandatory release regulations like turtles or sharks. Limited deck space and net dimensions prevent other mitigation activities, most of which would be inappropriate for these fisheries (e.g. escape windows or sorting grids in the net). Bycatch like turtles or sharks are generally released from the net or from deck. Occasionally, depending on the region, these species may be kept and consumed on board. Sharks are not sold at port as it is prohibited by current regulations and skippers risk losing their fishing licenses. This rule also applies to larger vessels. Note that the occurrence of sharks in aFADs in Indonesia is relatively low according to skippers' comments, especially in floating objects closer to the coastline where fishing effort by multiple gears has been more intense over the years.

Figure 20. Dolphinfish and rainbow runners unloaded at port of Bitung (Sulawesi)

3.2. VESSELS 30–100 GT

3.2.1. General description 30–100 GT

In Indonesia purse seine vessels > 30 GT are known as "kapal pukat cincin". Many of the medium sized purse seiners range between 70 GT and 100 GT (Fig. 21, 22) with few intermediate sized vessels of 30-70 GT observed during port visits. The following description is based on a 93GT tuna purse seine vessel constructed of heavy wooden beams with some sections overlaid with fiberglass matting. Note there are multiple boat configuration variations to this description, but the general boat design remains. The vessels have an aft wheelhouse with refrigerated fish holds in a low foredeck with high upraised bow. The wheelhouse had basic steering gear, gearshift and throttle controls, magnetic compass, main engine monitoring panel and (when fishing), was equipped with a basic echo sounder and a GPS receiver (Fig. 23).

Figure 21. Medium size purse seiners at Sibolga port (Sumatra)

Figure 22. Medium size purse seiner at Benoa port (Bali)

Figure 23. Wheelhouse of medium sized purse seiner in Sulawesi waters

Net hauling is accomplished by hand or by raising portions of the net with hydraulic winch rigged through blocks on a simple boom. Some vessels of similar size and design in Sibolga (Sumatra) and Jakarta (Java) were equipped with small deck mounted hydraulic power blocks (Fig. 24).

Figure 24. *Powerblock on medium sized purse seiner in Sibolga (Sumatra)*

Larger purse seine boats observed in Bitung (Sulawesi) were rigged in a more conventional manner with a large working deck located behind the wheelhouse equipped with horizontal capstan winches, a mast, a “modern” brailing boom and pursing davit with two pursing blocks (Fig. 25, 26) The working deck was separated from the net pile by a large above deck engine room. In some instances, they also tow behind another auxiliary vessel which operates as a skiff during net setting (Fig. 27). A typical wheelhouse of a vessel in this class is equipped with communication radio, depth sounder and GPS unit. A common characteristic across all ports was the use of a small wooden light boat on the catcher vessel (Fig. 28) to assist with FAD inspection, attractor replacement or to aggregate catch during the pre-dawn set. Some of these simple small wooden speedboats had a box to hold a petrol or diesel generator power the lights used before the set.

Figure 25. *Working deck with davit, purse blocks, capstan, boom, fish holds and engine room in medium size purse seiner at Bitung (Sulawesi)*

Figure 26. *Medium size purse seiner's boom, powerblock, brailing boom and purse rope in Bitung (Sualwesi)*

***Figure** 27. Auxiliary vessel, used as a skiff, towed behind catcher vessel at Bitung (Sulawesi)*

***Figure** 28. Small work boat used to hold light and attractor rope during fishing operation in Sibolga (Sumatra)*

3.2.2. Fishing and fish loading gear 30–100 GT

The purse seine of a medium sized purse seiner in Bitung (Sulawesi) was stated to be approximately 500-600 m in corkline length and 80-100 m in depth and constructed of dark red dyed knotless webbing of about 6 cm stretch mesh dimension with yellow poly floats. The leadline was constructed of tubular lead weights of about 700 g each threaded onto a nylon line. Stainless steel purse rings were used to close the net. (Fig. 29).

Figure 29. Net, rings, leadline and weights of a medium sized purse seiner at Bitung (Sulawesi)

Pursing is accomplished by retrieving a heavy (approximately 7 cm diameter) multi strand nylon line through the davit blocks using the horizontally opposed capstan winches. Net hauling is accomplished with a standard, boom mounted hydraulic power block with a long auxiliary boom used for brailing the catch from the net using a stainless steel brailer of about 1.5-2 tonne capacity (Fig. 30). Different power block configurations were observed in vessels of this size category (Fig. 24, 26, 31).

Figure 30. *Medium size purse seiner brailer (approx. 2-3 t) in Sibolga (Sumatra)*

Figure 31. *Powerblock and purse rings on medium sized purse seiner in Kendari (Sulawesi)*

3.2.3. Fishing operation 30–100 GT

The set is initiated by the release of a large (e.g. 15 GT) auxiliary vessel with the bow end of the seine attached, performing the same function of net skiffs on super-seiners. This vessel is far too large to be hoisted onto the main vessel and is towed behind (Fig. 27). Note the towing hawse hole in the bow of the net boat which also doubles as a light boat for fish attraction.

Fishing operations are conducted on aFADs inside the Indonesian EEZ with some effort on found natural drifting objects (e.g. logs). FAD sets occur before dawn with the assistance of a light boat that serves to draw the aggregation away from the anchored FAD to allow the set to be made without tangling the FAD mooring line. It was stated that the vessel and net was not capable of capturing daytime unassociated schools, likely due to the small and shallow net size and slow pursing speed. Pre-set assessment is conducted with the onboard echo sounder and also utilizing divers to visually assess the tuna aggregation prior to a set. Often vessels are equipped with long, flexible hoses connecting a standard SCUBA second stage regulator to an air compressor. Fig. 32 shows the foredeck area with an anchored FAD, fish storage wells, three sets of hookah diving gear and the fish loading brailer. The diving gear is also used during the fishing operation to check the net (Fig 33).

***Figure** 32. Hose gear for vessel divers (Bitung, Sulawesi)*

Figure 33. *Divers during fishing operation checking the net*

Vessels typically conduct one set per day. The fishing operation starts in the early hours before dawn, around 4 am. The set starts about 2 h before first light to take advantage of the behavioral pattern of FAD-associated tuna that ascend to shallower depths before dawn and remain relatively shallow within reach of the purse seine net, before descending at dawn. This is a common phenomenon in the Western Pacific Ocean characterized by a deep thermocline and very clear water. These factors prevent or inhibit successful sets on floating objects during daytime hours by purse seine gear as the tuna can easily observe and dive below the reach of the nets. This is especially true for smaller vessels with slower net setting speeds, slow pursing and shallow nets.

According to fishers the 80-100 GT catcher vessels often work in group seine operations with auxiliary boats (1-4 per vessel) and several carrier vessels (Fig. 34). When the set is completed by the catcher boat the catch is loaded directly onto a carrier vessel. In some instances, instead of a carrier vessel the operation is completed between two purse seiners (Fig. 35). The maximum set size that one of these purse seiners can handle is around 30 tonnes. However average sets during the better fishing seasons (e.g. May to July in North Sulawesi) will yield 8-12 tonnes. Each carrier vessel can store and transport back to port the catch of 3 or 4 sets, equivalent to about 25-50 tonnes (Widodo et al., 2016). This way the catcher boat can stay 6 months or more at sea fishing, only returning to port in case of maintenance and repairs.

In 2014 Indonesia prohibited transshipment operations at sea within their EEZ (Ministerial Regulation 57/2014), aimed at prevention of IUU fishing and to stop the operation of large foreign purse seiners fishing in their EEZ and taking the catches abroad. This regulation also impacted medium-scale Indonesian flag purse seiners that normally operated by loading catch to an Indonesian carrier vessel. The regulations caused many vessels to cease operations because of limited fish hold space making fishing operation economically unviable without carrier vessels. In some areas like Kendari and Bitung many of the > 60 GT purse seiner companies went bankrupt and a considerable part of the fleet has since ceased to operate. In 2015 amendments to the prohibition were introduced to alleviate this situation by allowing for transshipment on the condition that ship owners could ensure the catch was landed in an Indonesian fishing port.

In the case of privately owned house aFADs or rakits, the keeper will radio call a catcher boat when there is enough tuna aggregated and the benefits of the catch are split (e.g. 30 per cent for rakit owner and 70 per cent for catcher boat). Similarly, small vessel (e.g. < 5 GT) handline fishers can fish on purse seiner owned aFADs often on the condition that they protect the rumpon from other purse seiners and inform the owner when enough fish for a set have aggregated. In addition, each purse seiner has their own auxiliary "ranger" vessels for fabricating, replacing or setting new FADs. They also regularly check aFADs for fish and carry out maintenance work (e.g. replacement of degraded attractor leaves).

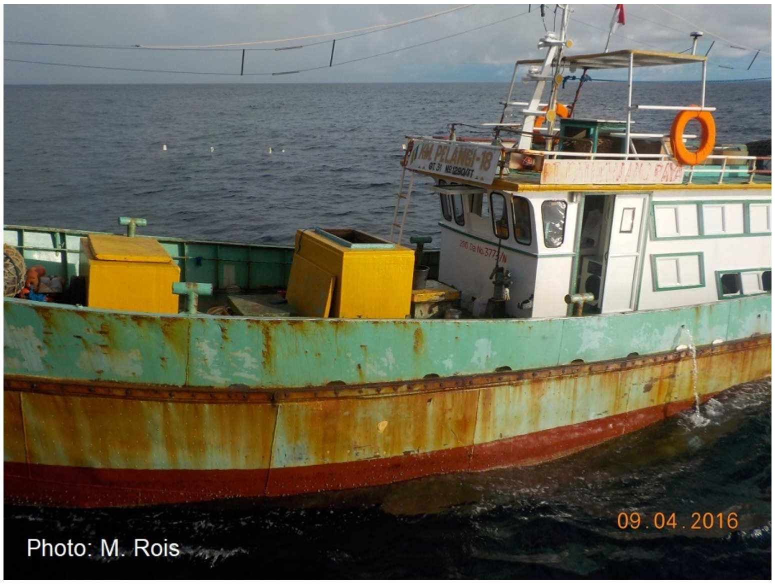

Figure 34. *Carrier/tender vessel (Sulawesi, Indonesia)*

Figure 35. *Fish loading between two purse seiners (Sulawesi, Indonesia)*

3.2.4. Catch composition, onboard storage and utilization 30–100 GT

The 30-100 GT vessels mainly target skipjack tuna while taking a sizable proportion of yellowfin tuna (Fig. 36). For example, in Sorong catches for 2013-2015 medium class purse seiners were reported as 75 % skipjack, and 20 % juvenile yellowfin and bigeye and 5% other species (Widodo et al., 2016). Care should be taken when referring to yellowfin or bigeye catches as captains may not distinguish well between both species and rarely separate them in their catch reports. Recent projects like WPEA introducing port samplers in some key Eastern Asian ports are helping to improve the quality of catch data. Meanwhile neritic tunas are also regularly taken on aFAD sets along with scads, rainbow runner and other common aFAD associated species. Everything is saved and eaten or marketed. Sharks are rarely seen or caught, fishers in different regions estimated about 0.1-0.3 sharks per set (e.g. 1-3 sharks in 10 sets), most being juvenile silky shark (*Carcharhinus falciformis*) of small size (e.g. < 70 cm). Whale sharks are very infrequently encountered, once or twice a year according to some fishers, and are actively avoided as they can easily rip the net. If accidentally caught they are always released alive either by cutting an opening in the net or releasing over the corkline.

Figure 36. *Catch sample from a medium size purse seiner in Bitung (Sulawesi)*

Catch is held in fiberglass lined fish holds located on the bow deck. The holds are lined with refrigeration coils in more modern boats, with fish held in refrigerated seawater or possibly frozen in brine (Fig. 37). Other vessels just carry ice in the fish holds for fish preservation (Fig. 38). Carrier vessels have similar fish hold systems. Catches are stored in the holds in metallic trays, each with capacity for 4-5 kg of fish (Fig. 39). Mixed species are stored in the trays and frozen. Sorting into species and sizes takes place after unloading at port (Fig. 40).

Figure 37. *More modern vessels use refrigeration coils in the fish holds in Bitung (Sulawesi)*

Figure 38. *Loading ice blocks into the fish holds in Sibolga (Sumatra)*

Figure 39. *Stack of metallic trays used for fish storage in Benoa (Bali)*

Figure 40. *Blast frozen small yellowfin (top) and bigeye tuna (bottom) for sale at Jakarta port market (Java)*

Part of the stored catch is sold to local canneries, especially skipjack, yellowfin and bigeye tuna. North Sulawesi has the highest number of canneries in Indonesia, but other important canneries are distributed in Sumatra, Bali and Java. Prior to the ban on transshipment to foreign vessels an important proportion of the Indonesian Western Pacific tuna catch was being delivered to the Philippines for canning. Meanwhile, small tuna-like species, scads and other finfish are normally sold at local markets (Fig. 41).

Figure 41. Tuna and rainbow runner at Bitung fish market (Sulawesi)

3.3. VESSELS OVER 100 GT

3.3.1. General description > 100GT

The number of vessels over 100 GT in Indonesia (and Vietnam) is very limited. During 2012-2017 port visits only few larger sized vessels were observed in Bitung (Fig. 42) and Benoa. The hull in these vessels is wooden and covered in fiber glass. Until recently some foreign built vessels fishing in the Indonesian EEZ (e.g. mostly from neighboring Philippines) had a metallic structure (Fig. 43), but these have been banned from operating in the domestic fishery since 2014. Larger vessels can reach up to 250 GT. Note that these tuna vessels are still very small compared to large purse seiners in other fleets (e.g. 500-2,500 GT). A prohibition of new fishing licenses to vessels over 150 GT in Indonesia in 2014 has resulted in a reduction of the number of large vessels in this country.

These vessels usually operate in the outer zones of their EEZ and sometimes may also fish in international waters. Most stay for prolonged times at sea and rely entirely on carrier vessels for taking their catches to port. Many of these vessels in Indonesia stopped fishing after the imposed transshipment ban issued in November 2014 under Ministerial Regulation 57/2014 and currently extended with exceptions to allow legal operators (e.g. Indonesian flagged) to ensure that fish catches could still be landed at Indonesian fishing ports provided an independent observer was on board to monitor transshipment activity (Fig. 44).

Figure 42. *Larger scale purse seiner (approx.200 GT) at Bitung (Indonesia)*

Figure 43. *Larger foreign scale purse seiner (approx.250 GT) in the background stopped at port of Benoa (Bali)*

Figure 44. Indonesian purse seiner brailing with helper vessels in the background

The aFADs used are predominantly with metallic/fiber glass pontoons and are usually moored in deeper waters (e.g. > 3000 m). The number of owned aFADs per vessel is larger than for smaller sized categories with up to 20 aFADs per vessel. Each catcher vessel operates in conjunction with a small network of ranger/auxiliary vessels (3-5) and carrier boats (3-4) (Fig. 45).

Figure 45. FAD tender vessel for larger scale purse seiner at Bitung (Sulawesi)

3.3.2. Fishing and fish loading gear > 100 GT

The net pile is located on the stern (Fig. 46). Observed net lengths were between approximately 800 m to 1200 m with net depth of 80 m to 150 m. Fish loading is completely mechanized with vessels equipped with deck winches and a powerblock to haul the net (Fig. 47, 48). The size of the brailer is also larger, between 3-5-tonne capacity. No sorting hoppers where observed on the vessels and brailing is assumed to be directly to the catcher boat's wells or to metallic chutes that lead to brine wells, limiting opportunities for sorting and release of species of special interest. However, fish are usually loaded directly to assisting carrier vessels.

Figure 46. Net pile with aFAD pontoons and brailer on top at Bitung (Sulawesi)

Figure 47. Powerblock of large purse seiner in Bitung (Sulawesi)

Figure 48. Top deck and purse winches of large purse seiner in Bitung (Sulawesi)

3.3.3. Fishing operation > 100 GT

The aFADs are located further offshore than for smaller vessels, but mostly within the 200 nm of their EEZ. Each large catcher boat will have 3 to 5 helper vessels regularly inspecting aFADs to determine which have tuna aggregations. The fishing operation is not very different from the one described for medium sized purse seiners setting on aFADs, with a light boat and an assisting helper vessel operating as the skiff. No scuba gear was observed on these boats, but it is possible they also use divers, and pre-estimation of catch is done with higher technology echo-sounders.

According to fishers the maximum set size in these vessels is around 35-40 tons. Some of the larger boats can catch about 1000 tonnes per year. On average catcher boats stay six months at sea before returning to port and rely mainly on a network of carrier vessels to transship the fish back to domestic landing ports. Many of the boats stopped operating in 2014 when the ban on large foreign built vessels and transshipment came into place. As of now, in 2018, certain conditions of the moratorium have been relaxed so that Indonesian flagged large purse seiners can continue their activity but must carry onboard observers to verify that catches are not being transshipped abroad.

3.3.4. Catch composition, onboard storage and utilization > 100 GT

Catch composition from larger vessels is similar to medium sized vessels, as they also fish on aFAD aggregations. The principal species caught is skipjack and to a lesser extent juvenile yellowfin and bigeye tuna. These vessels have chilled refrigeration systems and can store tuna for longer periods, but as stated previously most of the catch is directly loaded to carrier vessels. Most of the catch is sold to canneries, located in Bitung in Sulawesi, Jakarta in Java or Medan in Sumatra.

FAD bycatch finfish species like rainbow runner, dolphinfish, wahoo, etc. are retained for sale in local markets. Only small scads or other low value species may be discarded in these boats.

4. Bycatch mitigation solutions for small-scale tuna purse seiner vessels in Indonesia

The concept of “bycatch species” in the Indonesian small-size purse seine fleet, and other similar ones (e.g. Vietnam, Philippines, etc.) is quite different from that of super-seiner fleets. While small tuna species (e.g. bullet tuna, frigate tuna, kawakawa) and other characteristic FAD-associated finfish like mahi-mahi, rainbow runner, triggerfish, etc. are not targeted by industrial-scale purse seiners and rarely utilized in the WCPO (but see Eastern Pacific and Atlantic, Murua et al., 2018), in the Indonesian fleet these so called “bycatch species” are targeted and market value can exceed that of larger tuna species. Therefore, bycatch thought of as species discarded, dead or moribund catch back to sea is very low. Only scads taken in the medium and semi-industrial purse seiners (e.g. 30-250 GT) are sometime discarded.

One bycatch that super-seiners and small-scale purse seiners have in common are turtles, sharks, mantas and whale sharks. These Endangered Threatened or Protected (ETP) species, according to skippers, are released when they arrive to the deck, except for whale sharks which are released directly from the net by making a cut in the net or lowering the corkline. Accidental ghost fishing of sharks or turtles by entanglement in FADs is not existent in aFADs as they are completely non-entangling due to lack of netting material in their construction.

Most release of bycatch is done from the work deck, although sometimes divers can also assist in releasing bycatch specimens directly from the net. Most turtles are believed to be released alive and survive, as fishers say they are returned to the water in good condition and care is taken to prevent damage as they are considered “sacred” in many regions of Indonesia. Meanwhile, strict government regulations prohibiting the landing of sharks by these vessels with severe fines associated, has probably also promoted to some extent live release of elasmobranchs. Despite fishing near coastal areas, shark incidence in purse seine sets appears to be low according to fishers. Reliable observers’ data would be desirable to confirm this statement. One explanation is that these coastal areas have been subjected to such high fishing intensity by multiple gears throughout decades, that elasmobranch populations are already quite depleted. Unlike in super-seiners where post-release survival rate of sharks released from deck has been evaluated (Hutchinson et al., 2015; Restrepo et al., 2016), in small-scale purse seiners this information is unknown. In super-seiners shark survival after release from deck is about 15-20%, but presumably in smaller-purse seine nets where crushing pressures in the sac are likely to be less extreme, the survival of sharks from the deck could be higher. Note however that many sharks are obligate ram ventilators (e.g. need to be moving to breathe) and movement restriction in the sac could also cause mortality in any size nets.

While a guide for best and safer release practices for sharks and manta rays has been developed in the super-seiner industry by scientists and fishers (Poisson et al., 2014), no guidelines have been published for small-sized purse seine vessels. Some of the manual release methods, such as how to return turtles and small sharks and mantas safely and efficiently to the sea, may be transferrable between super-seiners and small-seiners. In fact, throughout ISSF Skippers Workshops posters on best manual handling practices where well received by Indonesian fishers. However, other release methods which entail specific gear such as cranes to lift heavy manta rays or sharks are not applicable or relevant in small vessels. In addition, other potential bycatch mitigation activities such as using net modification like sorting grids or shark release windows would not be viable in smaller nets as they require enough space inside the net to accommodate these important structural modifications.

Therefore, further research, observation and documentation is needed in the small-scale purse seine sector to identify ways to safely and efficiently release some of the larger bycatch ETP species individuals. While some selective technology (e.g. echo-sounder buoys) is unlikely to be used for bycatch mitigation soon, better knowledge of the fishing gear and operational details is critical to find ways to reduce bycatch. Alternatives like moving sharks away from the FAD by attracting them with bait, or having divers manipulate the net to free manta rays are some options that could be explored. Experimental work in bycatch mitigation for small-purse seiners is still a grey area that needs further research. Cooperation with skippers could provide much needed practical knowledge on aFAD fishing to help arrive faster at these practical solutions.

IV. Conclusions

Indonesia is one of the principal producers of tuna and tuna-like species in the world, caught by a variety of gears within its Indian and Western Pacific Ocean EEZ. Among them ringnet and purse seine fishing constitutes the principal source of catches. Despite its importance, little data is available on the characteristics of these small-scale vessels, necessary to better assess fisheries impacts. The same is true for other East Asian tuna fleets like those of Vietnam and the Philippines. This document provides a synthesis of the equipment and fishing operation associated with the multiple seiner types, from small artisanal to industrial, to assist scientists and managers with the design of appropriate bycatch mitigation and stock management measures.

Indonesian purse seine and surround net gears rely almost exclusively on anchored FADs, with a small amount of effort on natural drifting objects and on anchored FADs that have broken free of their mooring, all of which are non-entangling and rigged with bio-degradable attractors. Indonesian regulations impose a limit of 3 aFADs per vessel which is rarely complied with in practice. All sets are made in pre-dawn darkness just before sunrise. Artificial light is often used to attract species to the surface and to concentrate the tuna tightly around the auxiliary vessel prior to the set. For larger vessels skipjack is the principal tuna species, while for < 30 GT boats fishing closer to shore other small coastal pelagic, and tuna-like species are more common. Often small sized skipjack, yellowfin and bigeye tuna are caught, but the extent is uncertain due to poor identification and enumeration of species and data collection challenges. Even in larger >100 GT category vessels the fishing technology used to locate and assess fish abundance is quite basic and tools like echo-sounder buoys, bird radar or modern sonars are absent. Catcher vessels rely on a network of auxiliary vessels and carrier vessels to increase fishing efficiency.

For “bycatch” species, best release practices can be designed but note that the majority of aFAD non-tuna finfish species (e.g. dolphin fish, rainbow runner, etc.) are considered “target” and are utilized and sold at local markets, thus the amount of discarded bycatch is very low. Species like sharks or turtles are rarely found and most are apparently released, in part due to current legislation prohibiting their landing.

As much of the small purse seine vessel tuna in Indonesia and Vietnam is exported abroad, developing selective fishing practices for each gear and vessel type is important as international markets and consumers are increasingly demanding tuna from sustainable and ecologically compatible fisheries.

V. Recommendations

Tuna fisheries for fleets with a large component of small-scale purse seine vessels like Indonesia and others (e.g. Philippines, Vietnam) have generally been poorly characterized despite their potential impacts on stocks and ecosystems.

This study resulted in four recommendations:

Recommendation 1:

- Improve collection of quantitative and qualitative information on fishing gear and technology and operational strategies for different types of small-scale vessels to monitor advances in fishing technology (e.g. “effort creep”) and better assess potential effects on stocks.

Recommendation 2:

- Support and strengthen small-scale vessel tuna fisheries data collection programs such as vessel registration databases, national FAD plans, observer programs, or collaborative scientists-fishers exchanges

Recommendation 3:

- Obtain better characterization of catches at the species level by different kinds of small and medium sized tuna vessels and determine levels of utilization or discards (e.g. bycatch) for each species in the fishery.

Recommendation 4:

- Evaluate bycatch impacts, especially for ETP species, by small-scale purse seine fleets and develop specific bycatch reduction solutions with the help of fishers and industry which are appropriate and specific to each size-category of purse seiner.

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Appendix I

VIETNAMESE MEDIUM-SIZED (30–60 GT) TUNA PURSE SEINERS

The description of Vietnamese tuna purse seiners in this section is based on boats observed during a visit in 2016 to the port of Quy Nhon, which is one of the principal tuna ports in the country. A bycatch mitigation workshop was held with around 50 captains who provided feedback on their fishing practices. The authors are uncertain if purse seine characteristics and fishing practices in other parts of Vietnam differ significantly from those reported here and is by no means an exhaustive review of types of small-scale tuna purse seiners in this fleet. The following paragraphs describe the structure and catch composition of semi-industrial 30-60 GT purse seiners inspected during the visit.

Vietnam is another example of an Eastern Asian domestic fleet with a variety of small-scale purse seine vessels whose technological and operational characteristics are not well documented. Nguyen (2012) reported about 1000 small-scale tuna purse seiners, most based in the province of Binh Dinh which has seen a sharp growth in fleet size in recent years (e.g. from 208 tuna purse seiners in 2010 to 786 in 2012), although part of this large increase could be an artefact of improved data collection. Efforts by the WCPFC through projects like WPEA have been improving fisheries data collection in Vietnam in recent years (Vietnam, 2013; WCPFC, 2013).

General description 30–60 GT

According to skippers in Quy Nhon the standard purse seiner is about 40 GT, but there are some 90 GT vessels and even a few 150 GT vessels. Vietnamese fisheries registration and licensing is based on the size of the main engine (horse power; HP) and not GT or fish storage capacity, with most registered vessels being150 to 250 HP. Boats are constructed of heavy wooden beams with some areas covered with fiberglass matting. The wheelhouse, engine room and living area are located at the stern. Equipment in the wheel house is very simple with a radio and basic echo sounder. Capstans and deck mounted power block to assist with net hauling are located in front of the wheel house (Fig. 1A).

In the central area of the deck, in line across the middle section are 6 to 8 fish storage wells. The net is piled on the starboard towards the bow (Fig 2A). Net length for a 90 GT purse seiner is about 500 m and depth 100 m.

Figure 1A. View of wheel house, capstan and deck mounted power block of a 50 GT purse seiner at port of Quy Nhon (Vietnam)

Figure 2A. Vietnamese 30-60 GT purse seiner at port (Quy Nhon, Vietnam)

Fishing operation 30–60 GT

The average trip of a 40 GT vessel is 20 days, taking 1-2 days to reach the fishing grounds which can be up to 200 nm away from the coast. During this time, a normal trip will involve 7-8 sets (e.g. a set every other day) and a catch of 15-20 tonnes. At the Quy Nhon port there are 3 larger vessels of about 150 GT, and these make trips that last over a month. Apparently, these boats are not very efficient because they have to make longer trips, consume more fuel, and often come back only half full. Even these larger Vietnamese catcher boats are not assisted by carrier vessels or auxiliary vessels. All the catch is loaded on the catcher vessel and transported to port for unloading.

Unlike Indonesia or the Philippines, Vietnamese purse seiners do not use anchored FADs (nor drifting FADs). Instead they only use light to attract fish schools. Note though that technically speaking utilizing a light source to attract tuna might be considered as using a FAD, as based on the WCPFC definition "any man-made device, or natural floating object, whether moored or not, that is capable of aggregating fish" is a FAD.

Normally, the way the fishing operation takes place is by a purse seiner remaining overnight at a location with its lights on to attract a fish aggregation. Divers are used to inspect fish aggregated before the set and also after the set to check that the net has closed properly and that it is operating correctly. Some divers use snorkeling masks, while others use a hookah style rig with a SCUBA regulator connected by a long flexible air hose to an onboard air compressor to stay longer under water. By 4 am the catcher vessel deploys a small round "basket" boat. traditionally made of woven bamboo, but now constructed of fiberglass with bamboo struts (Fig. 3A). This vessel is deployed before the set with two fishers; one manoeuvres it with a paddle, while the other one holds in place a 1000-watt light to attract fish. The light is powered by a cable that comes from the catcher purse seiner. The purse seiner then turns off its lights and moves away to make a set around the basket boat. Typical FAD associated non-target species such as oceanic triggerfish and rainbow runner were reported to be caught infrequently on these sets but are encountered when fishing on logs or natural floating objects. According to fishers, opportunistic sets on natural floating objects (e.g. logs) may occur, but these will only constitute up to 10-20 percent of all sets. During the winter months (October-December) purse sein boats in Quy Nhon often halt operations due to dangerous stormy weather conditions.

Figure 3A. *Basket helper boat temporarily being used for ice storage (Quy Nhon, Vietnam)*

Catch composition, onboard storage and utilization 30–60 GT

The size of the brailer is small, holding about one ton. The purse seine vessels have no freezing capacity; all catches are stored in wells with ice (Fig. 4A). This limits the time they can spend at sea to less than 20 days. Most of the catch, about 90-95%, is skipjack. About 5-10% is yellowfin plus bigeye tuna of small size (<50 cm). Neither fishers nor fish traders could accurately discriminate between these two species. Sometimes neritic tuna like bullet tuna (*Auxis rochei*) and frigate tuna (*Auxis thazard*) can amount to 10% of the catch, but kawakawa (*Euthynnus affinis*) or longtail tuna (*Thunnus tonggol*) are less abundant.

Figure 4A. *Unloading catch from ice-stored well (Quy Nhon, Vietnam)*

Most of the tuna caught is bought from fishers by intermediaries, local fish agents, that then sell it on to canneries or other retailers (Fig. 5A). According to VINATUNA (Vietnam Tuna Association) most of the tuna caught in Vietnam is exported to the international market. The local fish agents not only buy tuna but other species caught in purse seiners as well (e.g. wahoo, dolphinfish, etc.). These non-tuna species are generally sold at local markets. For example, purse seiners at Quy Nhon catch wahoo and also dolphinfish of large size (e.g. >25kg), but rarely encounter triggerfish or rainbow runner which might be fish species more often associated with floating objects. The price of skipjack depends on its size, there are three price categories, but overall it sells at about $1 USD per kg, while small bigeye plus yellowfin tuna will reach $2 USD, adult yellowfin tuna (caught by longliners) can sell at $6 USD. Meanwhile non-target species like dolphinfish can reach a high price, about $6 per kg. There is little or no discard in this fishery and most species are utilized (Fig. 6A). Fishers say that shark, mantas and other elasmobranch bycatch are extremely rare as they do not use FADs.

Figure 5A. *Purse seine catch sorting and storage at port before transport to processing plant (Quy Nhon, Vietnam)*

Figure 6A. *Wahoo catch set aside for sale in Vietnamese purse seiner (Quy Nhon, Vietnam)*

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www.iss-foundation.org

1440 G Street NW
Washington D.C. 20005
United States

Phone: + 1 703 226 8101
E-mail: info@iss-foundation.org