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A Characterisation of Indonesia's FAD-based Tuna Fisheries

FINAL REPORT

ACIAR Project FIS/2009/059

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Cover image: A bamboo and bungalow type FAD and hand-line/troll-line fishing vessels. Photo taken by C. Proctor in 2009 in waters NE of Ayu Islands, Halmahera Sea, Indonesia.

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Acronyms

AMAFRAD	Agency for Marine and Fisheries Research and Development (Indonesia)
AMAFRHR	Agency for Marine and Fisheries Research and Human Resources (Indonesia)
BET	Bigeye Tuna
CFR	Centre for Fisheries Research
DGCF	Directorate General of Capture Fisheries (Indonesia)
FAD	Fish Aggregation Device
FMA	Fisheries Management Area
IO	Indian Ocean
IOTC	Indian Ocean Tuna Commission
NGO	Non Government Organisation
RFMO	Regional Fisheries Management Organisation
RIMF	Research Institute for Marine Fisheries (Indonesia)
RCFMC	Research Centre for Fisheries Management and Conservation (Indonesia)
RCCF	Research Centre for Capture Fisheries (Indonesia)
SKJ	Skipjack tuna
SPC	Secretariat of the Pacific Community
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
YFT	Yellowfin Tuna

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1. Executive summary

The Project: Developing research capacity for management of Indonesia's pelagic fisheries resources. ACIAR Project FIS/2009/059.

The study: A characterisation of FAD-based tuna fisheries in Indonesian waters.

Key issues

A key 'driver' in development of this study during 2011 – 2012 was recognition that the use of anchored tuna FADs had become standard practice within the Indonesian tuna fisheries, for the gears of purse-seine, pole & line, hand-line and troll-line. The number of these FADs was rising exponentially, with little or no effective regulation, and conflicts between the FAD users was an growing issue. This study was initiated to address the lack of knowledge on how the FAD fisheries were operating and on the characteristics of the FADs and the catches of fish caught on and around them; information agreed as essential in the steps towards improved management of the tuna fisheries.

Primary objective

To assess and characterise Indonesia's FADs associated tuna fisheries.

Methodologies

1. A review (as a bibliography compilation) of earlier FAD related studies in Indonesian waters; 2. An enumeration program at 4 key tuna landing locations (Padang, Palabuhanratu, Kendari and Sorong) to gather information on a wide range of aspects of the FADs and the FAD-based fisheries; 3. A preliminary survey of socio-/bio-economic aspects of FAD-based fisheries at Kendari and at Palabuhanratu; and 4. Trials of acoustic and visual census of assessing fish aggregations on and around FADs.

Study outcomes

1. The literature review produced a bibliography of 116 FAD related research studies from Indonesian waters; 2. The enumeration program achieved 2,643 fishing trips surveyed for 3 vessel types (hand-line/troll-line, pole & line, and purse-seine) across the 4 focus locations and a total of 48,368 fish measured in the biological sampling program, and was sustained at two of the locations for 39 months; 3. The socio-/bio-economic study provided useful insights into the cost 'dynamics' of the FAD fishery operations, and capacity development in assessing the socio-economic aspects of the fisheries; and 4. The acoustic and visual census trials on FADs provided a foundation for further research on the behaviour of fish species following fishing events i.e. 'recovery' times around the Indonesian anchored FADs.

Impacts achieved

The FAD study was initiated in response to the need for targeted information on the deepwater tuna FADs and associated fishing operations, and, overall, its outcomes have met that need. The catch characterisations results have already assisted in gear selectivity analyses as part of Indonesia's current Harvest Strategy (HS) development and confirmed that juveniles of both species comprise significant proportions of the catch of the gears (hand-line/troll-line in particular) fishing on Indonesian deepwater anchored FADs. This information has informed the HS process and will assist the technical development of management measures for improved sustainability of the fisheries. The capacity development achieved in the preliminary study assessing the socio-/bio-economic aspects of the fisheries will be directly relevant to minimising the impact of new management measures on the most vulnerable components of the fishery (i.e. the small-scale subsistence fishers).

Recommendations

Further research on the FAD fisheries is required to determine 'realistic' and effective FAD management options and the likely impacts of FAD-based management measures for both industrial scale and small-scale fishers e.g. restrictions on FAD numbers by region, regulated FAD sharing within and between gear-types, seasonal closures etc. There is a need to address the question of whether free school (i.e. FAD-free) tuna fishing by 'One by One fishing gears' (pole & line and hand-line/troll-line) and by purse-seine is likely to achieve the operational efficiencies, sufficient catch and sustainable incomes for the communities and industries associated with those gears. With increasing recognition of the importance of including socio-economic impacts on fishing communities (in particular impacts to small-scale fishers) in development of new management measures, the capacity development of Indonesian scientists in socio-/bio-economic assessment skills should continue and, if possible, be expanded. The combined initiatives and efforts of Indonesian Government, together with all stakeholder groups, in identifying implementable fisheries measures relating to FAD use within the current Harvest Strategy development for the tuna fisheries, should be continued as a high priority.

Ringkasan eksekutif

Proyek: Pengembangan kapasitas penelitian untuk pengelolaan sumber daya perikanan pelagis Indonesia. Proyek ACIAR FIS/2009/059.

The study: Karakterisasi perikanan tuna berbasis rumpon di perairan Indonesia.

Isu kunci

Satu 'pendorong' utama dalam pengembangan studi ini selama 2011 - 2012 adalah kenyataan bahwa penggunaan rumpon tuna dipasang menetap telah menjadi kebutuhan utama untuk perikanan tuna Indonesia, terutama bagi alat tangkap pukat cincin, huhate, pancing dan tonda. Jumlah rumpon saat ini meningkat secara berlebih, dengan sedikit atau tanpa implementasi peraturan yang efektif, sehingga timbul konflik antara pengguna rumpon menjadi masalah yang berkembang. Studi ini dimulai untuk memenuhi kebutuhan kurangnya pengetahuan tentang bagaimana perikanan rumpon dioperasikan , karakteristik rumpon dan hasil tangkapan ikan yang ditangkap di sekitar rumpon; informasi yang diperoleh sangat penting dalam langkah-langkah menuju peningkatan pengelolaan perikanan tuna.

Tujuan utama

Untuk mengevaluasi dan mengkarakterisasi perikanan tuna Indonesia yang berasosiasi dengan rumpon.

Metodologi

1. Mereviu (sebagai kompilasi bibliografi) dari studi pustaka terkait rumpon di perairan Indonesia dimasa lampau; 2. Program enumerasi di 4 lokasi pendaratan tuna utama (Padang, Palabuhanratu, Kendari dan Sorong) untuk mengumpulkan informasi tentang berbagai aspek rumpon dan perikanan berbasis rumpon; 3. Survei pendahuluan tentang aspek sosial-biologi-ekonomi perikanan berbasis rumpon di Kendari dan Palabuhanratu; dan 4. Uji coba pengamatan dengan akustik dan visual untuk menilai agregasi ikan di sekitar rumpon.

Hasil studi

1. Tinjauan pustaka menghasilkan buku bibliografi dari 116 judul hasil kajian/penelitian terkait rumpon di perairan Indonesia; 2. Program enumerasi tercatat 2.643 trip penangkapan yang diamati untuk 3 jenis kapal penangkap ikan (pancing/tonda, huhate, dan pukat cincin) di 4 lokasi terpilih dan sebanyak 48.368 ekor ikan telah diukur dalam program pengambilan sampel biologis, dan dilanjutkan di dua lokasi pendaratan ikan selama 39 bulan; 3. Studi sosial-/bio-ekonomi memberikan wawasan yang bermanfaat terkait 'dinamika' biaya operasi penangkapan tuna berasosiasi dengan rumpon, dan pengembangan kapasitas dalam menilai aspek sosial-ekonomi perikanan; dan 4. Uji coba sensus dengan metode akustik dan visual terhadap ikan di sekitar rumpon sebagai dasar untuk penelitian lebih lanjut tentang tingkah laku bagi masing-masing spesies ikan setelah dilakukan operasi penangkapan ikan yaitu waktu ‘pemulihan' di sekitar rumpon .

Dampak yang dicapai

Studi rumpon diinisiasi sebagai tanggapan terhadap keperluan tentang informasi yang ditargetkan terkait rumpon tuna laut dalam dan operasi penangkapan ikan di sekitarnya., Secara garis besar hasilnya yang diperoleh telah tercapai untuk memenuhi keperluan tersebut. Hasil karakterisasi tangkapan ikan tuna telah membantu dalam analisis selektivitas alat tangkap sebagai bagian dari pengembangan Harvest Strategi (HS) Indonesia saat ini dan menegaskan bahwa juvenil dari kedua spesies (madidihang dan tuna mata besar) tersebut memiliki proporsi yang signifikan dari hasil tangkapan khususnya alat tangkap pancing/tonda yang dioperasikan di sekitar rumpon laut dalam di Indonesia. Informasi ini telah disampaikan dalam proses penyusunan HS dan akan membantu pengembangan teknis dari langkah-langkah pengelolaan perikanan tuna yang berkelanjutan. Pengembangan kapasitas yang dicapai dalam studi pendahuluan untuk mengkaji aspek sosial / bio-ekonomi perikanan akan secara langsung terkait dengan meminimalkan dampak langkah-langkah pengelolaan baru terhadap komponen perikanan yang paling rentan (yaitu nelayan subsisten skala kecil).

Rekomendasi

Penelitian lebih lanjut tentang perikanan tuna berasosiasi dengan rumpon diperlukan untuk menentukan opsi pengelolaan rumpon yang 'realistis' dan efektif dan kemungkinan dampak dari langkah-langkah pengelolaan berbasis rumpon pada nelayan skala industri dan kecil, mis. pembatasan jumlah rumpon menurut wilayah, pengaturan pembagian rumpon untuk masing-masing jenis-alat tangkap, penutupan musim penangkapan ikan, dll. Diperlukan informasi untuk menjawab pertanyaan apakah penangkapan kelompok tuna 'free school' (tanpa penggunaan rumpon) oleh 'One by One fishing gears' (huhate dan pancing/tonda) dan dengan jaring pukat cincin bagaimana mencapai efisiensi operasional, hasil tangkapan yang cukup dan pendapatan yang berkelanjutan untuk masyarakat dan industri yang mengoperasikan alat tangkap tersebut. Dengan meningkatnya pengakuan terhadap pentingnya memasukkan dampak sosial-ekonomi komunitas nelayan (khususnya dampak terhadap nelayan skala kecil) dalam pengembangan langkah-langkah pengelolaan yang baru, pengembangan kapasitas para ilmuwan Indonesia dalam keterampilan meneliti aspek sosial-/bio-ekonomi harus dilanjutkan dan, jika memungkinkan dapat diperluas. Inisiatif dan upaya gabungan dari Pemerintah Indonesia, bersama dengan semua kelompok pemangku kepentingan, dalam mengidentifikasi tindakan pengelolaan perikanan yang dapat diterapkan terkait dengan penggunaan rumpon dalam pengembangan Harvest Strategi perikanan tuna saat ini, harus dilanjutkan dan sebagai prioritas utama.

2. Introduction

Indonesia's tuna fisheries are arguably the most complex of any capture fisheries globally. They encompass both industrial and small-scale sectors, operating in archipelagic, EEZ territorial and high seas waters, and include several fishing gears: longline, gill-net, purse-seine, pole and line, troll-line and hand-line, with a broad variety of operations (Proctor et al. 2003; WWF 2008; CEA 2018; Ruchimat et al. 2018). The processing and market chains are also complex (Bailey et al. 2016, Satria et al. 2018). Collectively, for all the gears, Indonesia's tuna fisheries production has been among the highest for Western and Central Pacific Ocean (WCPO) countries, with an estimated total catch of around 466,300 tonnes of skipjack tuna (SKJ), yellowfin tuna (YFT) and bigeye tuna (BET) combined in 2017 (MMAF-RI 2018). This represents around 19.3% of the total catch for those three species in the WCPO region (Williams and Reid 2018). Although not as large as in the WCPO, the tuna catch by Indonesian fleets operating in the Indian Ocean are also highly significant - around 158,730 tonnes for SKJ, YFT and BET combined in 2017 (Ruchimat et al. 2018). Deepwater, anchored Fish Aggregating Devices (FADs) have been a feature Indonesia's tuna fisheries since the mid-late 1970s or early 1980s (exact timing unclear) (Tuasamu 1985; Subani and Barus 1989; WWF 2008). As the numbers of FADs increased with little to no effective regulation, concerns had grown around the sustainability of catches, the sustainability of fish stocks, and around the impacts to the stocks of juvenile yellowfin and bigeye tunas in particular (Langley et al. 2009; IOTC 2010; WCPFC 2010; Davies et al. 2011).

This FAD Fisheries Study was included as a major activity of ACIAR Project FIS/2009/059, *Developing research capacity for management of Indonesia's pelagic fisheries resources*, after the scoping phase of project identified the addressing of the large information gaps surrounding Indonesia's FAD-based tuna fisheries as a very high priority. The Director of the Directorate of Fisheries Resources (within DGCF) at that time, Mr Agus Budhiman, voiced FADs as the Directorate's biggest management "headache" and DGCF specifically asked for a FAD fisheries study to be included in the next phase of Indonesia – Australia collaboration in tuna fisheries research. DGCF were well aware of the use of FADs within the tuna fisheries and that numbers of the FADs were increasing rapidly, but they lacked information on the 'mechanics and dynamics' of the FAD-based fishing operations. This included information on the true scale of FAD numbers across the archipelago, the types of FADs, and the forms of FAD ownership and FAD use. Obtaining information on the latter was seen as particularly important as conflicts between fishing gears using the tuna FADs had become a significant issue. AMAFRAD, CSIRO and ACIAR supported DGCF in their request, as there was recognition that a better understanding of all aspects of the FAD-based fisheries was required as foundation to establishing effective management measures and for Indonesia to be in an improved position to meet its RFMO reporting obligations.

Other important information needed to begin formulating effective management for the FAD-based fisheries and for improved reporting to the RFMOs was that pertaining to catch; the catch composition in terms of size and types of fish caught by the different gears using the FADs, but also catch volumes, and catch effort. In 2010, at time of commencement of this project's development phase, Research Centre for Fisheries Management and Conservation (RCFMC) were already involved in a new program of port-based monitoring for the tuna fisheries at Bitung (North Sulawesi) and Kendari (SE Sulawesi). This monitoring evolved out of the Indonesia and Philippines Data Collection Project (WCPFC 2008, 2015) and was done as part of the Global Environment Facility (GEF) funded Western Pacific and East Asia (WPEA) program, under coordination of WCPFC, SPC, and RCFMC. The WPEA program had as a primary objective, the collection of data that would enable Indonesia to better meet its reporting obligations to WCPFC, particularly with respect to catch parameters (catch by gear, by species and by fish size), fishing effort measures, and characteristics of the fleets. An earlier ACIAR project FIS/2002/074[1] participated in the early phase of establishment of the WPEA program.

[1] *ACIAR Project FIS/2002/074 Capacity development to monitor, analyse and report on Indonesian tuna fisheries.*

In considering and planning how this ACIAR project could best build on the WPEA program's daily enumeration of the tuna fisheries at Bitung and Kendari, the decision was made to include establishment of trial enumeration at four more tuna landing ports; two in western Indonesia for fleets operating in Fisheries Management Areas (FMAs) 572 and 573, and two in eastern Indonesia for fleets operating in the archipelagic and Western Pacific waters of FMAs 714 - 717. The planned enumeration would trial data collection on all FAD-based activity, in terms of vessel operations and in terms of catches landed, for tunas but also bycatch species. The underlying key goal in doing the trial enumeration at the four ports was to develop improved port-based monitoring procedures for obtaining high-quality, long-term catch and effort data specific to the FAD fishery operations.

There was also recognition that the FAD Fisheries Study afforded opportunity to further develop Indonesia's capacity in the area of socio-/bio-economic assessment of fisheries. This capacity had taken a significant step forward in 2010 with a bio-economic, socio-economic and fishing capacity training workshop in Jakarta, as part of ACIAR Project FIS/2006/142 (West et al. 2013). The knowledge gathering to occur on the operations of the FAD-based fisheries was extended to include a preliminary assessment of bio- and socio-economic aspects of the fisheries in two regions (West Java and SE Sulawesi). This was to increase the utility of the FAD Study findings, but also to provide capacity development for Indonesian partner scientists in this increasingly important area of fisheries research.

In recognition that there had been earlier research studies linked to FADs in Indonesian waters and that outputs from these studies could prove useful, it was decided to include in this project's FAD Fisheries Study a review of existing knowledge. We were aware of some of the earlier studies but also aware their reporting in theses, papers and technical reports were almost all in Bahasa Indonesia only (but usually accompanied by an abstract in English). The review part of the project subsequently morphed into creating a bibliographic compilation of abstracts of all known FAD studies that had been done in Indonesian waters.

A key recommendation that emerged from the International Conference on "Tuna Fisheries and Fish Aggregating Devices" in Tahiti , French Polynesia, in 2011 was that the outcomes of studies of fish aggregations on FADs in one region may not be directly applicable to other oceanic regions, as variability in environmental factors (both physical and biological) are likely to result in different fish schooling behaviours. The recommendation extended to suggesting that countries 'grappling' with the challenges of FADs management should conduct appropriate research to better understand fish behaviours on and around FADs in their waters, such as 'recovery times' of aggregations on FADs after purse-seine fishing events. It was for this reason that the project included in its planning, the idea of doing trials of scientific fish aggregation assessment, using both acoustics and visual assessment methods, but also as a means of delivering capacity building in new skills in spatial dynamics research. Research Institute for Marine Fisheries had already commenced some trials of acoustic surveys of fish aggregations on FADs and we saw this ACIAR project as a good opportunity to build on that work.

3. Objectives

The objectives of the FAD Fisheries Study were to:

1. Review existing knowledge of the Indonesian FADs and their associated fisheries;
2. Assess the number, type and distribution of tuna fishery FADs across the Indonesian archipelago;
3. Characterise the catch on FADs by gear, species and size of fish, for target tunas and bycatch species;
4. Establish, through trial programs at four ports, improved port-based monitoring procedures for obtaining high-quality, long-term catch and effort data for the FAD fishery operations;

5. Draw on information obtained through the above, to scope/complete preliminary assessments of bioeconomic, socioeconomic, fishing capacity and risk aspects of the FAD-based tuna fisheries for each major gear type;
6. Explore capacity development opportunities for Indonesian scientists in research on fish aggregations on FADs, with possible focus on aggregation behaviours and influencing factors, spatial dynamics, or tropho-dynamics.

Methodologies

The methodologies for the various activity components within the FAD Fisheries Study are covered in detail in the respective sections below.

4. Review of earlier FAD studies in Indonesian waters

An original objective of the FAD Fisheries Study was to do an initial review of the current 'FAD situation' in Indonesian waters, as a first phase activity. However, early in the study it became clear that little information was readily available and that the planned enumeration program and field surveys would hopefully provide the necessary information. Also, there was recognition that there had been many earlier research studies linked to FADs in Indonesian waters, but that the outcomes of the majority of these earlier studies were only available in Bahasa Indonesia and were unpublished.

The review part of the study subsequently morphed into creating a bibliographic compilation of abstracts (in both Bahasa Indonesia and English versions for each study) of all known FAD studies that had been done in Indonesian waters.

The identification of the earlier studies and sourcing of associated abstracts was done primarily by on-line literature searches (including library databases held by the research institutes within MMAF and those of Indonesian universities), and by direct enquiries (in person for some and via a letter of enquiry for many others) to the research institutes and universities. These investigations yielded a total of 116 studies and the abstracts for these were compiled (alphabetically as the first level of order) into a bibliography, with both Bahasa Indonesia and English versions of each abstract, and published[2] in late 2017:

Natsir M., Proctor C., Wudianto, Nurdin E., Sadiyah L., Taufik M. and Hargiyatno I. T. (2017). A collection of abstracts of FAD fisheries research in Indonesia. A publication of Australian Centre for International Agricultural Research Project FIS/2009/059. Center for Fisheries Research. Agency for Marine and Fisheries Research and Human Resources. Jakarta. 308 pp.

The long period (more than 4 years), from commencement of compilation of the abstracts to publication of the bibliography, was the combination of time required to source and collate the abstracts, and the time consuming process of translation of the majority of the abstracts to English. Due to budget constraints, the latter task could not be done with a professional translation service, and relied on the joint efforts of the abovementioned authors. It is intended that the bibliography of abstracts will be a living document and will be updated as more FAD related studies, done in Indonesian waters, come to light.

5. General information on tuna FADs in Indonesian waters

Deepwater, anchored FADs have been a common feature of Indonesia's tuna fisheries since the mid-late1970s or early 1980s. The exact timing of their first appearance in Indonesian waters appears to be

[2] https://kkp.go.id/brsdm/pusriskan/artikel/7663-bibliografi-kumpulan-abstrak-hasil-penelitian-perikanan-rumpon-di-indonesia

unclear (Tuasamu 1985; Subani and Barus 1989; WWF 2008). Until now, drifting FADs have not been used in the Indonesian tuna fisheries, even by purse-seine vessels. Developments in Indonesian FAD construction, including region specific designs, were first detailed by Subani and Barus (1989) and many studies have since described FAD types and FAD construction for those used in Indonesia's waters (Itano 1993; Itano et al. 2004; Monintja 1993).

In common with anchored tuna FADs employed by fisheries of other countries, the Indonesian FADs have four key components: the surface float, the mainline to seafloor, a subsurface attractor, and the anchor (Figure 5.1).

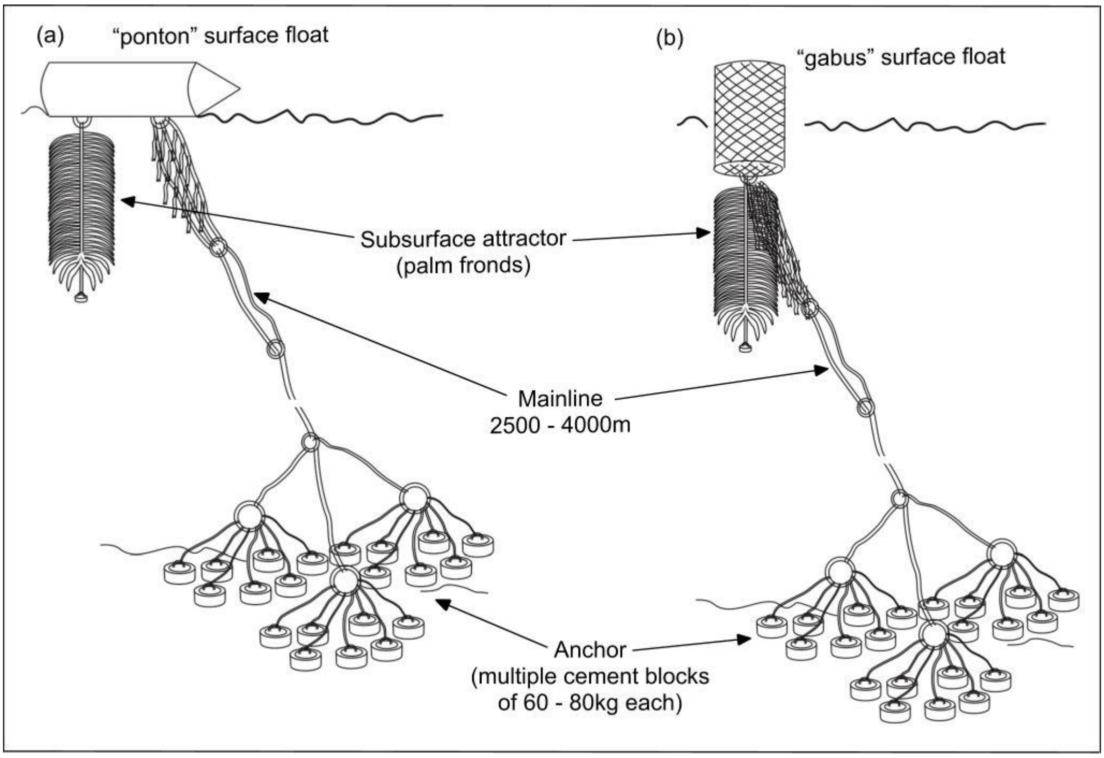

Figure 5.1 Typical FAD construction for (a) steel *ponton* type, and (b) polystyrene *gabus* type. From: Widodo *et al.* (2016).

The FAD surface floats [3] are of three main types (Figure 5.2):

1. steel cylinder of 2 – 3 m length and approximately 0.8 m diameter, with generally one end is conical. These are called pontoon type or *"ponton"*, and were, until recent years, the most common type of FAD float in western and southern Indonesia;
2. bamboo raft, the most sophisticated version having a bungalow ("*rakit*") in which the fishers and/or caretakers of the FAD reside, for weeks or even months. Fresh supplies of food and water, and other necessities for the persons staying at the FAD are brought by fishing vessels or carrier vessels. FADs with *rakit* are found in eastern Indonesia, but to date, have not extended to western Indonesia;
3. large cylinders or blocks of styrene foam, encased in cloth and often bound by rope and used-motorcycle tyres, and strengthened by a wooden frame. These are commonly called "*gabus*" type FAD. This type of FAD has replaced *ponton* as the most common FAD type, due to its lower cost.

[3] Until recently there had been no evidence of under-surface floats being used on Indonesian anchored tuna FADs. However, in November 2018, we received information from port authority in Bitung that at least one company in that region was now using submersed floats (i.e. ones that cannot be seen on the surface). This is in conflict with the current fisheries regulations pertaining to FADs (see Section 6.5).

In general, the FAD surface floats are not equipped with navigation aids (no radio signal emitters or r

Figure 5.2. Types of anchored FAD floats in Indonesia (a) & (b) steel *ponton*, (c) bamboo raft with *rakit*, and (d) polystyrene *gabus* (photos: C. Proctor).

The FAD mainline, of up to 4000m in length for FAD deployment in water depth of 2000 – 3000m (but sometimes as deep as 6000m), is most commonly a 2.5 – 4.0 cm diameter synthetic rope (Figure 5.3), sometimes with wire core, but other types of synthetic rope of lesser diameter and less cost are also not uncommon, particularly with *gabus* FADs. The subsurface attractors are most commonly branches of nipa palm (*Nypa fruticans*) or coconut palm (*Cocos nucifera)*, which are usually attached as a hanging cluster to the underside of the surface float. Attractors made of plastic strips (synthetic *raffia*) have also been encountered on FADs during this study, but current regulations prohibit the use of non-biodegradable materials. Nets and netting-like materials are not used as subsurface attractors on the FADs, and therefore Indonesian tuna FADs pose minimal risk of entanglement of turtles or other marine fauna.

FAD anchors are most commonly comprised of 60 – 80kg concrete blocks or cylinders (Figure 5.3), with embedded ropes or motorcycle tyres as attachment points in each block, and 25 – 40 blocks linked together to form an anchor of total weight 2 – 3 tonnes (Figure 5.1).

Tuna fisheries that operate in association with FADs in Indonesia include the gear types purse seine, pole and line, hand-line, troll-line, and surface fishing using kites and lures. Two types of purse seine (PS) fleet size operate in the waters of FMA 713 – 717: smaller vessels of <30 GT which are called “mini-purse-seine” (Figure 5.4a) of local name “*pajeko*”, and larger purse seine vessels (“*kapal pukat cincin*”) of > 30 GT (Figure 5.4b). Pole and line (PL) vessels operating around FADs are also of two main types: small size vessels of <20 GT, commonly called ‘*funae*’ (Figure 5.4c) and larger vessels of > 20 GT, commonly called “*huhate*” (Figure 5.4d). The numbers of *funae* vessels are not increasing, but still operate in several areas in northern Sulawesi (e.g. Belang and Pulau Gangga).

Figure 5.3. Examples of components for Indonesian anchored FADs: (a) coils of rope used for FAD mainline, (b) 60-80 kg cement weights which are linked together to form the FAD anchor, and (c) coconut palm branches attached to mainline as subsurface attractor (Photos: C. Proctor). From: Widodo *et al.* (2016).

Hand-line fishing, troll-line fishing and kite fishing are generally done by a single vessel type i.e. multi-gear vessels, which switch between gears depending on season, prevailing seas conditions and catch success. These hand-line/troll-line (HL/TL) vessels, commonly wooden-hull vessels of size 6 – 10 GT (Figure 5.4e), have different local names across regions, including "*penongkol*" in northern and south-eastern Sulawesi, and "*sekoci*" in Bali and east Java. These hand-line/troll-line vessels and their fishing methods originated from southern Sulawesi (Bugis fishermen) and have spread to many other areas of the Indonesian archipelago.

Another type of tuna hand-line vessel that have operated widely in the eastern Indonesian waters, and particularly in northern Sulawesi, are *'pump boats*', which operate as a 'mother-vessel' servicing several small catcher boats (*sampan*) which are carried on board during travel. Some Indonesian HL/TL vessels, primarily in southern Sulawesi (e.g. in Bone) and SE Sulawesi (Kendari) have adopted this style of fishing, routinely carrying as many a 6 – 8 of the *sampan*, from which both large (up to 100 kg yellowfin tuna) and small tunas are caught (Figure 5.4f).

Figure 5.4. Examples of Indonesian vessel types that fish on FADs: (a) Mini purse-seine (*pajeko*), < 30 GT, at PPP Sodohoa; (b) larger purse-seine (*pukat cincin*), > 30 GT, at PPS Kendari; (c) small pole and line (*funae*) in Belang, North Sulawesi; (d) pole and line, >50 GT, in Sorong; (e) hand-line/troll-line (*penongkol*) at PPP Sodohoa; and (f) hand-line/troll-line 'mother-ship' carrying several small catcher boats (*sampan*) in Kendari (Photos: C. Proctor). From: Widodo *et al.* (2016).

6. Enumeration program at focus ports

6.1 Vessel trips enumerated and data entry

The four ports chosen for enumeration were Padang (West Sumatra), Palabuhanratu (West Java), Kendari (SE Sulawesi), and Sorong (West Papua) (Figure 6.1). Their selection was based on geographical coverage (two ports in western Indonesia and two ports in eastern Indonesia) and on gear types. These 4 ports were considered appropriate for information gathering on all the key gears/vessel types that fish for tuna on FADs in Indonesian waters; purse-seine, pole and line, troll-line, and hand-line.

Two enumerators were recruited at each port. Some of the recruits had prior experience as enumerators in other programs e.g. the Western Pacific and East Asia (WPEA) program of RCFMC/WCPFC, whereas others were new to fisheries monitoring. At one port, Palabuhanratu, the enumerators were existing staff of the port authority (*Pelabuhan Perikanan Nusantara Palabuhanratu*). In Padang, one of the recruits was staff of the local fisheries office (*Dinas Kelautan dan Perikanan Kota Padang*).

A sampling protocol (Proctor *et al.* 2018) and data collection sheets (Appendix 1) were developed, both as Bahasa Indonesia and English versions, in the months prior to the commencement of enumeration in October 2013. The sampling protocol was largely based on that developed for the WPEA program (Widodo et al. 2013), but with additions tailored to the FAD-based operations. As example, the enumerators were tasked with obtaining information from skippers at time of a vessel's return to port, on FAD types used, FAD locations, and numbers of FADs visited in the fishing trip. In-field training was provided by the project's scientists to the enumerators at each port.

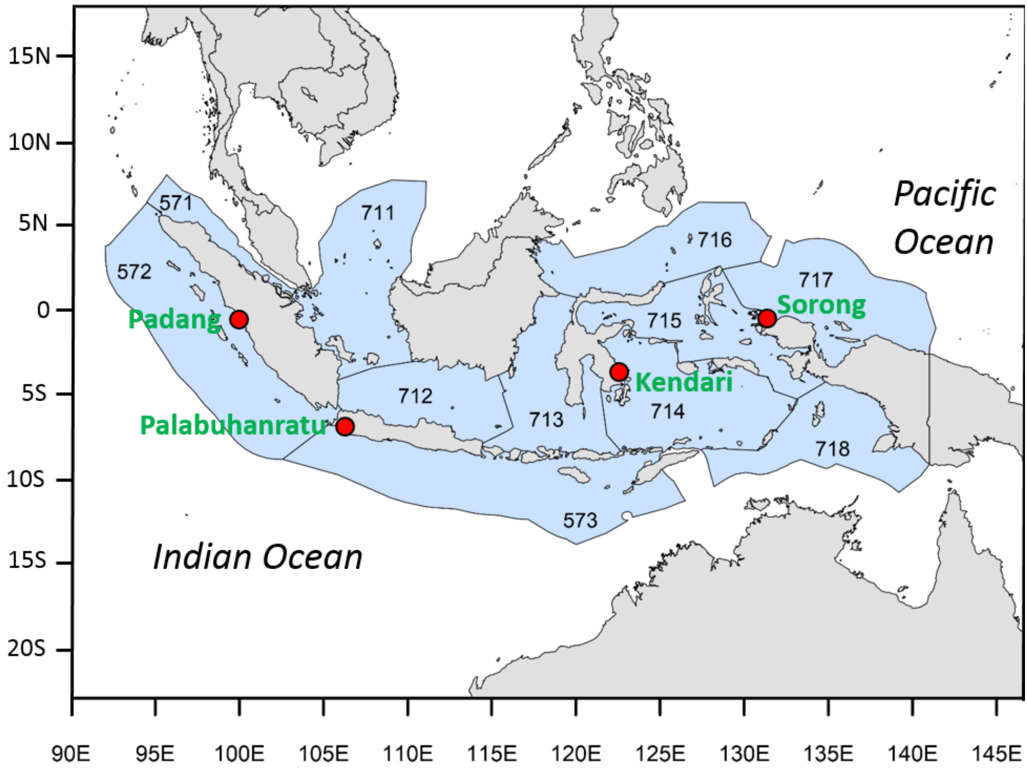

Figure 6.1. Location of the 4 focus ports for the ACIAR project's enumeration program. The blue shaded and numbered zones are the 11 Indonesian Fisheries Management Areas (FMAs).

The combination of direct observations by the enumerators of catch unloadings from vessels, data they collected from fish auction places (*Tempat Pelelangan Ikan*) and processing companies, and information collected via interviews with vessel skippers enabled adequate completion of the data collection sheets in most cases.

For the first year of the enumeration program, the enumerators submitted their completed data collection sheets (landings forms and biological sampling forms) to Jakarta via mail, for data entry by RCFMC staff. Following training provided at the Enumerators Training Workshop in Bali in October 2014, and with provision of laptop computers to the enumerator teams at each focus port, data entry was done by the enumerators themselves.

Entry of the data and information collected by the program was done to an Oracle-Apex database, named the *FAD Fisheries Database* (*Database Perikanan Rumpon*), with internet-interface, which was developed and established by project member Scott Cooper (CSIRO), with inputs from Indonesian counterpart, Bayu Sedana (RCFMC), and from Craig Proctor. The database provided both Bahasa Indonesia and English options and was designed to capture and validate all the information collected by the enumerators on the landings and biological sampling forms. A relationship diagram of the database and 'screen-grab' examples of the database front-end are provided in Appendix 2. A *Data Entry User Manual* was prepared and used as the basis for the training delivered to the enumerators at the Enumerators Training Workshop.

Enumeration of a total of 2643 fishing trips was achieved across the four focus ports during period October 2013 – December 2016 (Table 6.1). The original plan was for the program of data and information collection to run for a minimum of 15 months. At Padang and Sorong the program ran for 18 months, and at Palabuhanratu and Kendari for 39 months, thereby exceeding expectations.

Table 6.1. Summary of enumeration of fishing vessel trips, by vessel type, at the four focus ports. HL/TL = Hand-line/Troll-line, PL = Pole & Line, PS = Purse Seine, CV = Carrier Vessel, NA = source gear Not Available.

Location	Period	Total Trips	Vessel type						
			HL/TL	PL	PS	CV			
						CV-PL	CV-PS	CV-HL/TL	CV-NA
Padang	Oct 2013 - Apr 2015	182	177		5				
Palabuhanratu	Oct 2013 - Dec 2016	1,152	1,152						
Kendari	Oct 2013 - Dec 2016	1,188	547	29	4	459	94	2	53
Sorong	Oct 2013 - Apr 2015	121	1	98			16		6
	Total	**2643**							

The majority (~75%) of the enumerated trips were for HL/TL vessels. Carrier vessels (CV) for both PL and PS vessels, operating out of Kendari and Sorong, accounted for 630 of the enumerated trips. In some cases the enumerators were unable to determine whether the source of fish landed by the CV was PL or PS or from a mix of both vessel types, hence use of “CV-NA”.

The enumeration activity shown for Padang included 5 trips of PS vessels that unloaded catch in port of PPS Bungus, approximately 16 km to south of Padang city. The remainder of the Padang enumeration was done at two small landing places (each with an auction centre, *Tempat Pelelangan Ikan*) at Muara Padang[4], the base for the majority of the HL/TL fleet. A smaller number of HL/TL vessels were based at PPS Bungus.

The enumeration activity shown for Kendari included landings at the main fishing port, Pelabuhan Perikanan Samudera Kendari (PPSK), but also landings at Pelabuhan Pantai Sodohoa (PP Sodohoa), a fish landing centre on the northern side of Kendari Bay, directly opposite the location of PPS Kendari on the southern side. Located on the northern shore of Kendari Bay, almost directly opposite PPSK. PP Sodohoa was established in 1978 and has a landing wharf (est. 50 x 3m), fish auction area (TPI), and fish market. Vessels that land and unload catch at PPI Sodohoa are primarily HL/TL (local name = *penongkol*), and mini purse-seine (local name = *gae*, pronounced “gay-eh”). Catch from these vessels is sold locally through the fish auction centre and fish market at Sodohoa, but some is trucked to other centres for wider distribution. Most unloading activity at Sodohoa is early morning, between 0530 and 0900 hrs. PL and PS vessels do not unload at PPI Sodohoa, only at PPSK. Of the 573 HL/TL vessel trips enumerated at Kendari, 401 of those were for vessels that unloaded catch to PP Sodohoa and the remaining 172 were for vessels unloading to PPSK.

6.2 Catch characteristics – average catch by volume and species compositions

The following presents catch compositions, by location and by gear, based on information collected through the enumeration program.

Padang

A conspicuous feature of the catch composition data collected for the HL/TL vessels at Muara Padang in the 2014 and 2015 enumerations is the high proportion (39% and 36% respectively) of juvenile YFT

[4] *Muara* = estuary, and *Muara Padang* is the estuary located in the southern area of Padang city and is the waterway fed by the rivers *“Padangbesi”* and *“Padangidah”* (source: Army Map Service T5II, dated 1944).

and juvenile BET (the two species combined) in the total catch (Table 6.2, Figure 6.3). These were of similar proportions to that of SKJ in both years. Interestingly, the proportion of juvenile BET in the total catch (15% and 12% in 2014 and 2015 respectively) was highest for catches by any gear at the four surveyed locations, and this result concurs with the relative ease with which the juvenile BET sampling targets were achieved at Muara Padang for the ACIAR project's population structure study[5] in 2013 and 2014.

Table 6.2. Catch composition of enumerated landings from HL/TL vessels at Muara Padang, 2014 – 2015.

Species		Total Catch Enumerated (kg)			
Common name	Scientific name	2014 n = 74	2015 n = 78	Total 152 trips	%
Skipjack tuna	*Katsuwonus pelamis*	17,945	28,800	46,745	34.61
Yellowfin tuna (small)	*Thunnus albacares*	12,685	19,250	31,935	23.65
Bigeye tuna (small)	*Thunnus obesus*	8,103	9,500	17,603	13.03
Yellowfin/Bigeye tuna nei	*Thunnus sp.*	3,490	7,400	10,890	8.06
Common dolphinfish	*Coryphaena hippurus*	4,362	5,770	10,132	7.50
Frigate/Bullet tuna nei	*Auxis spp.*	1,000	5,450	6,450	4.78
Rainbow runner	*Elagatis bipinnulata*	1,481	2,370	3,851	2.85
Frigate tuna	*Auxis thazard*	3,400		3,400	2.52
Eastern little tuna (kawakawa)	*Euthynnus affinis*	850	1,900	2,750	2.04
Yellowfin tuna (large)	*Thunnus albacares*	430	550	980	0.73
Bigeye tuna (large)	*Thunnus obesus*	100	150	250	0.19
Black marlin	*Makaira indica*	70		70	0.05
	Total	**53,916**	**81,140**	**135,056**	**100**

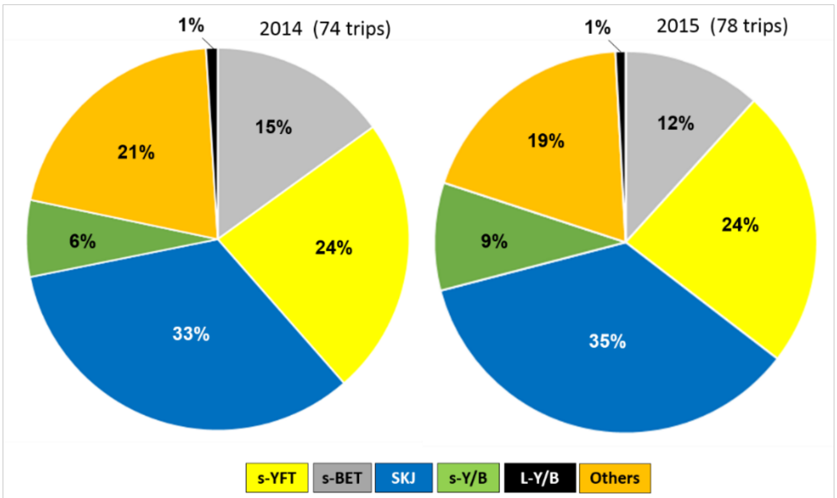

Figure 6.3. Catch composition of enumerated landings from HL/TL vessels at Muara Padang, 2014 – 2015. s-YFT = small YFT, s-BET = small BET, s-Y/B = small YFT/BET nei[6], L-Y/B = large YFT + large BET combined. For species that comprise "Others" see Table 5.2.

[5] Proctor C. H., Lester R. J. G., Clear N. P., Grewe P. M., Moore B. R., Eveson J. P., Lestari P., Wujdi A., Taufik M., Wudianto, Lansdell M. J., Hill P. L., Dietz C., Thompson J. M., Cutmore S. C., Foster S. D, Gosselin T. and Davies C. R. (2019). Population structure of yellowfin tuna *(Thunnus albacares)* and bigeye tuna *(T. obesus)* in the Indonesian region. Final Report as output of ACIAR Project FIS/2009/059. Australian Centre for International Agricultural Research, Canberra. 139 pp.

[6] *nei* = not enough information i.e. where fish were not able to be identified confidently to species due to small size or for other reason (e.g. poor fish condition).

Palabuhanratu

In common with the HL/TL fishery at Padang, the combined proportions of juvenile YFT and juvenile BET in the total catch in the 2013 – 2016 period were similar to those for SKJ (Table 6.3, Figures 6.4 and 6.5). In the 3 months (Oct – Dec) of survey for the fishery in 2013, the juveniles of YFT and BET were at a combined 60% of total catch, well exceeding that of SKJ at 21%. Large YFT also make up a significant proportion (10 – 19%) of the HL/TL landings; fish that are generally caught around the FADs at depths of 150 – 200m on deep hand-line or by surface fishing, often including use of kite-fishing. The juvenile and adult components of the catch are clearly seen in the length frequency distribution for YFT for this fishery (Figure 6.13).

Table 6.3 Catch composition of enumerated landings from HL/TL vessels at PPN Palabuhanratu, 2013 – 2016.

Species		Total Catch Enumerated (kg)					
Common name	Scientific name	2013* n = 165	2014 n = 548	2015 n = 263	2016 n = 176	Total 1152 trips	%
Skipjack tuna	*Katsuwonus pelamis*	16,824	84,451	77,047	36,972	215,294	32.97
Yellowfin tuna (small)	*Thunnus albacares*	41,617	97,476	45,479	28,395	212,967	32.61
Yellowfin tuna (large)	*Thunnus albacares*	7,984	53,393	17,866	21,496	100,739	15.43
Striped Marlin	*Tetrapturus audax*	5,011	24,212	21,071	13,719	64,013	9.80
Bigeye tuna (small)	*Thunnus obesus*	5,159	14,798	13,380	6,143	39,480	6.05
Common dolphinfish	*Coryphaena hippurus*	1,621	6,940	3,165	2,594	14,320	2.19
Yellowfin tuna (small/large nei)	*Thunnus albacares*	1,528	858	979	168	3,533	0.54
Other fish nei	Other fish nei	520	665	285	170	1,640	0.25
Bigeye tuna (large)	*Thunnus obesus*		173	252	47	472	0.07
Albacore	*Thunnus alalunga*		252		145	397	0.06
Barracuda	*Sphyraena spp.*	106				106	0.02
Southern Bluefin Tuna	*Thunnus maccoyii*			49		49	0.01
Rainbow runner	*Elagatis bipinnulata*	24				24	0.00
	Total	**80,394**	**283,218**	**179,573**	**109,849**	**653,034**	**100**

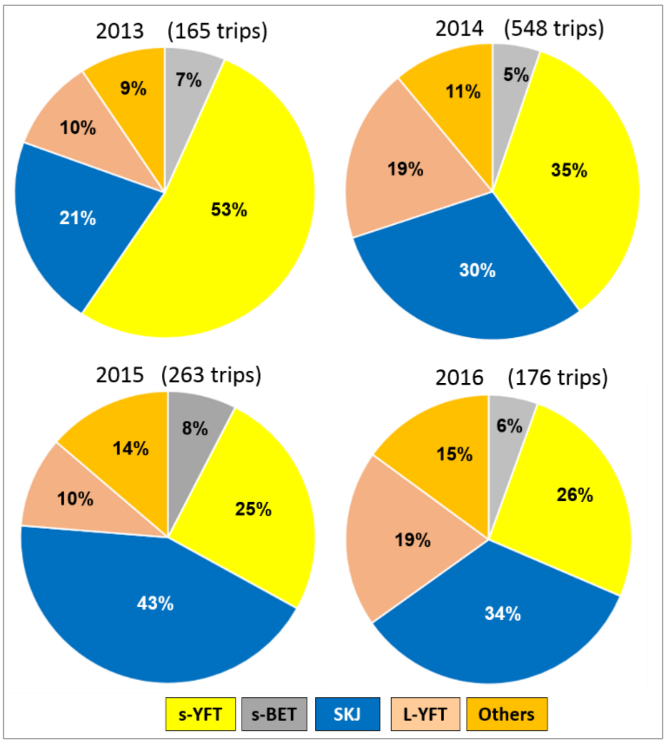

Figure 6.4. Catch composition of enumerated landings from HL/TL vessels at PPN Palabuhanratu, 2013 – 2016. s-YFT = small YFT, s-BET = small BET, L-YFT = large YFT. For species that comprise “Others” see Table 6.3.

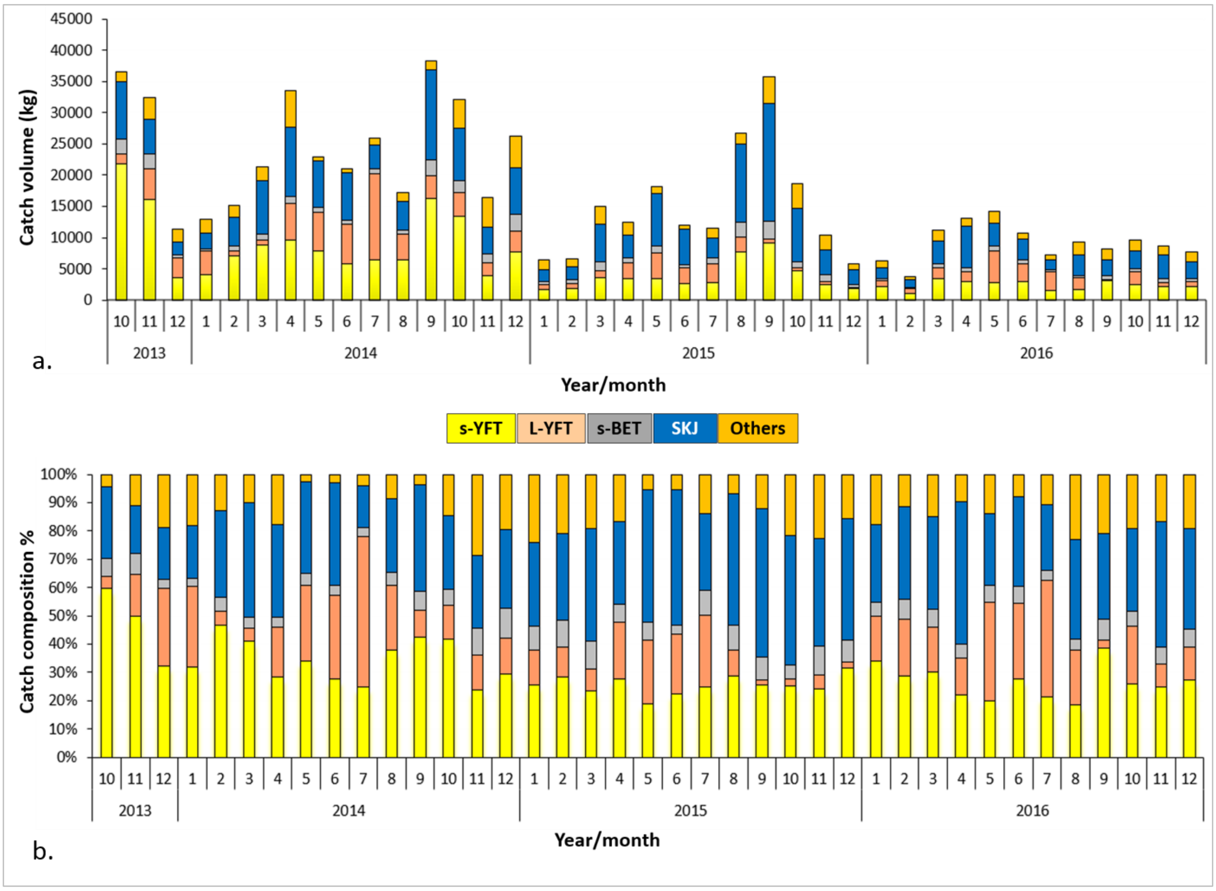

Figure 6.5. Catch composition by (a) volume (kg) and (b) % of total catch of enumerated landings from HL/TL vessels at PPN Palabuhanratu, 2013 – 2016. s-YFT = small YFT, s-BET = small BET, L-YFT = large YFT. For species that comprise "Others" see Table 6.3.

Kendari

In common with the HL/TL landings at Muara Padang and Palabuhanratu, the proportions of juveniles of YFT and BET combined in the catches enumerated from HL/TL vessels at Kendari were large (49 – 55%), and exceeded the SKJ proportions (36 – 43%) across the 4 years (Table 6.4, Figures 6.6 and 6.7). However, the data from Kendari is complicated by the situation of large YFT. The proportions of these larger fish appear as only 1 – 2% of the total catch, which does represent the true situation. Large YFT are caught by the Kendari-based HL/TL vessels in similar ways to those at Palabuhanratu (i.e. by deepwater handline and surface kite-fishing) but were generally landed at PPS Kendari as fillets after processing at sea. Our enumeration program did not adequately 'capture' this component of the catches. At least one similar monitoring program, that of MDPI for the HL/TL fisheries in NTT, Banda Sea and Molucca Sea regions, instruct their enumerators to record data on measurements of fillet length and numbers of fillets in order to achieve estimates on the volume of adult fish in the catches. We see this as a worthy inclusion in any future enumeration if processing of the larger tuna at sea is allowed to continue. However, the level of confidence around estimates of whole fish volume based on fillet measures has yet to be determined.

Table 6.4. Catch composition of enumerated landings from HL/TL vessels at Kendari (PP Sodohoa and PPS Kendari), 2013 – 2016.

Species		Total Catch Enumerated (kg)					
Common name	Scientific name	2013*	2014	2015	2016	Total	%
		n = 76	n = 144	n = 162	n = 165	547 trips	
Yellowfin tuna (small)	*Thunnus albacares*	40,418	76,010	75,885	73,233	265,546	46.32
Skipjack tuna	*Katsuwonus pelamis*	31,954	74,405	64,805	56,978	228,142	39.80
Bigeye tuna (small)	*Thunnus obesus*	2,640	9,605	9,346	13,202	34,793	6.07
Frigate tuna	*Auxis thazard*	2,221	9,080		300	11,601	2.02
Eastern little tuna (Kawakawa)	*Euthynnus affinis*		600	1,620	6,927	9,147	1.60
Black marlin	*Makaira indica*	1,568	2,352	2,170	1,246	7,336	1.28
Yellowfin tuna (large)	*Thunnus albacares*	1,303	1,671	2,140	1,848	6,962	1.21
Frigate tuna/Bullet tuna nei	*Auxis spp.*		900	910	2,045	3,855	0.67
Bigeye tuna (large)	*Thunnus obesus*	222	858		615	1,695	0.30
Various sharks nei	NA		120	535	933	1,588	0.28
Common dolphinfish	*Coryphaena hippurus*	656	236	100	60	1,052	0.18
Tiger shark	*Galeocerdo cuvier*			700		700	0.12
Marlins, sailfish, spearfish etc. nei	Istiophoridae	163	100			263	0.05
Blue marlin	*Makaira nigricans*	233				233	0.04
Silky shark	*Carcharhinus falciformis*		130			130	0.02
Scads nei	*Decapterus spp.*	80				80	0.01
Blue shark	*Prionace glauca*	65				65	0.01
Striped marlin	*Tetrapturus audax*		65			65	0.01
Narrow-barred Spanish mackerel	*Scomberomorus commerson*	6	8			14	0.00
Rainbow runner	*Elagatis bipinnulata*				8	8	0.00
Barracuda	*Sphyraena spp.*		5			5	0.00
	Total	**81,529**	**176,145**	**158,211**	**157,395**	**573,280**	**100**

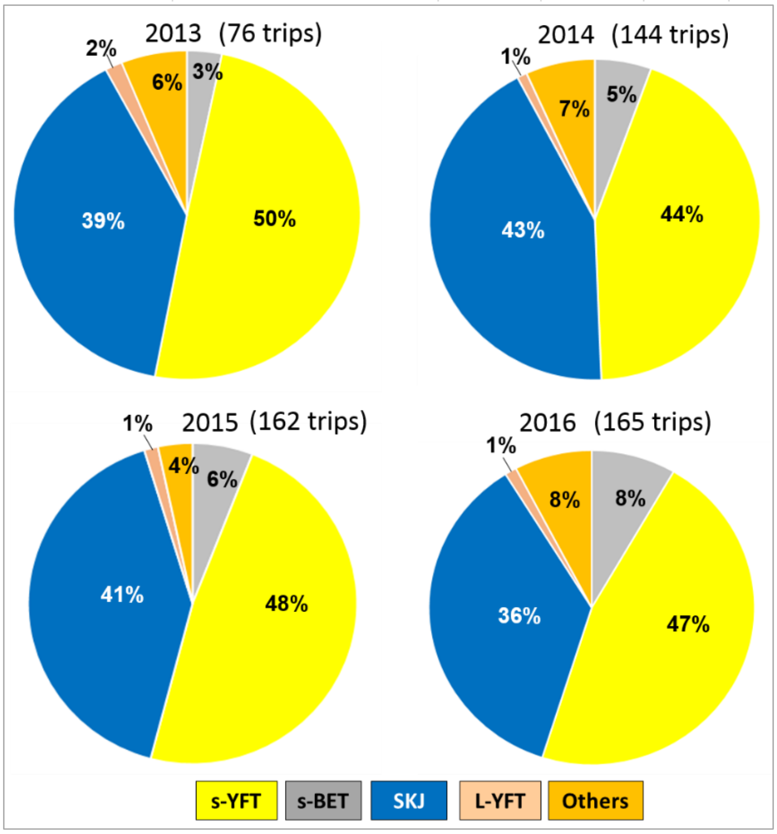

Figure 6.6. Catch composition of enumerated landings from HL/TL vessels at Kendari, 2013 – 2016. s-YFT = small YFT, s-BET = small BET, L-YFT = large YFT. For species that comprise “Others” see Table 6.4.

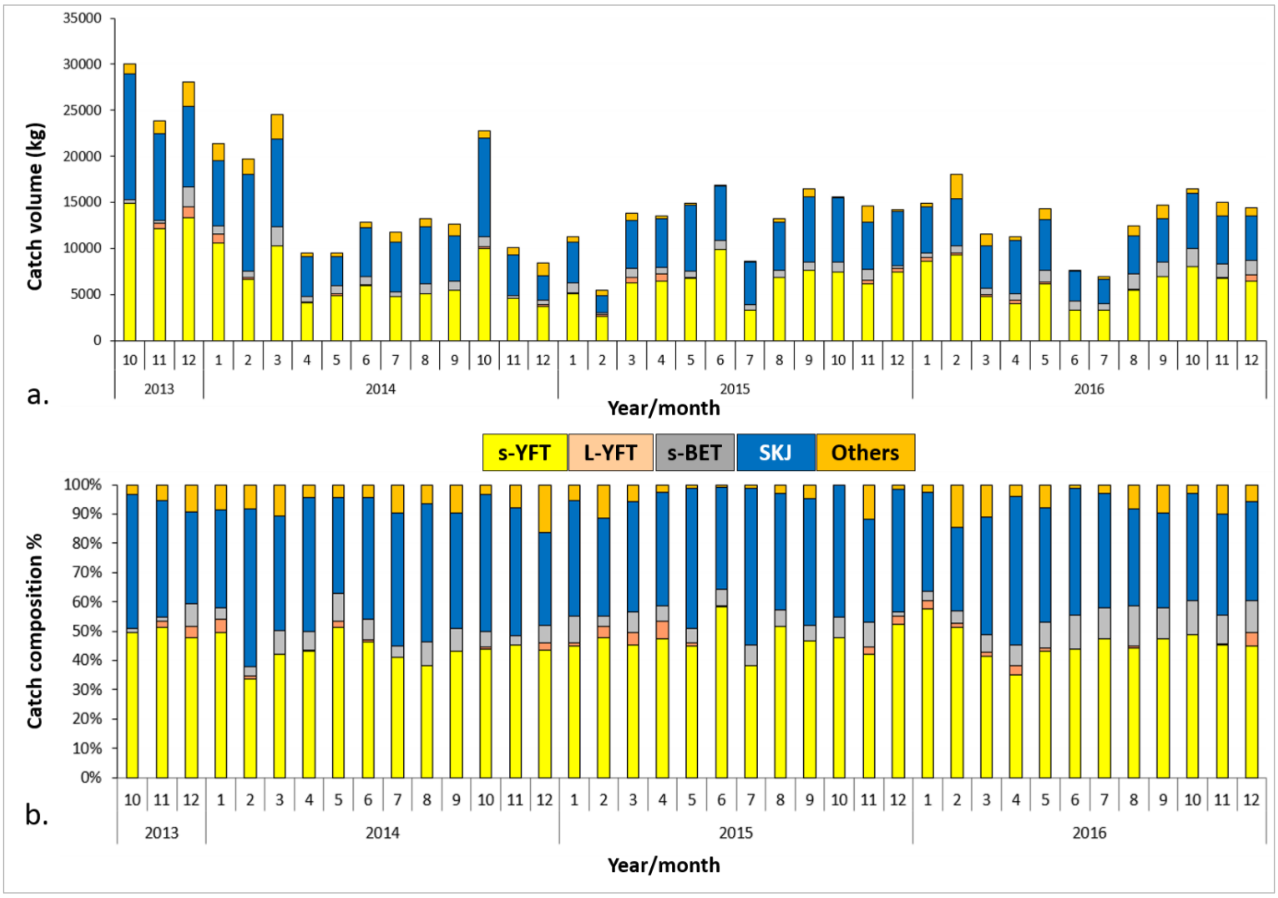

Figure 6.7. Catch composition by (a) volume (kg) and (b) % of total catch of enumerated landings from HL/TL vessels at Kendari, 2013 – 2016. s-YFT = small YFT, s-BET = small BET, L-YFT = large YFT. For species that comprise "Others" see Table 6.4.

The catch compositions of carrier vessel landings of catch at PPS Kendari, collected at sea from PL vessels, were largely as expected, based on earlier reports for Indonesian PL fisheries and also results of the Indonesian component of the tagging program in 2009 – 2010. SKJ were the dominant component of the enumerated landings, at 60 – 80% for period 2014 – 2016, and juveniles of YFT and BET combined at 21 – 32% of total catch (Table 6.5, Figure 6.8). In contrast, the proportion of SKJ in the carrier vessel landings for the enumerated period of 2013 (Oct – Dec) was at only 35%; the result of unusually large catches of frigate tuna and scads (combined proportion of ~41%) in that period.

Table 6.5. Catch composition of enumerated landings from carrier vessels at PPS Kendari, with catch from PL vessels, 2013 – 2016.

Species		Total Catch Enumerated (kg)					
Common name	Scientific name	2013* n = 39	2014 n = 99	2015 n = 158	2016 n = 160	Total 456 trips	%
Skipjack tuna	*Katsuwonus pelamis*	248,725	410,407	456,257	450,168	1,565,557	59.99
Yellowfin tuna (small)	*Thunnus albacares*	145,600	194,315	112,537	160,388	612,840	23.48
Frigate tuna	*Auxis thazard*	132,900	47,815			180,715	6.93
Scads nei	*Decapterus spp.*	150,200	26,300			176,500	6.76
Bigeye tuna (small)	*Thunnus obesus*	25,450	21,238	1,750	5,928	54,366	2.08
Common dolphinfish	*Coryphaena hippurus*		13,400		210	13,610	0.52
Indo Pacific sailfish	*Istiophorus platypterus*	4,800				4,800	0.18
Frigate tuna/Bullet tuna nei	*Auxis spp.*			200	1,000	1,200	0.05
	Total	**707,675**	**713,475**	**570,744**	**617,694**	**2,609,588**	**100**

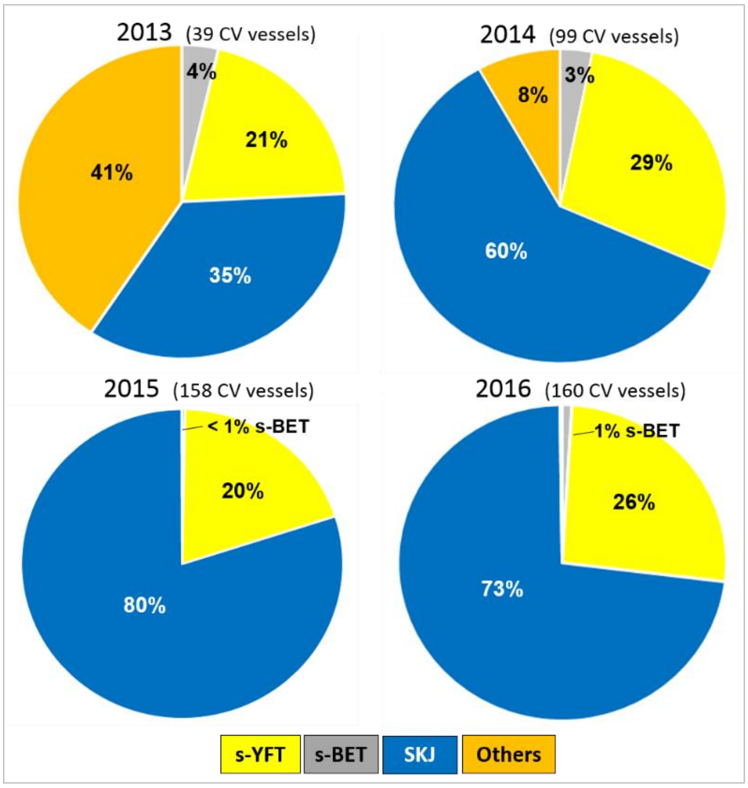

Figure 6.8. Catch composition of enumerated landings from carrier vessels at PPS Kendari, with catch from PL vessels, 2013 – 2016. s-YFT = small YFT, s-BET = small BET. For species that comprise "Others" see Table 5.5.

The catches from PS vessels, collected at sea and landed by carrier vessels at PPS Kendari during the 2013 – 2015 enumeration period, were dominated in proportion by the "Others" category, which included frigate and bullet tuna (*Auxis thazard* and *A. rochei*), scads (*Decapterus spp*.), and kawakawa (*Euthynnus affinis*) (Table 6.6, Figure 6.9). Juveniles of YFT and BET combined were at 26% of the catch.

Table 6.6. Catch composition of enumerated landings from carrier vessels at PPS Kendari, with catch from PS vessels, 2013 – 2015 combined.

Species		Total Catch Enumerated (kg)	
Common name	Scientific name	2013 - 2015 n = 92 trips	%
Frigate tuna	*Auxis thazard*	745,405	27.343
Skipjack tuna	*Katsuwonus pelamis*	664,696	24.383
Yellowfin tuna (small)	*Thunnus albacares*	542,608	19.904
Scads nei	*Decapterus spp.*	524,099	19.225
Bigeye tuna (small)	*Thunnus obesus*	149,711	5.4918
Frigate tuna/Bullet tuna nei	*Auxis spp.*	88,262	3.2377
Eastern little tuna (kawakawa	*Euthynnus affinis*	11,300	0.4145
	Total	**2,726,081**	**100**

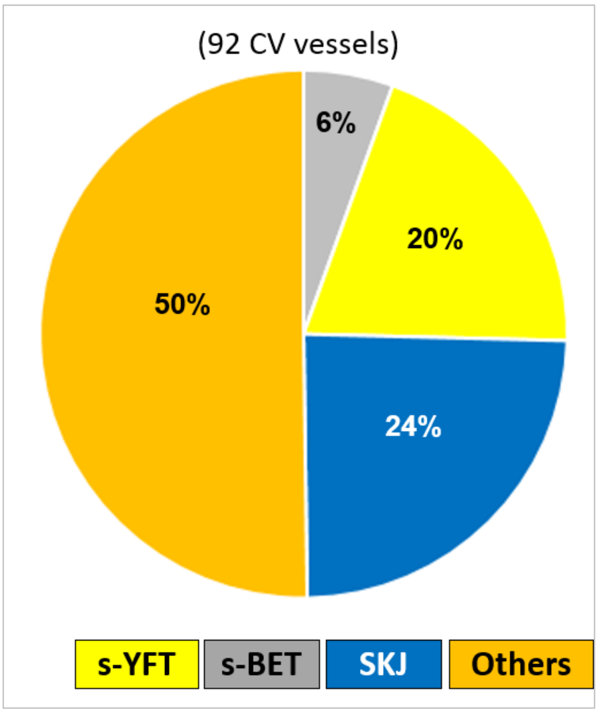

Figure 6.9. Catch composition of enumerated landings from carrier vessels at PPS Kendari, with catch from PS vessels, 2013 – 2015 combined. s-YFT = small YFT, s-BET = small BET. For species that comprise "Others" see Table 6.6.

Sorong

The enumerated landings of PL vessels at Sorong showed, unsurprisingly, a similar catch composition (all enumerated landings combined for 2013 – 2015, Table 6.7, Figure 6.10) to the PL landings at PPS Kendari, with SKJ dominating at 75%, and the juveniles of YFT and BET combined at 23% of total catch.

Table 6.7. Catch composition of enumerated landings from PL vessels at Sorong, 2013 – 2015 combined.

Species		Total Catch Enumerated (kg)	
Common name	Scientific name	2013 - 2015 n = 98 trips	%
Skipjack tuna	*Katsuwonus pelamis*	805,092	75.636
Yellowfin tuna (small)	*Thunnus albacares*	199,268	18.721
Bigeye tuna (small)	*Thunnus obesus*	37,271	3.5015
Yellowfin tuna (large)	*Thunnus albacares*	7,037	0.585
Yellowfin/Bigeye tuna nei	*Thunnus spp.*	6,227	0.0447
Frigate tuna	*Auxis thazard*	3,036	0.0775
Eastern little tuna (kawakawa)	*Euthynnus affinis*	2,575	0.2852
Yellowfin tuna (small/large nei)	*Thunnus albacares*	1,906	0.2419
Rainbow runner	*Elagatis bipinnulata*	825	0.1791
Rays bream (pomfret)	Bramidae *spp.*	711	0.6611
Common dolphinfish	*Coryphaena hippurus*	476	0.0668
	Total	**1,064,424**	**100**

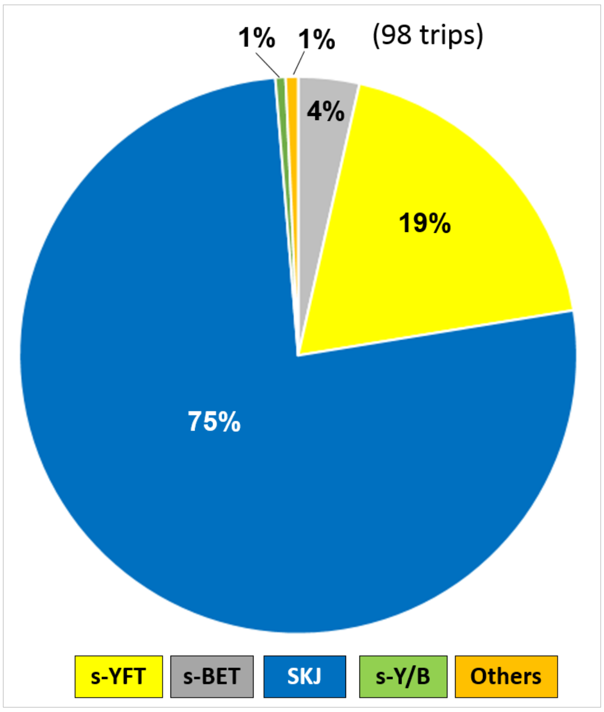

Figure 6.10. Catch composition of enumerated landings from PL vessels at Sorong, 2013 – 2015 combined. s-YFT = small YFT, s-BET = small BET, s-Y/B = small YFT/BET nei. For species that comprise "Others" see Table 6.7.

Only 16 landings of carrier vessels at Sorong with catches from PS vessels were enumerated. In the absence of a large "Others" component that was a feature for PS catches landed in Kendari, the catch composition for PS in Sorong was similar to that of PL; 78% SKJ, and 19% for juveniles of YFT and BET combined (Table 6.8, Figure 6.11).

Table 6.8. Catch composition of enumerated landings from carrier vessels at Sorong, with catch from PS vessels, 2013 – 2014 combined.

Species		**Total Catch Enumerated (kg)**	
Common name	**Scientific name**	**2013 - 2014** **n = 16 trips**	**%**
Skipjack tuna	*Katsuwonus pelamis*	443,950	78.39
Yellowfin tuna (small)	*Thunnus albacares*	90,167	15.92
Bigeye tuna (small)	*Thunnus obesus*	14,813	2.62
Frigate tuna	*Auxis thazard*	8,534	1.51
Eastern little tuna (kawakawa)	*Euthynnus affinis*	4,974	0.88
Rainbow runner	*Elagatis bipinnulata*	2,186	0.39
Common dolphinfish	*Coryphaena hippurus*	1,735	0.31
	Total	**566,359**	**100**

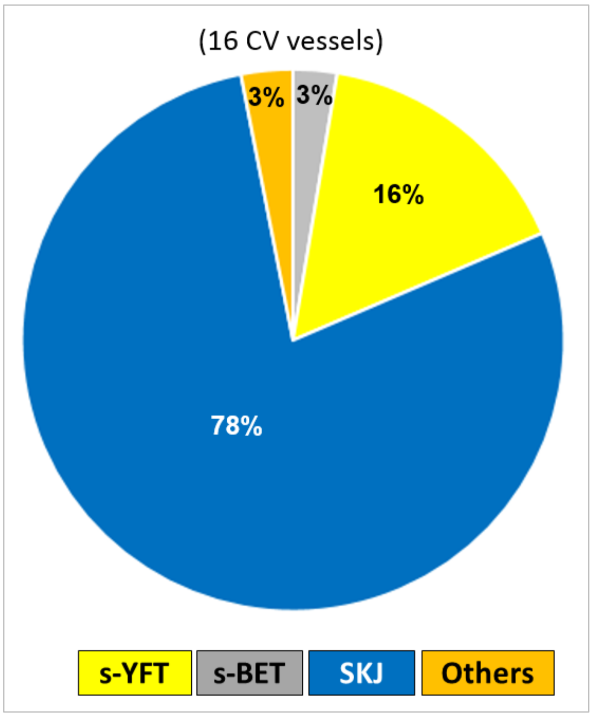

Figure 6.11. Catch composition of enumerated landings from carrier vessels at Sorong, with catch from PS vessels, 2013 – 2014 combined. s-YFT = small YFT, s-BET = small BET. For species that comprise "Others" see Table 6.8.

The enumeration program included an attempt to obtain a course measure of fishing success (i.e. a course measure of CPUE) by having the enumerators request information in their interviews with vessel captains on the numbers of FADs visited in the recently completed fishing trip and the number of those FAD visits that yielded fishing success. A successful FAD visit was loosely defined as any visit yielding catch, with no actual ranking of catch success. The number of FAD visits included return visits to FADs within a trip (i.e. the total number of FAD fishing events in the trip).

Perhaps the most interesting outcome of this assessment of fishing success (albeit coarse) is the result of only 34.5% FADs success for the HL/TL fleet at Padang, compared to significantly higher levels for the HL/TL fleets at Palabuhanratu and Kendari (85% and 68% respectively) (Table 6.9). This may be explained by the FADs used by the Padang HL/TL fleet being those owned by PS vessels based in Sibolga (west coast of North Sumatra). It is possible the low success rate (i.e. low rate of fish encounters on FAD visitation) is due to the PS vessel fishing activity and the 'recovery' periods required for fish numbers to rebuild around the FADs following PS sets.

Table 6.9. Details of FAD visitation and fishing success rates by location and by gear type; information collected through post-trip interviews with vessel captains. Average catch per trip determined from enumerated catches. Number of vessel trips refers to those trips where FAD visitation information was able to be collected by the enumerators.

Location	Gear Type	No. Vessel Trips	Average No. Fishing (days)	Av. Number of FADs visited	Av. Number of FADs with success	FADs Success rate	Average Catch (kg) per trip
Padang	HL/TL	166	12.6	12.9	4.0	34.5%	1,169
Palabuhanratu	HL/TL	1,142	7.6	1.4	1.0	85.0%	588
Kendari	HL/TL	537	7.1	12.9	8.3	67.7%	1,110
Kendari	PL	22	2.4	2.3	1.1	64.4%	3,167
Sorong	PL	91	5.8	4.5	3.9	84.9%	13,462

6.3 Biological sampling and length frequencies of tuna species

The enumeration program included biological sampling, primarily to provide information on the species diversity and size of species caught and landed by the vessels fishing on tuna anchored FADs in the region of the four focus ports. The enumerators were instructed, via the training and the sampling protocol (Proctor et al. 2018; based on WPEA sampling protocol Widodo et al. 2013), to achieve, as best as possible, a representative sample from each vessel's catch landing. The sampling targets were:

1. For landings from PS vessels, to do length measurements on about 1% of the catch (randomly selected prior to any sorting of catch by species and size);
2. For landings from PL vessels, to sub-sample at least 50 kg of fish (a randomly selected sample) for every 1 tonne of catch landed;
3. For landings from HL/TL vessels, to sub-sample at least 50 kg of fish (a randomly selected sample) for every 1 tonne of catch landed, and to measure all large tunas and large bycatch species (e.g. billfish and sharks).

An additional key objective of the biological sampling activity was to provide capacity development to the enumerators in the techniques of subsampling of catches from fishing vessels, the actual methods of measurement with callipers and measuring boards, in species identification skills, and in all steps of data recording, data processing, and reporting.

Across the four focus ports, a total of 51,610 fish in the "small" (i.e. ≤ 100 cm) category and 2,187 in the "large" (i.e. > 100 cm) category were measured during the enumeration program (Table 6.10). All data collected by the enumerators were recorded on the *Catch Sampling Form* for the relevant vessel gear type and subsequently entered into the *Biological Sampling (Small)* and *Biological Sampling (Large)* modules within the FAD Fisheries Database.

Table 6.10. Details of the numbers of fish measured, by species, for length in the enumeration program (all ports combined). nd = not able to be differentiated.

English	Scientific name	Number
SMALL (< 100 cm)		
Skipjack tuna	*Katsuwonus pelamis*	25,268
Yellowfin tuna	*Thunnus albacares*	16,312
Bigeye tuna	*Thunnus obesus*	4,874
Common dolphinfish	*Coryphaena hippurus*	1,825
Frigate/Bullet tuna (nd)	*Auxis thazard/A. rochei*	985
Yellowfin/Bigeye tuna (nd)	*Thunnus albacares/T. obesus*	618
Frigate tuna	*Auxis thazard*	520
Rainbow runner	*Elagatis bipinnulata*	502
Eastern little tuna, Kawakawa	*Euthynnus affinis*	432
Scads nei	*Decapterus* spp.	209
Various sharks nei		25
Narrow-barred Spanish mackerel	*Scomberomorus commerson*	17
Albacore tuna	*Thunnus alalunga*	12
Other fish nei		5
Silky shark	*Carcharhinus falciformis*	3
Black marlin	*Istiompax indica*	2
Striped marlin	*Kajikia audax*	1

Table 6.10. Continued.		
LARGE (> 100 cm)		
Yellowfin tuna	*Thunnus albacares*	1,478
Striped marlin	*Kajikia audax*	665
Common dolphinfish	*Coryphaena hippurus*	15
Marlins, sailfish, spearfish nei		13
Black marlin	*Istiompax indica*	10
Swordfish	*Xiphias gladius*	2
Bigeye tuna	*Thunnus obesus*	2
Various sharks nei		1
Albacore tuna	*Thunnus alalunga*	1
Blue shark	*Prionace glauca*	1

The length frequency histograms for SKJ, YFT, and BET, as determined from the biological sampling conducted at the four ports are provided below. As already highlighted in the catch composition section above, juvenile YFT and juvenile BET comprised significant proportions of the landings from all enumerated gear types (HL/TL, PL, and PS). The red lines in each frequency distribution (Figures 6.12 to 6.18) indicate the approximate lengths at maturity (L*m*) for the three tuna species, based on information from Fishbase[7] and other sources. However, it should be emphasised that the L*m* reported for each of SKJ, YFT, and BET does appear to vary across the species' geographic range, and that to date, determining this key population parameter for these species in Indonesian waters has not been rigorously examined[8].

[7] Fishbase: https://www.fishbase.in

[8] Determining L*m* for SKJ, YFT, and BET in Indonesian waters is a key objective of the follow-on ACIAR project FIS/2016/116.

Padang

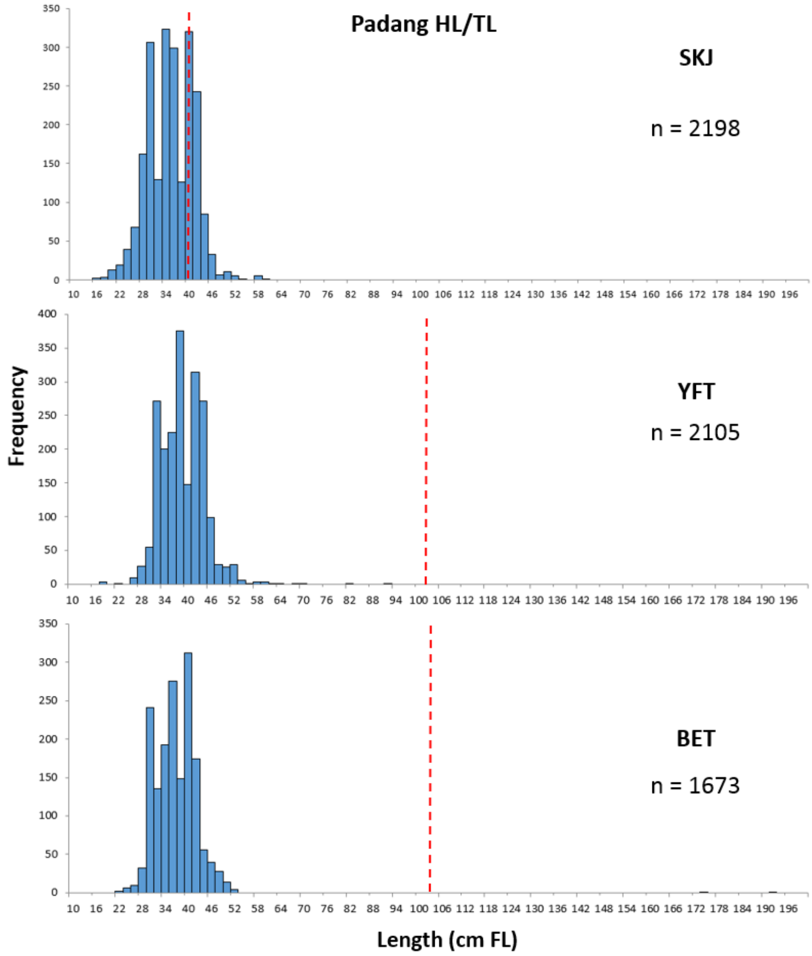

Figure 6.12. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Muara Padang from HL/TL vessels, 2013 – 2015 combined. Red dashed line indicates approximate L*m* for each species.

Palabuhanratu

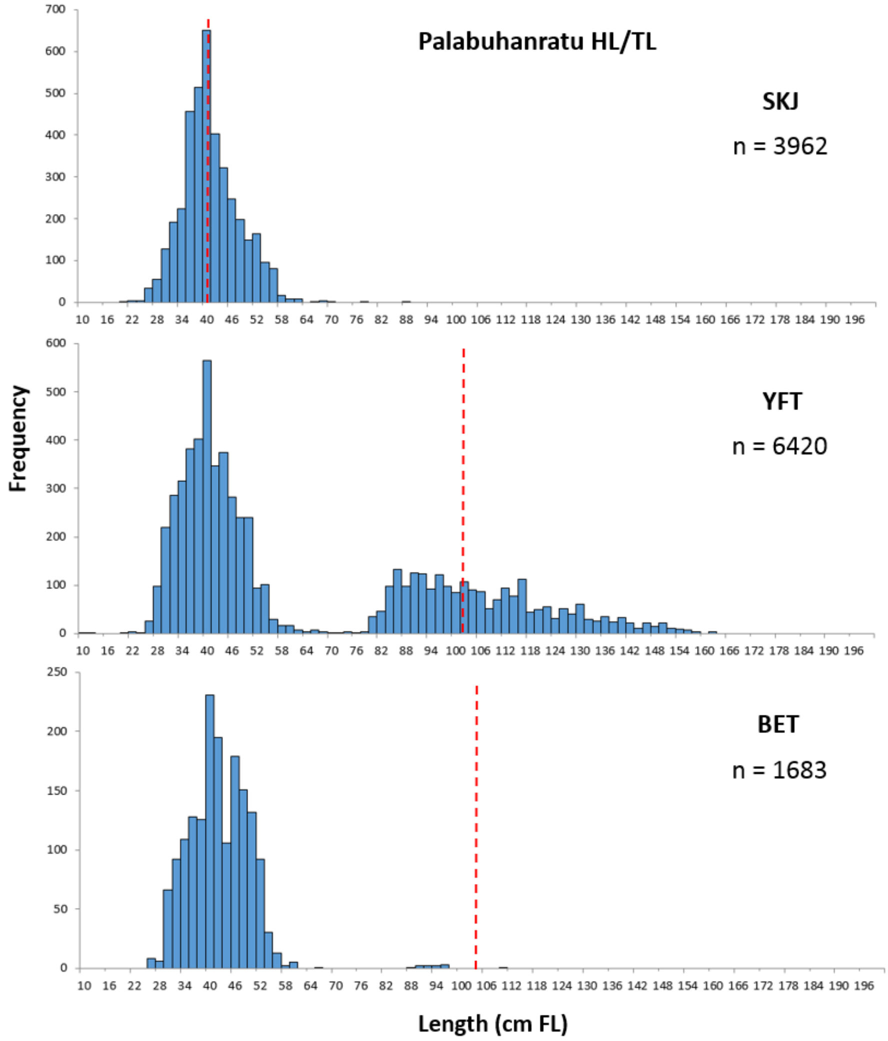

Figure 6.13. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Palabuhanratu from HL/TL vessels, 2013 – 2016 combined. Red dashed line indicates approximate L*m* for each species.

As detailed in Section 6.2, the catches landed by the HL/TL vessels in Palabuhanratu commonly include both small and large tuna. The small tuna include YFT and BET caught by troll-line and shallow water hand-line, and the large tuna are almost exclusively all YFT caught by deepwater handline and/or surface kite and lure fishing. The reason(s) for the paucity of YFT in the 60 – 80 cm size range is unclear. It could be the result of gear-generated selectivity i.e. the fish of that size are present around the FADs but for gear related reason(s) are not caught. Or perhaps the fish of that size are absent for behavioural reasons, or from a combination of both gear and behaviour reasons. It appears unlikely that the absence of this size 'class' is the result of seasonality in spawning i.e. a cohort effect, but until more research is done on the reproductive biology of this species (and for BET) in Indonesian waters, strong conclusions cannot be drawn.

Kendari

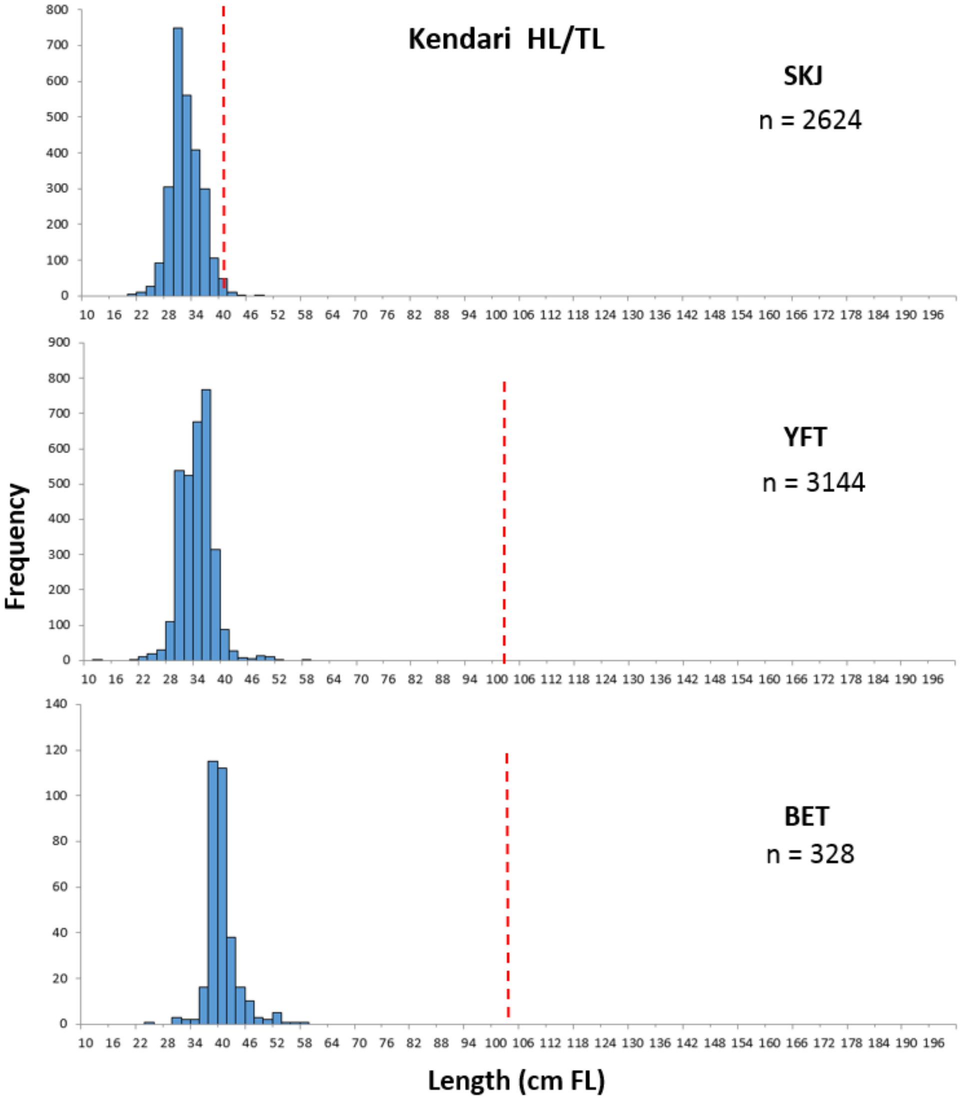

Figure 6.14. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Kendari from HL/TL vessels, 2013 – 2016 combined. Red dashed line indicates approximate L*m* for each species.

As mentioned in the catch composition section (Section 6.2), the enumeration program did not achieve 'capture' of the adult YFT component of landings from HL/TL vessels in Kendari, because of the processing of these larger fish into fillets that occurs at sea.

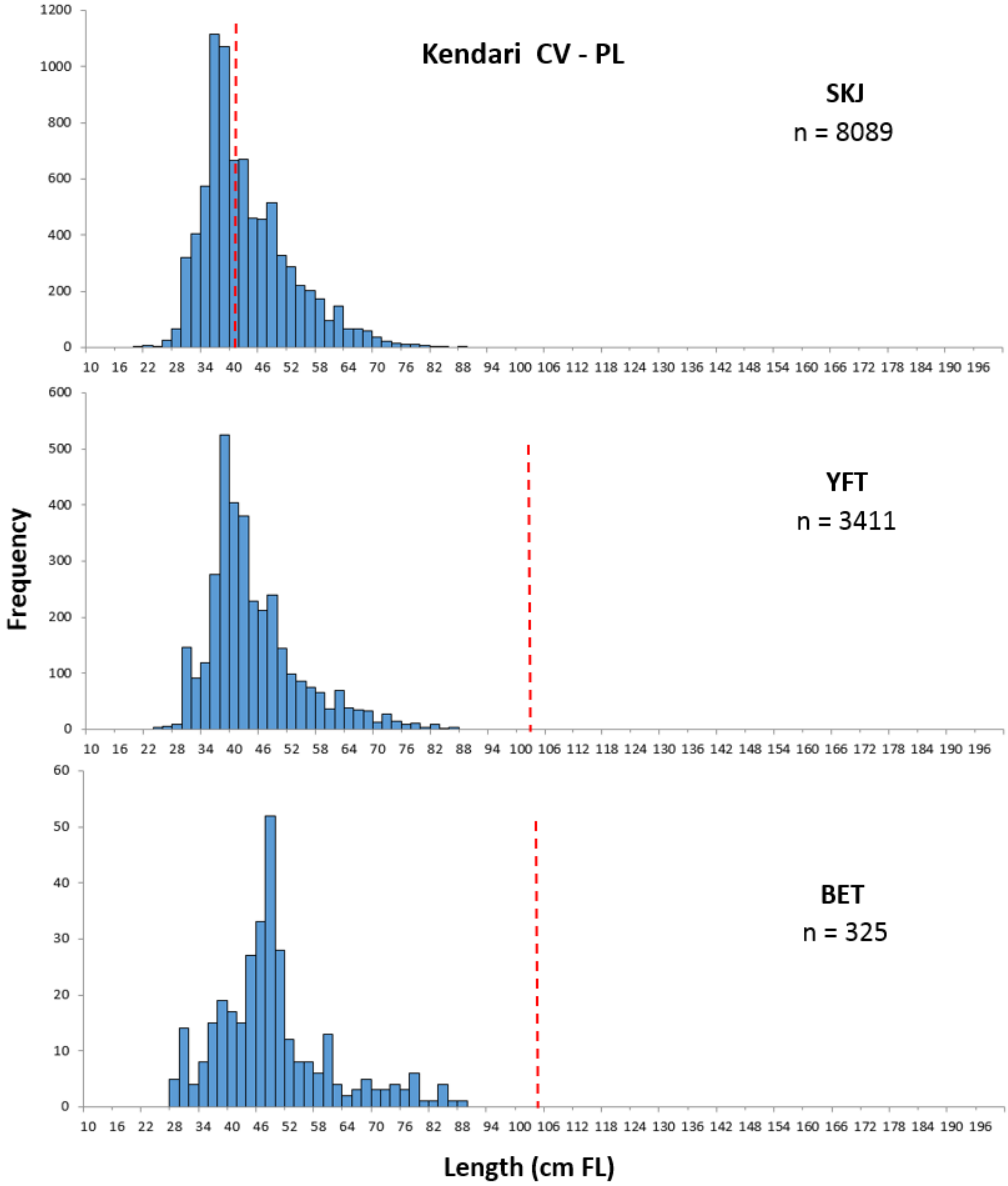

Figure 6.15. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Kendari from PL vessels, landed by carrier vessels, 2013 – 2016 combined. Red dashed line indicates approximate L*m* for each species.

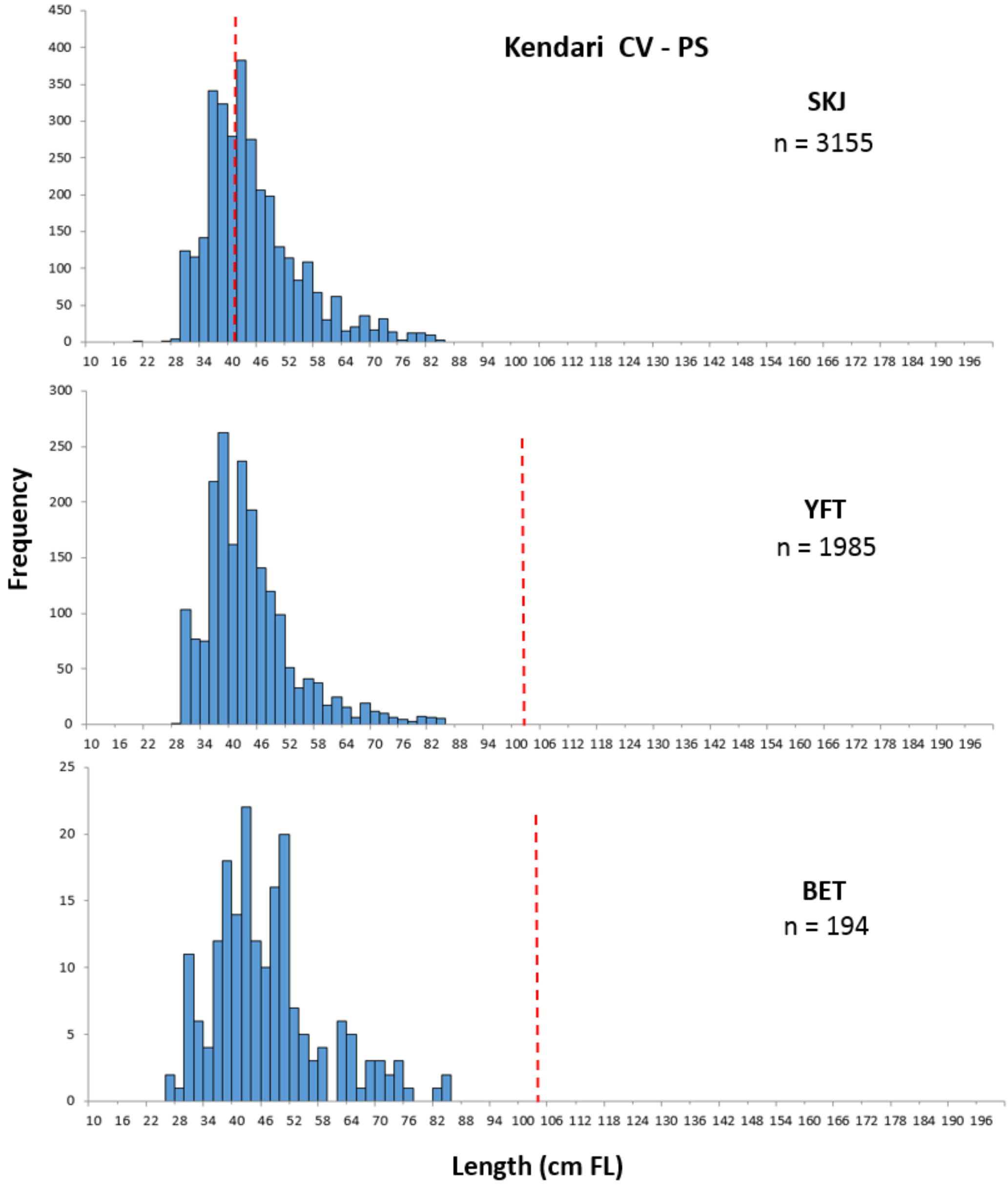

Figure 6.16. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Kendari from PS vessels, landed by carrier vessels, 2013 – 2014 combined. Red dashed line indicates approximate L*m* for each species.

Sorong

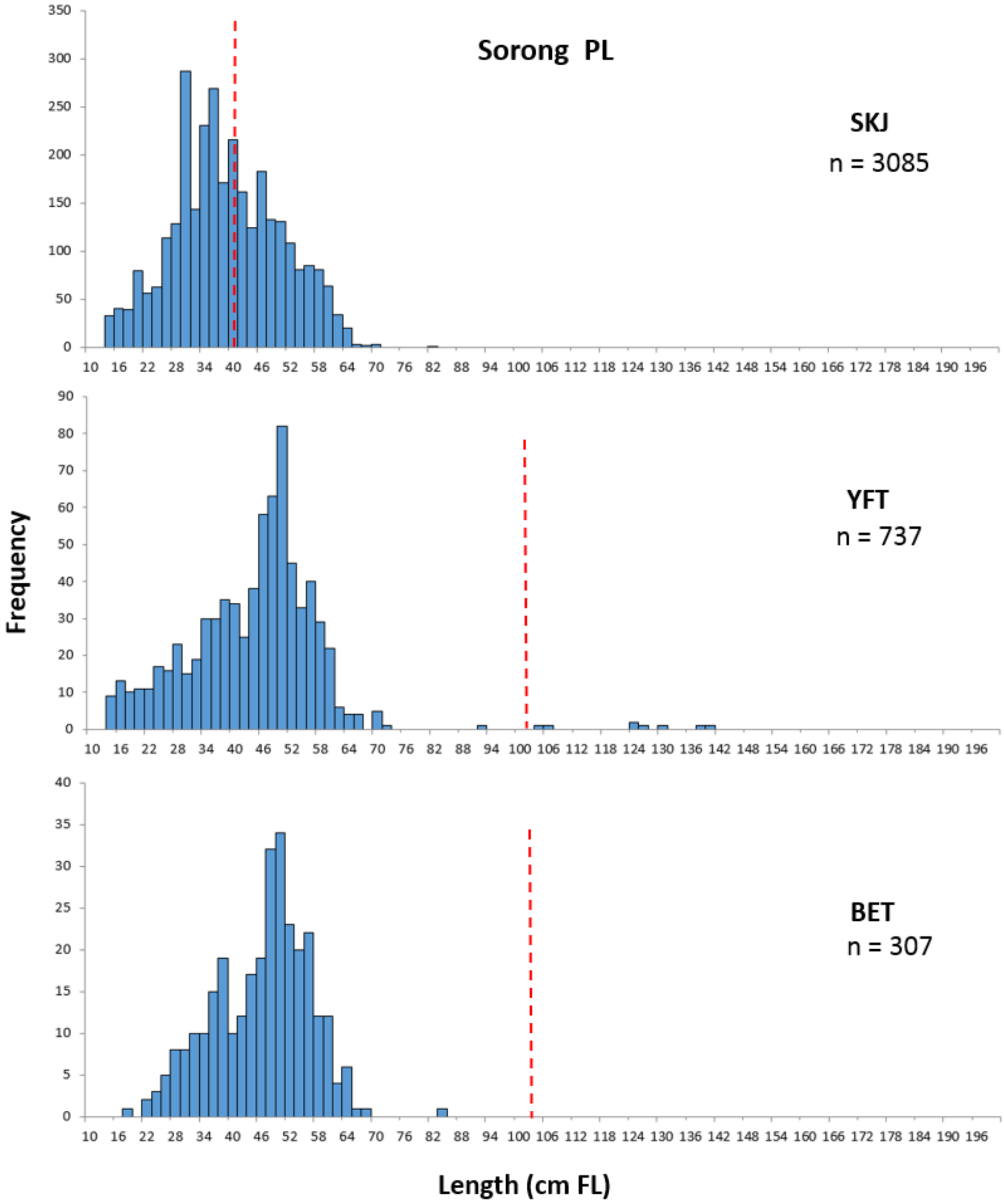

Figure 6.17. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Sorong from PL vessels, 2013 – 2015 combined. Red dashed line indicates approximate L*m* for each species.

It is possible that the few large YFT (i.e. > 100 cm FL) that appear in the above distribution were caught by PL, but it is also possible, and perhaps more likely, that these larger fish were caught opportunistically by hand-line during the fishing trips.

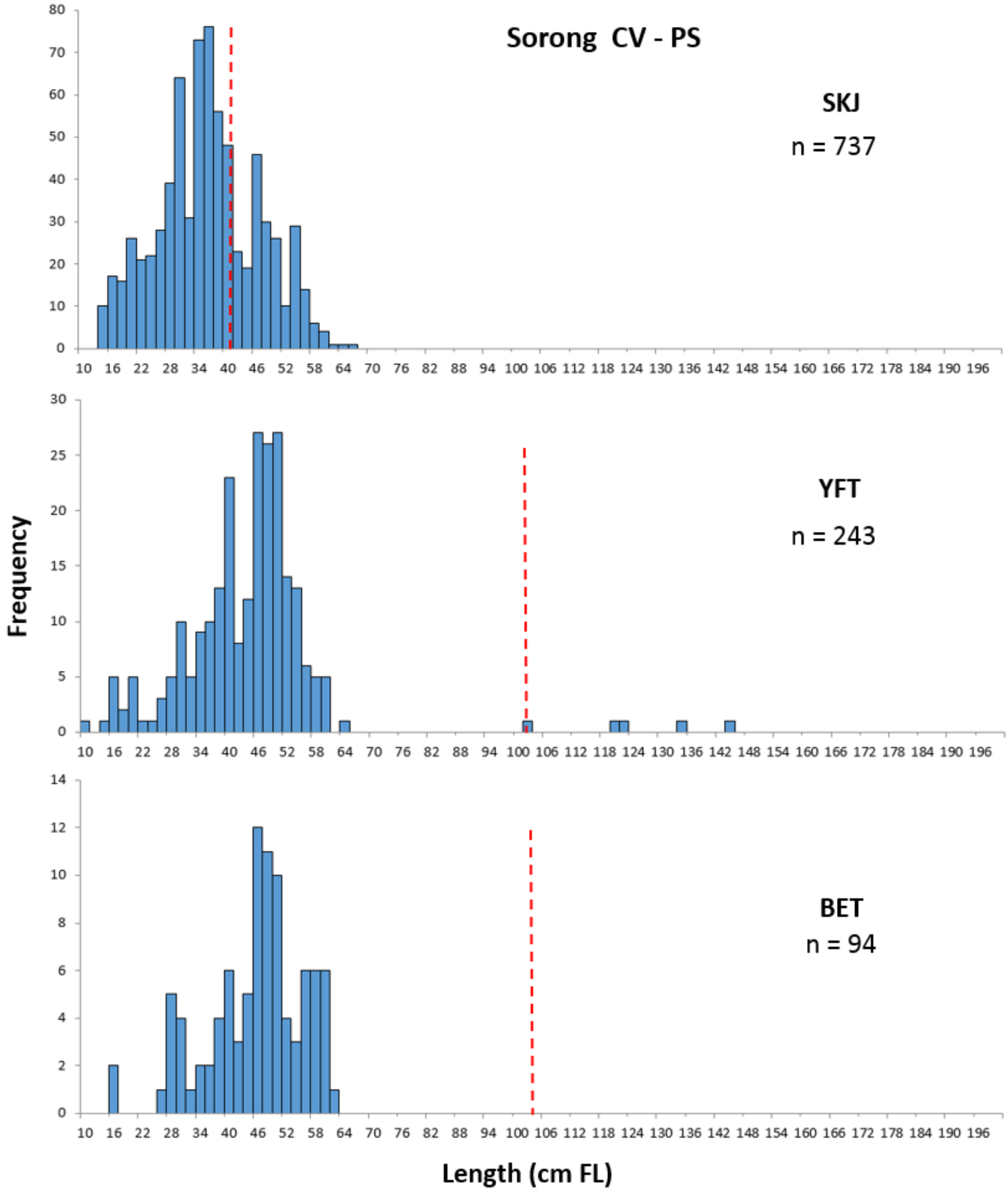

Figure 6.18. Length frequency distributions of SKJ (top), YFT (middle), and BET (bottom) subsampled from catches at Sorong from PS vessels, landed by carrier vessels, 2013 – 2014 combined. Red dashed line indicates approximate L*m* for each species.

As mentioned above for PL in Sorong, it is possible that the few large YFT (i.e. > 100 cm FL) that appear in the above distribution for PS were actually caught by PS, but it is also possible that these larger fish were caught opportunistically by hand-line during the fishing trips.

6.4 FAD 'dynamics' – numbers, locations, ownership and usage

In this section we present the results of information obtained through interviews performed by the enumerators with vessel captains post-fishing trips and from information gathered by project scientists visiting the four focus fishing ports and the other ports for the sampling of the project's population structure study.

FAD types

As reported in Section 5, the surface floats of anchored tuna FADs in Indonesian waters vary in construction. Vessel Captains were asked in interview "What type of FADs were visited by your vessel during this fishing trip?". Table 6.11 shows the types of FADs used by location and vessel gear type, and the styrofoam type ("*gabus*") were in the majority for western Indonesia, whereas in eastern Indonesia it was common for vessels to have used/visited FADs of multiple types in the one fishing trip.

Table 6.11 Types of FADs visited, by number of fishing trips, by location. Information obtained via post-trip interviews with vessel captains. S = styrofoam (i.e. *gabus*), P = steel pontoon, B = bamboo raft, B+B = bamboo raft + bungalow. Multiple FAD types includes the various combinations of FAD types.

Location	Gear type	Trips	FAD Type												
			S	P	B	B+B	Multiple FAD types								
							S, P	S, B	S, B+B	S, B, B+B	S, P, B	S, P, B+B	S, P, B, B+B	B, B+B	P, B+B
Padang	HL/TL	157	155				2								
Palabuhanratu	HL/TL	1119	1112	7											
Kendari	HL/TL	543		14	4	5	70	20	52	62	38	132	89	26	31
	PL	20				19							1		
Sorong	PL	74		50			23	1							

The styrofoam "*gabus*" type of FAD float had become increasingly popular because of its cheaper cost, ready availability of materials, and ease of construction compared to the steel pontoon and bamboo raft types. As example evidence of this change is that in 2006 – 2007, when our earlier ACIAR project FIS/2002/074 participated in a trial tuna tagging program in the West Sumatra region (Anon 2008), all of the ~56 FADs encountered in the Mentawai Strait were of the steel pontoon type. At time of this study, involving the same fleet of HL/TL fishing vessels based at Muara Padang, almost all FADs were *gabus* type.

FAD locations, numbers and density

At the beginning of the FAD study we anticipated that it would be difficult to obtain an accurate 'picture' of the numbers and distribution of tuna FADs by region, mainly because of lack of any effective registration system for the FADs at that time but also because of the dynamic nature of the FAD situation and the of the FADs themselves. This proved to be true. There is a high turn-over of the anchored tuna FADs, for various reasons including:

- FADs are often lost to natural forces such as storms and strong currents - breaking FAD lines or moving FADs significant distances if insufficient anchor weight;
- FADs are also lost through 'unnatural forces'. It is not uncommon for FAD lines to be cut through conflicts with other fishing gear types e.g. by longline and gill-net vessels whose fishing gears are prone to entanglement on FAD floats and FAD lines;
- Conflicts between the vessels that fish on FADs, involving cutting of FAD lines, were also reported to have occurred - primarily between purse-seine vessels and hand-line/troll-line vessels, and even vessels of the same gear type from rival fishing companies;
- FAD lines deliberately cut by cargo vessels or other vessels encountering FADs in navigation lanes;

- As the FAD surface floats are most often poorly marked and difficult to see, loss of FADs can also occur through accidental, direct 'hits' (impacts) from other vessels;
- FADs degrade in condition at sea and the life-span of an Indonesian anchored tuna FAD will be, on average, a maximum of 2 years, but often less;
- FADs are constantly being replaced, and also new FADs installed, with still no effective implementation of a FAD registration system in most regions (see discussion on current FAD regulations in Section 6.5).

In the absence of an effective FAD registration system, obtaining FAD numbers and locations from port authorities or other offices linked to fishing vessel activity proved difficult. This was through no reluctance by these offices to provide the information and was only due to the non-existence of such information. Some vessel captains were willing to provide the way points from their GPS units for the positions of FADs they were using, but others were reluctant to do so for fear of giving up information viewed as too confidential in competing with rival fishers.

The majority of vessel captains interviewed post-fishing trip by the enumerators were, at least, willing to mark the grid-square (1^{o} x 1^{o}) positions for the FADs used in their trip, on the map provided on the back of the enumerator's data collection sheet. These records enabled a 'visitation frequency map' to be generated for the four focus regions (Figure 6.19).

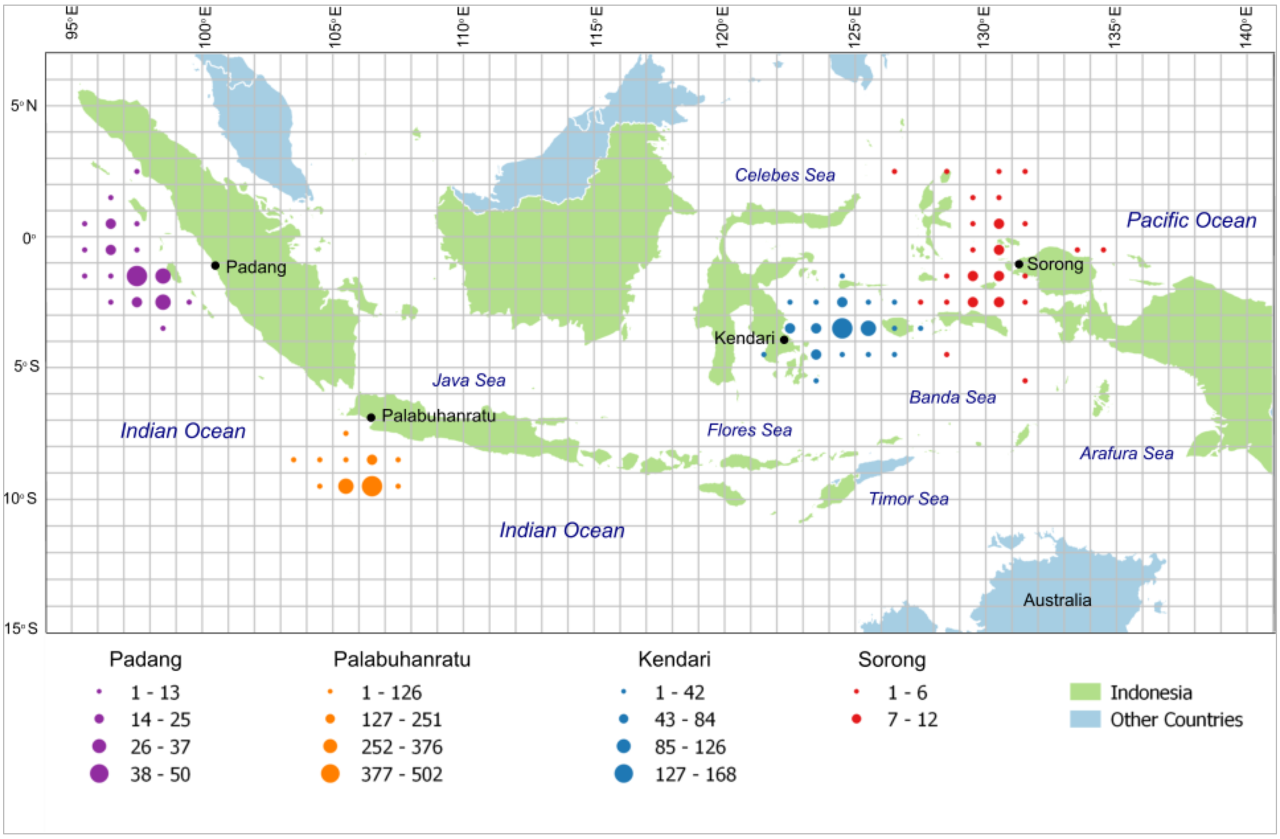

Figure 6.19. Map showing the distribution of FAD-based tuna fishing activity, based on numbers of fishing trips recorded with activity in 1^{o} x 1^{o} grid squares (information provided by vessel captains in post-trip interviews with enumerators). The coloured spot markers indicate the level of activity within the areas bound by the grid squares, and not the exact location of fishing activity. The activity shown is for the four focus regions of the project's study for vessels operating out of Padang (purple), Palabuhanratu (orange), Kendari (blue), and Sorong (red). Note that this is not a representation of all the FAD 'hot spots' in Indonesian waters – there are others.

Information collected through this study concurred with information available from other sources (ABPC pers. comm. 2014; Hargiyatno et al. 2013 and 2015; Nurdin et al. 2012; Nurdin 2017; Satrioajie et al.

2017), in showing that the Indonesian anchored tuna FADs are often installed in close proximity to each other. The most recent FAD regulations (No.26/PERMEN-KP/2014) and DGCF FADs Management Plan of 2015 – 2017 (DGCF 2014) include the stipulation that "the distance between FADs must not be less than 10 nmi and must not be installed in a fence-effect (i.e. in a zig-zag pattern). There is clear evidence of this regulation not being adhered to nor enforced, at least in respects of inter-FAD distance. Our data presented in Figure 6.20 shows that many of the FADs used by the vessels in enumerated trips in the four focus regions, had inter-FAD distances of ≤ 10 nmi, and a significant number at ≤ 5 nmi. We do acknowledge the difficulty in obtaining a 'snapshot' of FAD positions to do such inter-FAD distance assessments, given the mobility of FAD surface floats. Anchored tuna FADs are commonly installed in deepwater (1500 – 5000 m) locations and subject to strong currents. FAD surface floats 'swing' on the FAD lines under the influence of these currents and can change position by as much as 2 or more nmi.

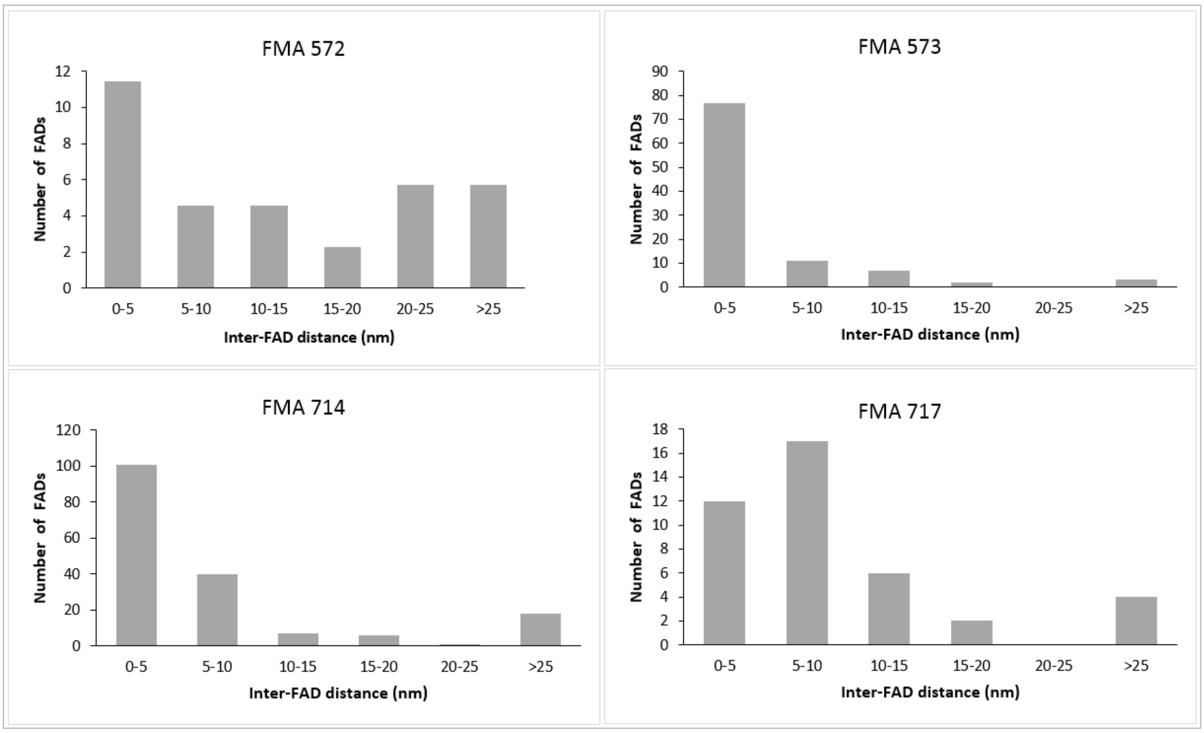

Figure 6.20. Histograms to show the frequency of inter-FAD distance (nm) for the FADs recorded by the enumeration program in each on the four Fisheries Management Areas (FMAs).

Information reported by Australia's Border Protection Command[9] (ABPC pers. comm. 2014) of hundreds of FAD sightings, detected in aerial surveillance conducted close to the Australian-Indonesian maritime border in the Timor Sea, to south of West Timor, showed that "many Indonesian FADs are arranged in grids, with regular spacing of between three and seven nautical miles apart". Similarly, the results of a detailed study of anchored tuna FADs in the Celebes and Molucca Seas by Satrioajie et al., presented to the FADs Fisheries Management Workshop in Bali in early 2017, reported a high incidence of inter-FAD distances of <10 nmi, and "within ~ 7km (3.78 nmi) from each other" (Satrioajie et al. 2017, and in prep). Their study, which drew on positional information sourced from fishers logbooks, interviews with fishers, and direct observations of FAD positions, did acknowledge the likelihood of some level of 'double counting' of FADs due to the mobile nature of the FAD surface floats.

Table 6.12 provides a summary of information from several earlier studies on numbers of FADs in particular regions of Indonesian waters (within and outside the internal archipelagic waters). The

[9] *Information provided in 2014 by Australian Border Protection Command, from a confidential internal report on results of aerial surveillance in the region of the Australian - Indonesian maritime border in the Timor Sea.*

majority of the estimates of FAD numbers are based on GPS position coordinates obtained directly from skippers through interview and/or from their notebooks/logbooks.

Table 6.12. Summary of FADs in various regions of Indonesian waters as reported by earlier studies. HL/TL = hand=line/troll-line, PL = pole & line, PS = purse-seine.

Region	Approx. Lat/Long Coord. of area	No. of FADs (Main users)	Year	Study	Source of FAD positions
W, SW, S, SE of Palabuhanratu West Java) - NE Indian Ocean	6.8 – 9.7 °S 105.0 – 107.4 °E	**112** (HL/TL from PPN Palabuhanratu)	2013	Hargiyatno et al. (2013)	Information from PSDKP Palabuhanratu and from skipper.
As above	As above	**85** (HL/TL from PPN Palabuhanratu)	2015	Nurdin (2017) – unpublished PhD thesis.	GPS coordinates from skipper.
S, SW of Prigi (East Java) - NE Indian Ocean	8.5 – 9.4 °S 110.6 – 112.0 °E	**54** (HL/TL from PPN Prigi)	2011	Nurdin et al. (2012)	GPS coordinates from skipper.
NE of Kendari (SE Sulawesi) - northern Banda Sea	2.0 – 3.0 °S 124.0 – 127.0 °E	**83** (PS from PPS Kendari)	2015	Hargiyatno et al. (2015)	GPS coordinates from skippers.
NE, SE, S, SW of Kendari (SE Sulawesi) – Banda Sea, northern Flores Sea	2.5 – 6.0 °S 121.0 – 125.0 °E	**51** (HL/TL from PPS Kendari and PP Sodohoa)			GPS coordinates from skippers.
SE, S, NW from Ambon – Banda Sea, Arafura Sea	4.0 – 8.0 °S 125.0 – 134.0 °E	**39** (PS from PPN Ambon)			Fishing company in Ambon
N, S from Maumere – Flores Sea, Savu Sea	7.5 – 9.0 °S 122.5 – 124.0 °E	**5** (PL from Maumere)			GPS coordinates from skippers.
Molucca Sea	2.0 °N – 2.0 °S 123.0 – 128.0 °E	**673** (PL, HL/TL, PS from PPS Bitung and smaller ports)	2013 - 2015	Satrioajie et al. (2017)	GPS coordinates from skippers.
Celebes Sea	1.0 – 5.0 °N 120.0 – 126.0 °E	**289** (PL, HL/TL, PS from PPS Bitung and smaller ports)			
Ceram Sea (south of Misool Is.) and southern Halamahera Sea (north of Waigeo Is.)	0.5 °N – 2.0 °S 129.5 – 131.0 °E	**37** (PL from Sorong)	2018	WCPFC-WPEA-SM Program (2018) (A. Widodo pers. comm. Report in prep.)	Fishing company in Sorong (PT Citra Raja Ampat)
FAD positions unknown but in West Papua region.	na	**75** (Deepwater HL from Sorong)	2018		Fishing company in Sorong (UD. Jangkar Emas)

Scott and Lopez (2014), in their EU report on anchored and drifting FADs in countries worldwide, list Indonesia as having a total of 3858 anchored FADs, a number that had been reported by Natsir and Proctor (2011). Wibisono (2015), as mentioned in PT Hatfield Indonesia report[10] (2016), referred to

[10] PT Hatfield Indonesia (2016). FAD (Fish Aggregating Device) Fishing in Indonesia. Report prepared for The Nature Conservancy's Fisheries Conservation Program. PT Hatfield Indonesia. 12 pp.

these 3858 FADs as being "official FADs", suggesting they had been officially registered. The figure of 3858 was provided to Natsir by DGCF, but it was and still is unclear how that figure was derived, and whether it was a measure of officially registered FADs at that time. Based on the numbers of FADs reported by the earlier studies, and the number of regions where anchored tuna FADs are known to be used across the Indonesian archipelago, we (the authors of this FAD fisheries study) consider a total figure in the range of 5,000 – 10,000 to be 'realistic'.

FAD ownership and operations

The various ways in which FADs are owned and operated for the fisheries based in Palabuhanratu and Kendari are reported in Section 7 (*Preliminary socio- and bio-economics surveys of FAD-based tuna fisheries at two key ports*). A following is a summary for the Indonesian tuna FADs more generally:

1. **FADs provided by local government (Province, Regency)**

   - for use by local fishers (one or more gear types);

   - all associated costs of FAD production, installation, and maintenance are borne by local government, or by fishers, or mix of both;

   - in some cases, support also provided through vessel assistance schemes;

2. **FADs owned by local fishing association or fishers 'group'**

   - all costs of installation and maintenance borne by the association/group;

3. **FADs privately owned**

   - installed by private fishing company or vessel owner and only used by vessels of that company/owner and/or by 'contracted' vessels in *mitra kolaborasi*[11] arrangement;

   - sometimes use a 'rolling system' of vessels to guard FADs against use by other fishers/companies (i.e. a vessel using a FAD does not leave until a 'sister' vessel arrives to maintain a presence at the FAD);

   - installed by private fishing company for their company vessels but they also allow use by vessels of other fishers/companies;

   - FAD 'time sharing' by unwritten agreement e.g. HL/TL vessels can use the FADs owned and installed by PS vessel companies, but the former must depart the FAD if a PS vessel arrives;

   - 'outside' vessels permitted to use the FAD but must pay a fee (often % catch fee), or provide payment by acting as 'watch-dog' and reporting use of FADs by other vessels to FAD owner (e.g. HL/TL vessels allowed to 'anchor to' FADs owned by PS or PL vessel companies in return for 'watch-dog' reporting);

   - all costs of installation and maintenance are borne by owner company.

Until a few years ago, FADs provided by provincial and regency governments, to support local fishers and local fisheries, were a common occurrence. However, in recent times, the great majority of the deepwater tuna FADs, deployed in Indonesian waters, are privately owned i.e. owned by fishing companies, fishing vessel owner/operators, or by entrepreneurial persons who manufacture and install FADs as a business.

[11] *Mitra kolaborasi – An arrangement also known as "nuclear estate for small stakeholders" or "small holders nucleus system" (Soepanto and Nikijuluw 1999), a system of cooperation between a commercial fishing company and small scale fishers as suppliers, pioneered by company PT Usaha Mina for small scale tuna fishers in Irian Jaya (now known as West Papua), beginning around 1985.*

Large numbers of FADs (*payaos*) were introduced into the Indonesian EEZ in the early 1990s by Philippine purse-seine vessel operators; deployed primarily in Celebes Sea, west of the Sangihe Islands, in the area between Sangihe and Talaud Islands, and in the Maluku Sea (Naamin et al 1996). Indonesian fishing vessels were reportedly actively excluded from using these FADs and they were the cause for considerable ill feeling by Indonesian fishers towards those on the foreign vessels and their foreign fishing companies. There was a strong belief that the Philippine purse-seine activity, and the 'walls of FADs' installed by them, were significantly impacting on availability of tuna to the Indonesian fishers and were a major threat to the sustainability of the Indonesian fisheries (Mathews and Monintja 1996). However, these foreign owned FADs have since disappeared with the introduction of Indonesian Government strict laws in 2014 banning fishing by foreign owned vessels in Indonesian territorial waters.

6.5 Past and current FAD regulations and initiatives for improved management

The foundations of Indonesia's fisheries regulations relevant to FADs date back to 1997, with the **Minister of Agriculture Decree Number 51/Kpts/IK.250/1/97** "about the installation and utilization of FADs". According to the wording in the Decree, this followed recognition that the use of FADs was increasing rapidly, was unregulated, with potential for threatening fish habitat patterns and the sustainability of fish resources, and potential for causing social tension among fishermen. The Decree defined FADs into 3 types: 1. *Rumpon perairan dasar* (bottom water FAD), 2. *Rumpon perairan dangkal* (shallow water FAD), and 3. *Rumpon perairan dalam* (deepwater FAD) were defined as those installed in marine waters of > 200 m depth. The bottom and shallow water FADs were further defined as those under regulation of Regional governments; Level 2 Regional Government for waters from shore to 3 nmi, and Level 1 Regional Government for waters > 3 – 12 nmi from shore. The Decree stipulated that deepwater FADs could only be installed by fishing companies, government agencies, and research institutes and universities (the latter in a framework for developing science and technology). Fishing companies wanting to install deepwater FAD(s) were required to a obtain a Deepwater FAD Installation Permit from the Director General of Fisheries, and provide the planned timing and coordinates (Lat/Long) of installation and a copy of the proposed FAD design. The FAD installation permits were to be valid for 3 years with option of extension upon expiry.

Under the abovementioned 1997 Decree, in addition to requiring a FAD installation permit, fishing companies were required to:

- not install FADs in shipping lanes;
- have a minimum inter-FAD distance of 10 nmi;
- not disrupt the movement of fish in marine waters, and specifically not install FADs in a "zig-zag" effect that threatens the sustainability of pelagic fish species;
- not install FADs in waters < 200 m deep;
- not install FADs in waters < 12 nmi from shore;
- have the FAD marked for identification and maintain the FAD in the one location (i.e. nominated place of installation).

Use of installed deepwater FADs by other parties was permitted under the Decree, but only with the FAD owner's permission. And furthermore, fishing companies with deepwater FADs "shall be obliged to provide opportunities for small-scale fishermen to catch fish in the vicinity of FADs installed inside the Indonesian EEZ". Article 10 in the Decree refers to the allowed gear types for deepwater FADs as pole and line, hand-line, or troll-line. Purse-seine was also permitted but with the specific requirement of only to be used within the Indonesian EEZ and at least 20 nmi from the outer boundary of the Regional Seas (*Laut Wilayah*). Holders of FAD installation permits were also required to provide 6 monthly reports to the Director General of Fisheries and to the Head of Local Level 1 Fisheries Office (*Kepala Dinas Perikanan Daerah tingkat I setempat*).

The 1997 Decree did not include any limitation on the number of FADs that could be installed by any one fishing company, but did include the clause “To foster the preservation of fish resources, control and prevent social tensions, the Director General of Fisheries can restrict the number of Deep Water FAD Installation Permits”.

The next significant development in Indonesia’s FAD regulations came in 2004 with a review of the 1997 Decree under the Decree of the **Minister of Marine and Fisheries number KEP.30/MEN/2004**. Significant changes included:

- those able to apply for a FAD Installation Permit included “individuals” (Chapter III/Article 10) and not only fishing companies. However, confusingly, in Chapter 5/Article 12 of the Decree it is stated that “the utilisation of FADs may only be done by fishing companies”;
- the changes to the jurisdictional zoning, with installation permits granted by the relevant governing body: Regency Government for FADs in zone 2 – 4 nmi from shore, Provincial Government for those in zone > 4 – 12 nmi from shore, and National Government for those installed in the > 12 – 200 nmi (i.e. boundary of the EEZ);
- the permit period of 2 years, with option of extension upon expiry;
- the granting of permission to install FADs must consider the carrying capacity of fish resources and their environment and the socio-cultural aspects of the local community;
- each FAD installed must be given an ID by the relevant governing body, and the form and format of that identification will be stipulated by the Director General of Fisheries.

During the following decade there were other developments in Indonesia’s FAD regulations, including Regulations of the **Minister of Marine Affairs and Fisheries Number PER.02/MEN/2011** which include regulations on FAD and light (wattage) combinations for use by purse-seine vessels, determined by size of vessel, zone of operation and Fisheries Management Area.

Further significant amendments were made to the FAD regulations in concert with the drafting of Indonesia’s National Tuna Management Plan. In June 2014 came the **Minister of Marine Affairs and Fisheries Regulations Number 26/PERMEN-KP/2014** “about FADs”. Many of the earlier regulations, referred to above, remained unchanged or were upgraded. The most significant revisions/additions were as follows:

- the definition of FADs as either a drifting or an anchored FAD;
- the first mention in the regulations of sub-surface attractors as a key component of FADs;
- the inclusion of bottom FADs (*rumpon dasar*) as a type for attracting demersal fish;
- the stipulation that the anchored FADs must have a surface floating buoy (i.e. anchored FADs with sub-surface ‘floats’ not allowed);
- the FAD attractors must be composed of non-entangling, biodegradable, natural materials;
- the FADs must be made of materials strong enough to withstand heavy seas and strong currents;
- the FAD anchors must be of sufficient weight to maintain the FAD in position;
- the use of “*Surat Izin Pemasangan Rumpon*” (SIPR) as the permit to install a FAD, and the stipulation that every person who installs a FAD and every vessel which operates on a FAD must have a SIPR;

- the application for a SIPR to the Director General of Fisheries must include detail of the number of proposed FADs, the coordinates (Lat/Long)of proposed installation, an estimate of the proposed frequency of use, an estimate of the type and number of fish to be caught in each fishing operation, and drawings of the proposed FAD design and construction materials;
- inclusion in the requirements for installation that FADs should “avoid the capture of unwanted species (unwanted bycatch)” and, as such, no netting materials are to be used in FAD construction;
- that FADs and their installation are to monitored by officers and observers designated the Director General and to include regular written reporting to the Director General;
- that each vessel is only permitted to install a maximum of 3 FADs;
- that the use of FADs can be banned, based on time of fishing and/or fishing area, to protect the sustainability of fish resources and the environment, and to meet international requirements/standards;
- that every FAD must be equipped with an identification plate (including details of FAD owner, fishing license number, coordinates of installation, names of vessels using the FAD;
- that every FAD must be equipped with a radar reflector;
- that all holders of a SIPR must submit a report with details of the FAD(s) installation, within 14 days of installation, either direct to the Director General or via the reporting of officers monitoring the FAD installations.

In addition to Minister of Marine Affairs and Fisheries Regulations Number 26/PERMEN-KP/2014, this same year saw the release of the “Indonesia Fish Aggregating Devices Management Plan in Western Central Pacific Ocean (FADs Management Plan for 2015 – 2017)” (DGCF 2014).

In principle, these current regulations, if executed to their full intention, would have provided the foundation for effective management of the FAD situation in Indonesia, or at least, the basis for a greatly improved assessment of the FAD situation. Unfortunately, until now, there has been little evidence[12] that the implementation and enforcement of the regulations has occurred to any significant degree for all the regions of Indonesia where deepwater tuna FADs are in use.

Indonesia’s Directorate General of Capture Fisheries is fully aware of the challenges to implement the FAD regulations and the shortcomings to date and has been proactive in participating in stakeholder discussion workshops to determine appropriate options for improved FADs management. The discussion fora[13] have included participation by the relevant research institutes within AMAFRHR, and representatives from tuna fishing associations, including Asosiasi Pole & Line and Hand-line Indonesia (AP2HI) and Himpunan Nelayan Purse-seine Nusantara, fishing companies, and port authorities and provincial fisheries offices. Other participants have included CSIRO, University of Wageningen, the tuna RFMOs (WCPFC and IOTC), Pacific Community (SPC), and several NGOs, including Masyarakat Dan Perikanan Indonesia (MDPI), International Pole & Line Association (IPNLF), PT Hatfield Indonesia, The Nature Conservancy (TNC), International Seafood Sustainability Foundation (ISSF), Sustainable Fisheries Partnership (SFP), and World Wildlife Fund (WWF).

[12] On a recent survey trip to Ambon in November 2018, participating scientists for ACIAR Project FIS/2016/116 saw evidence of the FAD regulations being effectively enacted, with an up-to-date register of FADs held by the Office of Control and Surveillance of Fishing Vessels, and several FADs in the port that had been removed (i.e. mainlines cut) by patrol vessel for not being marked with the required identification markers and without evidence of current SIPR (pers. comm. Mahiswara, Widodo, and Proctor).

[13] Including FAD Fisheries Management Workshop, Bali, 21 February 2017 (a collaboration between DGCF, AMAFRHR, TNC, MDPI, University of Wageningen, CSIRO/ACIAR); National Forum on the Management of FADs, Bogor, 25 – 26 October 2017 (a collaboration between DGCF, MDPI and TNC).

Key issues that have been voiced in these workshop discussions and in other reports (e.g. PT Hatfield Indonesia 2016) include:

- The *sosialisasi*[14] of the FAD regulations to the persons who are required to comply with the has not yet been adequately achieved. An insufficient understanding of the 'finer points' of the regulations and how they are to be followed has been widely reported and was certainly evident from all interviews conducted in this project's activities with persons involved in the tuna fishing activities across Indonesia. This includes staff of some of the offices who have responsibility for implementing and enforcing the regulations in their respective regions;
- The *sosialisasi* has also failed to deliver sufficient information for adequate understanding by participants in the fisheries of the benefits that will come from their complying to the regulations and from improved FADs management. As example, this includes the benefits that accrue from having FADs at least 10 nmi apart, and not having too many FADs in the one region. This lack of understanding has contributed to a low level of 'engagement' with the regulations;
- There are no current guidelines to assist the offices charged with responsibility of implementing and enforcing the regulations;
- There are no maps readily available to fishing companies, vessel captains, and others wanting to install anchored FADs to show them the shipping lanes they are required by law to avoid;
- The wording and level of detail in some of the regulations is inadequate and makes them difficult to enforce and proceed through to successful prosecutions in courts of law. As one example, the regulation that FADs are limited to installation of 3 units per vessel (Chapter V/Article 14) requires revision if the intention of the regulation is to be an effective control of fishing effort. During the course of this project's FAD study, some individual vessel owners interviewed possessed up to 20 vessels or more in their fleet, and in theory, could potentially have their vessels operating on more than 60 shared FADs under the regulations.
- The current regulations for FADs do little to mitigate the catch of juvenile YFT and juvenile BET, which, as detailed in Sections 6.2 and 6.3, make up significant proportions of FAD-based catches of Indonesian hand-line, pole and line, and purse-seine vessels and occupy the issue of greatest concern for the sustainability of the fisheries regionally.

The FADs situation is universally accepted by all participants (MMAF, provincial and regency fisheries offices, industry associations, NGOs, RFMOs, contributing international experts) as one of the highest priority issues for addressing in the moves to improved management for Indonesia's tuna fisheries. And as such, the momentum for achieving effective fisheries regulations pertaining to FADs continues to strengthen.

[14] "sosialisasi" in Bahasa Indonesia differs in meaning of "socialisation" in English, and essentially means the provision of information to individuals, groups, or communities to enable their understanding of something that is being introduced/implemented.

7. Preliminary socio- and bio-economics surveys of FAD-based tuna fisheries at two key ports.[15]

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7.1 Introduction

Managing fisheries includes managing people and information on the socio- and bio-economic aspects of fisheries has gained recognition as being essential to fisheries improvement programs, fisheries certifications, and other programs directed to long term improved sustainability of fishers livelihoods and the fish stocks on which they rely. Such information is essential in determining, or at least predicting, the impacts to fishing sectors as result of new or revised management measures, including harvest strategy actions such as vessel and gear restrictions, and seasonal and/or spatial closures.

MMAF is acutely aware of the importance of socio-/bio-economics research and has within AMAFRHRD a research centre, the Centre for Socio-economic Research for Marine Affairs and Fisheries (*Balai Besar Riset Sosial Ekonomi dan Perikanan*). In 2010, ACIAR Project FIS/2006/142 (*Developing new assessment and policy frameworks for Indonesia's marine fisheries, including the control and management of Illegal, Unregulated and Unreported (IUU) Fishing*) ran a very successful 2 day training workshop on socio-/bio-economic and fishing capacity assessment of fisheries in Jakarta for scientists from AMAFRAD institutes and staff of Data and Statistics section of DGCF. A key outcome from that workshop was a recommendation that opportunities should be sought to further develop Indonesia's capacity for socio-/bio-economics assessments. Therefore during planning of this ACIAR project's FAD Fisheries Study in 2011, a decision was made to include a preliminary assessment of bio- and socio-economic aspects of the fisheries in two regions (West Java and SE Sulawesi). This was to increase the utility of the study's findings, and also to provide capacity development for Indonesian partner scientists in this increasingly important area of fisheries research.

7.2 Objectives

The objectives of this study were to:

1. Conduct surveys at two key fishing ports (one in eastern and one in western Indonesia), using questionnaires with vessel owners and vessel captains to gather data and information on socio-economic aspects of the FAD-based tuna fisheries. This was to include focus on operational parameters, social backgrounds and properties of the fishers' communities, and the costs and profitability of fishing as a livelihood;
2. Develop a preliminary bio-economics model for an improved understanding of the status of the exploitation, the economic benefits and profitability, and the impacts of the changes in cost variables to the fisheries;
3. Identify the main issues of the FAD-based fisheries, to assist this project in making recommendations for further management actions.

[15] *The Kendari component of this bio/socio-economic study was published earlier: Natsir, M. (2018). Bio-economic model and technical efficiency analysis for FAD-associated tuna fishery in Kendari fishing port – Indonesia. United Nations University Fisheries Training Programme, Iceland [final project].* http://www.unuftp.is/static/fellows/document/natsir15prf.pdf

7.3 Methods

Socio-economic survey

The data were collected in interviews with vessel owners and captains, using a structured questionnaire (a copy is provided in Appendix 3), in 2014 and 2015 in Kendari (SE Sulawesi) and in 2015 and 2017 in Palabuhanratu (Sukabumi, West Java). A total of 60 interviews were done in Kendari and 18 interviews in Palabuhanratu. In Kendari data were collected from three different fleets: purse seine (PS) - 31 respondents, pole and line (PL) - 17 respondents and hand-line/troll-line (HL/TL) - 12 respondents. In Palabuhanratu all data came from the hand-line/troll-line (HL/TL) fishery. The survey collected information on fishing costs, the characteristics of the vessel (size, engine type), fishing gear, crew size, catches, social aspects (age, education level, formal training, perception of ideal distance of FADs, other information), various aspects of FADs, fish prices, average revenue and the share-systems in operation.

Bio-economic analysis

Bio-economic modelling analysis for this project was based on a simplified aggregated model for multispecies and multi-fleets fishery. Biological analysis was done using a surplus production model developed by Schaefer (1957).

Cost, revenue and profit functions were estimated from the primary data and bio-economic models then compiled to yield estimates of static reference points (open access equilibrium, MSY, MEY). A comparison was then made between the existing level of fishing and associated profits and the level of fishing corresponding to maximum sustainable yield (MSY) and maximum economic yield (MEY). The bio-economic data analysis design is shown in Figure 7.1.

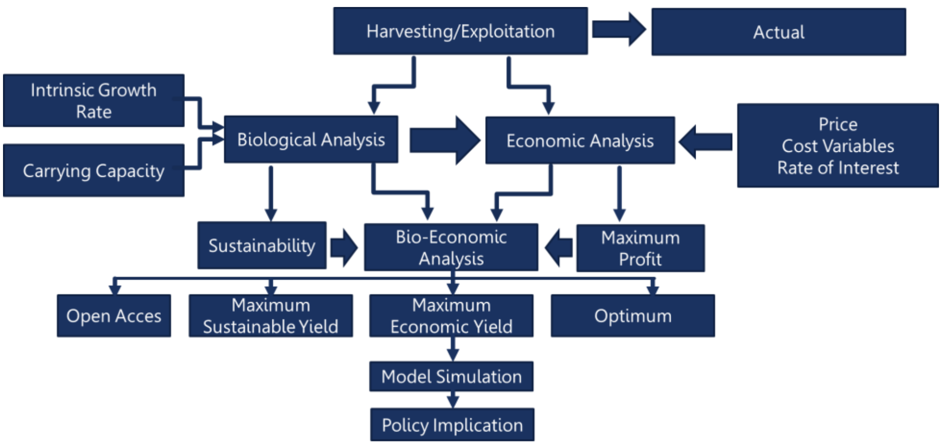

Figure 7.1. Bio-economic data analysis design. Source: Adopted from Zulbainarni (2012).

Biological Analysis

Following the methods used by Schaefer (1957) when examining changes in the stock of Eastern Tropical Pacific Ocean tuna fishery, tuna population biomass changes in Kendari fishery area could be described as:

$$\Delta P = C_e - C \qquad (1)$$

where ΔP represents the changes of total weight of the population of commercial size of fish during a year, C_e is equilibrium catch, C is the catch during the year.
Following equation 1 we could also describe the biomass as biological and harvesting function as:

$$\frac{dx}{dt} = G(x) - h(x, F) \qquad (2)$$

where *x* represents the biomass of fish population, *t* equals time, *G(x)* represents the biological net growth rate, *h* represents harvests and E fishing “effort”.

The biological growth function model *G(x)* is defined as the logistic from

$$G(x) = rx\,(1 - \frac{x}{K}) \qquad (3)$$

where *r* and *K* are positive parameter called the “intrinsic growth rate” and “carrying capacity”.

Harvest is defined as

$$h = qEx \qquad (4)$$

where *q* = catchability coefficient.

From equation (4) it follows that catch per unit of effort (*CPUE*) may be defined as

$$CPUE = U = \frac{h}{E} = qx \qquad (5)$$

In long-term equilibrium harvests equal natural growth, i.e.

$$h = qxE = rx(1 - \frac{x}{K}) \qquad (6)$$

Rewriting (5) yields

$$x = K(1 - \frac{qE}{r}) \qquad (7)$$

Substituting (6) into (4) yields then the sustainable yield function

$$h = qEK(1 - \frac{qE}{r}) \qquad (8)$$

The yield function may also be written as written

$$\frac{h}{E} = qK(1 - \frac{q}{r}E) \qquad (9)$$

Equation (8) may also be written as the linear regression

$$Y = \propto + \beta X + \varepsilon \qquad (10)$$

where $Y = \frac{h}{E}$, $\propto = qK$, $\beta = \frac{Kq^2}{r}$, $X = E, \varepsilon = error$.

Provided that data on CPUE and effort are available, it is therefore possible to estimate the linear regression in equation (9). However, as the two equations $\propto = qK$, and $\beta = \frac{Kq^2}{r}$ contain three unknown variables *q*, *K* and *r*, and only two equations it is only possible to obtain values for two of those three variables by assuming that the value of the third one is fixed. By, for instance, that *q* equals a fixed parameter it is therefore possible to obtain values for *r* and *K*.

Economic Analysis

Adapted from lecture notes UNU-FTP 2015 for Fisheries Economics and Modelling by Ragnar Arnason (2015), total cost function can be specified as:

$$TC = C(h, E) + fk = a\,p\,h + b\,E + fk \qquad (11)$$

Where *TC* is total cost, *a* is a measure of the crew share of the revenues, *p* is the price of landings and *b* is the marginal cost of effort.
The profits from the fishery are defined as the total revenues (*R* = *p h*) less total costs define above, i.e.:

$$\pi = p(1-a)h - fk - b\,E \qquad (12)$$

Substituting in for *h* yields

$$\pi = p(1-a)\,q\,e\,x - fk - b\,E \qquad (13)$$

Static reference points

Using the economic model outlined above it is possible to find the stock biomass, harvest and effort level that correspond to maximum sustainable yield (MSY), maximum economic yield (MEY) and open access yield (OAY) (see Figure 7.2).

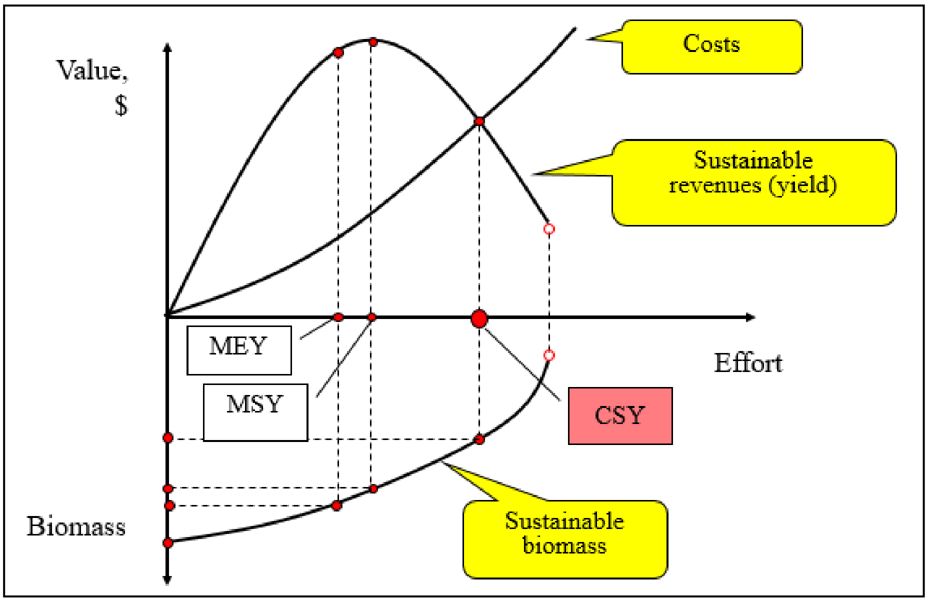

Figure 7.*2.* Bio-economic static reference points diagram. Source: Adapted from lecture notes UNU-FTP 2015 by Ragnar Arnason.

For MSY these are defined as:

$$h_{MSY} = \frac{Kr}{4} \qquad (14)$$

$$x_{MSY} = \frac{K}{2} \qquad (15)$$

$$E_{MSY} = \frac{r}{2q} \qquad (16)$$

The corresponding values for MEY are defined as:

$$x_{MEY} = \frac{K}{2}(1 + \frac{c}{Kpq}) \quad (17)$$

$$E_{MEY} = \frac{r}{2q}(1 - \frac{c}{Kpq}) \quad (18)$$

$$h_{MEY} = qx_{MEY} \; E_{MEY} \quad (19)$$

Finally, the OAY values defined as:

$$x_{OA} = (\frac{c}{pq}) \quad (20)$$

$$h_{OA} = \frac{rc}{pq}(1 - \frac{c}{Kpq}) \quad (21)$$

$$E_{OA} = h_{OA}/qx_{OA} \quad (22)$$

Stochastic frontier analysis

In applied microeconomics, efficiency may be calculated using either parametric or non-parametric methods. Here, we take the former approach and calculate technical efficiency (TE) using a model developed Batesse & Coelli (1995).

Consider the stochastic production function for panel data,

$$Y_{it} = exp\,(x_{it}\,\beta + V_{it} - \; U_{it}) \quad (23)$$

or taking logs

$$\ln(Y_{it}) = \; x_{it}\,\beta + V_{it} - \; U_{it} \quad (24)$$

Here, Y_{it}denotes the production of firm *i* at time *t* x_{it} is a (1 x k) vector values of inputs and other explanatory variables, while V_{it} is a random error term and U_{it} are non-negative random variables, associated with technical inefficiency of production.

The technical inefficiency effect, U_{it} in the stochastic frontier model is specified as

$$U_{it} = \; z_{it}\delta + W_{it} \quad (25)$$

where z_{it} is a vector of explanatory variables associated with technical inefficiency, and δ are unknown coefficients. The random variable, Wit,, is defined by the truncation of the normal distribution with zero mean and variance, σ2, such that the point of truncation is -zitδ, i.e., Wit, > -zitδ. These assumptions are consistent with Uit being a non-negative truncation of the N(zitδ, σ2)-distribution.

The method of maximum likelihood is used to simultaneously estimate the parameters of the stochastic frontier and the model for the technical inefficiency effects. The technical efficiency of production for the i-th firm at the t-th observation may then be defined by

$$TE_{it} = \exp(-U_{it}) = exp\,(\delta_0 - \; z_{it}\delta - W_{it}). \quad (26)$$

7.4 Results

7.4.1 Kendari (SE Sulawesi)

The Importance of fisheries sector in Kendari

Kendari Fishing Port, *Pelabuhan Perikanan Samudera Kendari* (PPSK), is the major port for fish landings in the Province of Southeast Sulawesi. During the period 2010 - 2014, annual landings averaged 20.4 thousand tons with an average value of more than USD20 million (Table 7.1).

Table 7.1 Total fish landings in Kendari Fishing Port

Year	Number of Landing	Total Landing (tons)
2010	4,438	21,554
2011	3,557	18,680
2012	3,542	19,519
2013	4,151	22,851
2014	3,193	19,727

Source: Landing monitoring report from Kendari fishing port.

Fleet Structure

The vessel fleets at PPSK vary in size and fishing gear. In 2012 (Figures 7.3 and 7.4), there were 1129 vessels registered to Kendari fishing port, with 43% of these vessels employing purse seine (PS), 26% hand-line and troll-line (HL/TL), and 5% pole and line (PL). 20% of the fleet in this year were carrier vessels (CV) which often accompany the PL vessels. Fleet composition at PPSK for 2017 shows slight changes from that in 2012, with a higher proportion of PS vessels at 58%. Most of the catcher vessels use FADs. Although the PL fishing fleet is relatively small in terms of vessel numbers, it is an important component of the Kendari tuna fishing activity. The PL vessels are regularly away from home port for lengthy periods of up to 22 days. Fishers in Kendari refer to one fishing trip from departure until return to their villages as one "*turo*" and this is also the base of the revenues sharing period. However, in general, the PL vessels do not stay at sea for long time, instead running their operations from an island (*Pulau Umbele*) nearer to the fishing grounds. Carrier vessels make regular collections from the island (approximately 58nm north of entrance to Kendari Bay) and bring the catches back for unloading at PPSK. Carrier vessels support the PL fleet, but there are some that service the PS fleet, with the latter carriers being considerably larger than the PL carrier vessels.

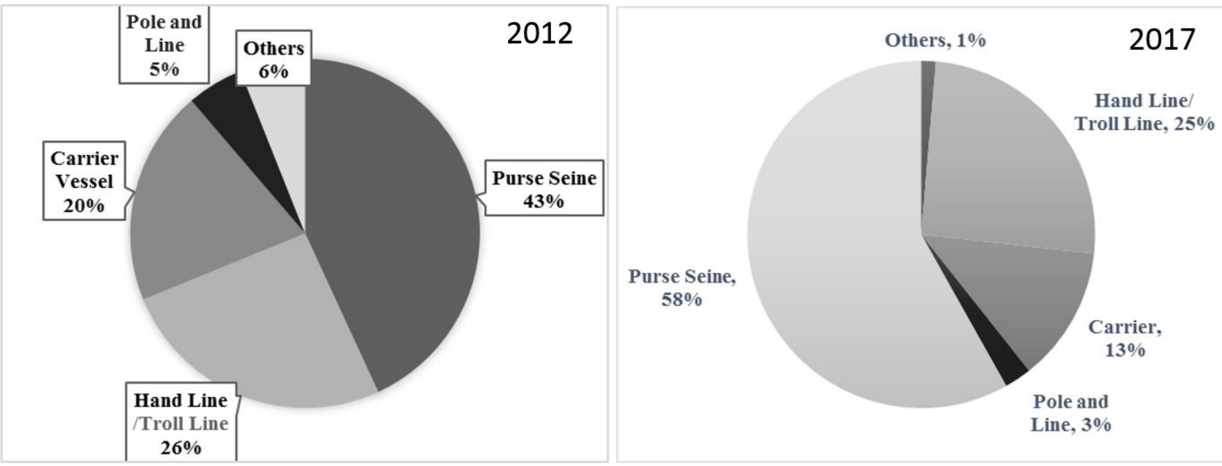

Figure 7.3. Fleet composition in Kendari fishing port in years 2012 (left) and 2017 (right). Source: Landing monitoring report from PPSK 2012 - 2017.

Characteristics of the tuna fishing vessels in Kendari are provided in Table 7.2 and Figure 7.4. On average, the HL/TL vessels are the smallest and the PL vessels the largest, but the PS vessels include the largest vessels, up to 51 GT. Unsurprisingly, the number of crew also varies considerably across the vessels of different gear type. PS and PL vessels carry the highest numbers of crew (15 on average, 26 – 27 maximum), with HL/TL vessels having fewer crew (7 on average, 13 maximum).

Table 7.1. Characteristics of the tuna fishing fleets in Kendari.

Fleet		GT	Length	Width	Depth	Engine (HP)	Crew
Hand-line/Troll-line	Average	4.50	12.12	2.33	0.91	33.63	7
	Maximum	30.00	17.00	3.70	1.90	270.00	13
	Minimum	2.00	9.00	1.00	0.35	16.00	3
Pole and line	Average	27.96	19.01	4.70	1.54	189.88	15
	Maximum	30.00	23.85	5.30	1.90	370.00	26
	Minimum	17.00	14.20	3.55	1.00	30.00	11
Purse seine	Average	14.29	16.65	3.48	1.19	121.81	15
	Maximum	51.00	25.30	14.15	2.50	360.00	27
	Minimum	5.00	10.00	2.00	0.50	14.00	6
Carrier	Average	25.83	16.04	3.64	1.28	81.10	6
	Maximum	148.00	27.98	8.68	2.89	380.00	17
	Minimum	3.00	9.21	2.00	0.62	15.00	3

Source: Source: Landing monitoring report from Kendari fishing port. 2014

Pole and Line | Hand Line/Troll Line | Purse Seine

Figure 7.4. Typical vessels in the Kendari tuna fishing fleet.

FAD costs

For details of design of Indonesian anchored tuna FADs, see Section 5.

According to the surveys undertaken with vessel owners and captains in Kendari in 2014 and 2015, the average total cost of FADs was USD1,180. The cost of building a FAD depends very much on the length of the rope, with rope costs typically being more than 70% of total costs. The average depth of the ocean where the FADs of the Kendari fleets are located is 3,500 metres. The cost of FAD components are provided in Table 7.3.

Table 7.3. FAD components and cost - Kendari. Source: Interviews with vessel owners and captains in 2014 and 2015.

FAD Component	Quantity	Price (USD)	Total Cost (USD)	Average Cost (USD)
Attractor (coconut leaf)	5 – 45 leaf	0.15 – 0.37	0.8 – 16.8	2.8
Rope	500 – 7500 m	0.16 – 0.49	82 – 2,393	1,382
Ponton/Raft (Float)	1 – 5 Rafts	7.9 – 15.0	37 – 636	98
Sinker	7 – 35	7.5 – 25.6	52 – 224	267
Labour	3 – 7 days	15.0 – 37.4	45 – 262	131
Total FAD Cost			218 – 3,532	1,880

FAD ownership and management

FAD ownership in Kendari has many variations. Most FADs were built and owned by vessel owners. This is especially true for PL and PS vessels. Some FADs are owned by individuals who do not operate fishing vessels, but they invest in FADs in order to collect shares from vessels that utilise their FADs. There are also several governments owned FADs which were usually provided as part of government (both provincial and district government) assistance to small boat owners who mainly use HL/TL to increase their catch.

Privately owned FADs are managed by the owners themselves. They benefit from the use of the FADs but also shoulder the costs. Government-owned FADs are maintained by cooperatives or groups of fishers called "*mitra kolaborasi*" that utilise the FADs. The fishers groups will not only repair the FADs from damages from natural causes but also from vandalism by the other fishers.

FAD operational arrangements

During operations, informal agreements are often made between owners of the FADs for the utilization of FADs by other vessels or other companies. As detailed in Table 7.4, similar arrangements are used by the PS and PL fishing fleets, whereas the HL/TL vessels employ different arrangements. HL/TL vessels are generally able to utilise the FADs as a place to 'anchor to', but in return they usually perform a role as a 'watcher' for the owner of the FAD in question and report to the FAD owner if another vessel is seen fishing on the FAD. This enables the FAD owner to seek a 'utilisation' payment.

Table 7.4. Operational arrangements for the use FADs, by vessel gear type.

	Purse Seine	Pole and Line	Hand line/Troll line
FAD sharing arrangement with other companies /vessels	Yes, with acknowledgment to the other companies /vessel	Yes, with acknowledgment to the other companies /vessel	No, free to use the FAD but if the owner want to use it they should leave
Arrangement of the operation	After the revenues are subtracted from the logistic cost then profit is divided by 3 (2 for the vessel, 1 for the FAD owner)	After the revenues are subtracted from the logistic cost then profit is divided by 3 (2 for the vessel, 1 for the FAD owner)	No
'Rolling system' for the FADs to make sure they are guarded from use/abuse by other vessels?	No, just watch each other FADs	No, just watch each other FADs, fishing and guarding the FADs at the same time	Help the FADs owner to watch their FADs

Source: Interviews with boat owners and captains in 2014 and 2015.

Socio economic aspects of FAD tuna fishery

No formal education is needed for the young men to become good fishers or captains, as their knowledge is developed through the 'autodidact' educational system. Young boys become fishermen at very young age, normally when they have finished elementary school at the age of 12 and became trained fishermen after the age of 20, although that does depend on the learning skills of each individual. Formal education is only required when fishermen want to undertake the training necessary to apply for the captain or engineer certificate. Such training is available through fisheries training institutes, including those in the cities of Bitung, Tegal, Banyuwangi and Ambon. Fishermen generally have no clear path to follow. Some of them become successful captains and vessel owners, while others remain as crew members for the rest of their lives until they become old and cannot continue fishing anymore.

Revenue from the fisheries are split between crew and FAD owners according to fixed rules and arrangements (see Table 7.5). First some of the catch is set aside for the crew, and the amount of this 'free fish' depends on the number of crew and the amount of the catch. Normally each crew will get 5 - 10 fish to eat with their families or neighbours, then 10% of the revenue is deducted as investment costs. If a vessel has utilised the FAD(s) of others, 33% of the catch must be paid to the FAD owner(s). The remainder is shared between the vessel owner, the captain and the crew, according to the shares of each individual. 2% of revenue is also set aside for certain fees which include costs associated with unloading the catches. There are variations in formulating the shares of each positions, but normally the captain receives the highest share of that received by the crew, with average share 3.64 (range from 3-4 shares), with ordinary deck hands only getting a share of 1.0. The sharing systems for each of the gear types, PS, PL, and HL/TL, are shown in Figures 7.5 a – c.

Table 7.5. Cost and share arrangements of the 3 different tuna fleets

Shares	**Unit**	**Purse Seine**	**Pole and Line**	**Hand line/ Troll line**
Free Fish for the Crew (5-10 fish for each crew)	Kg	176.25	30.00	19.44
Before Subtracted by the cost				
Investor and investment	percentage	10%	10%	11%
After Subtracted by the cost				
Vessel Owner (True Benefit)	percentage	49%	49%	49%
Captain + Crew	percentage	49%	49%	49%
Fees (include unloading)	percentage	2%	2%	2%
FAD (if utilized other vessel or companies FAD)	percentage	33%	33%	
Shares based on the position		Average (Range)	Average (Range)	Average (Range)
Captain	Shares allocation	3.64 (3-4)	2.5 (2-3)	2.15 (2-2.5)
Engineer	Shares allocation	2.08 (1.5-2.5)	1.96 (1.5-2)	1.50
Fishing Master	Shares allocation	1.50	2.31 (2-2.5)	
Boy-boy (bait thrower)	Shares allocation		1.85 (1.5-2)	
Net Thrower	Shares allocation	1.50		
Diver	Shares allocation	1.50		
Crew	Shares allocation	1.00	1.00	1.00

Source: Interviews with vessel owners and captains in 2014 and 2015.

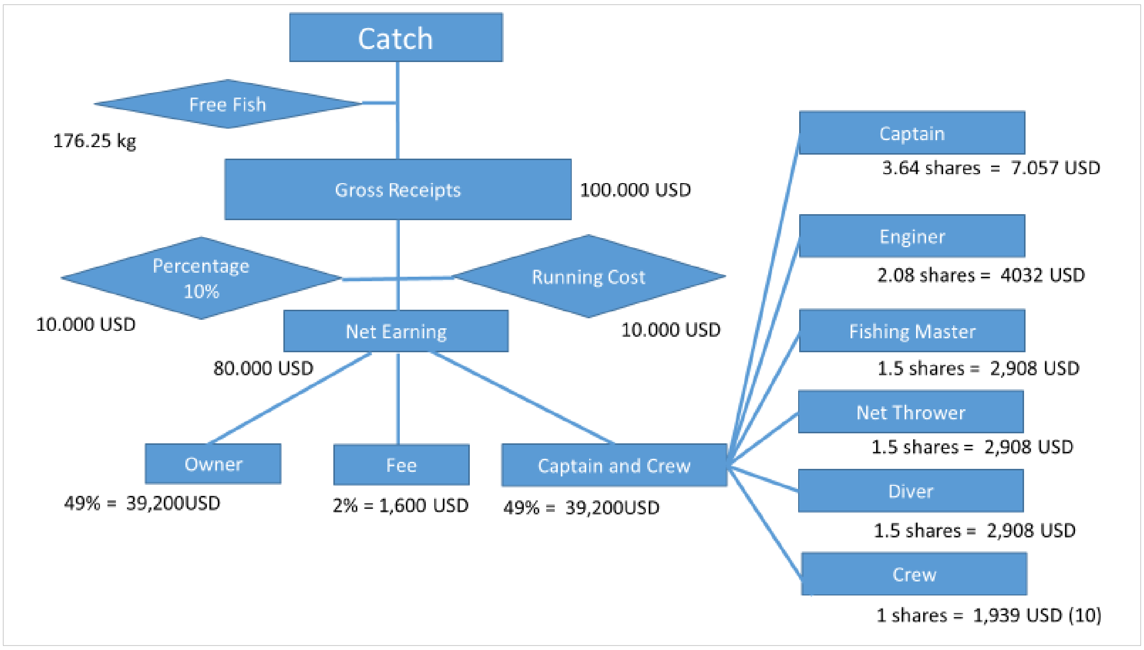

Figure 7.5 a. Sharing system of PS in PPS Kendari

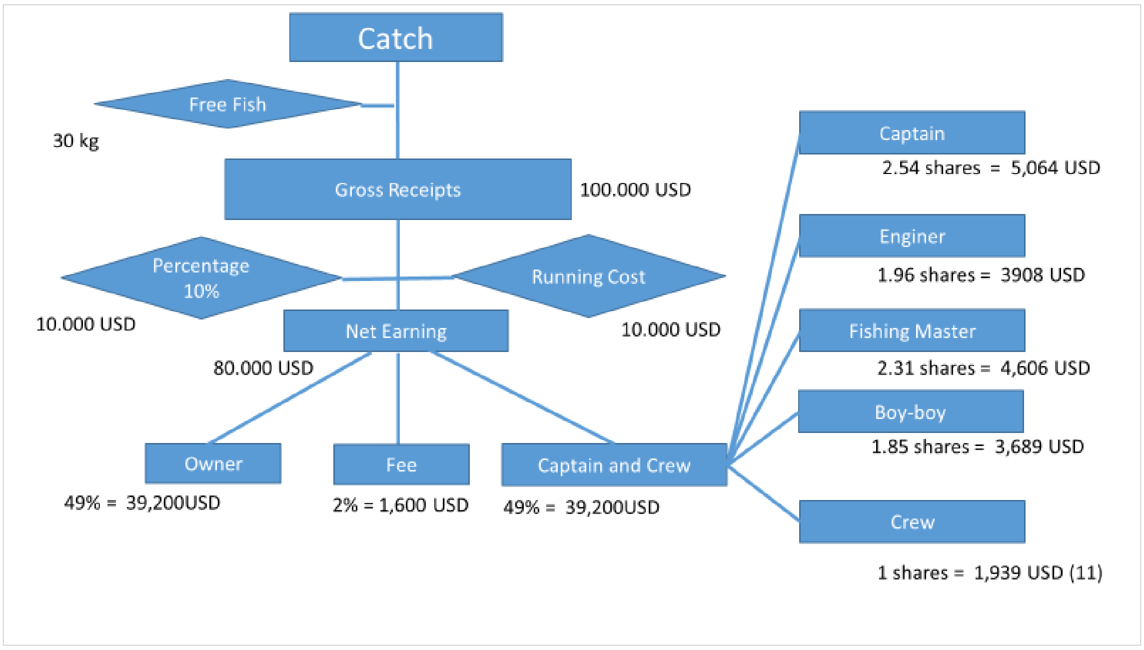

Figure 7.5 b. Sharing system of PL in PPS Kendari

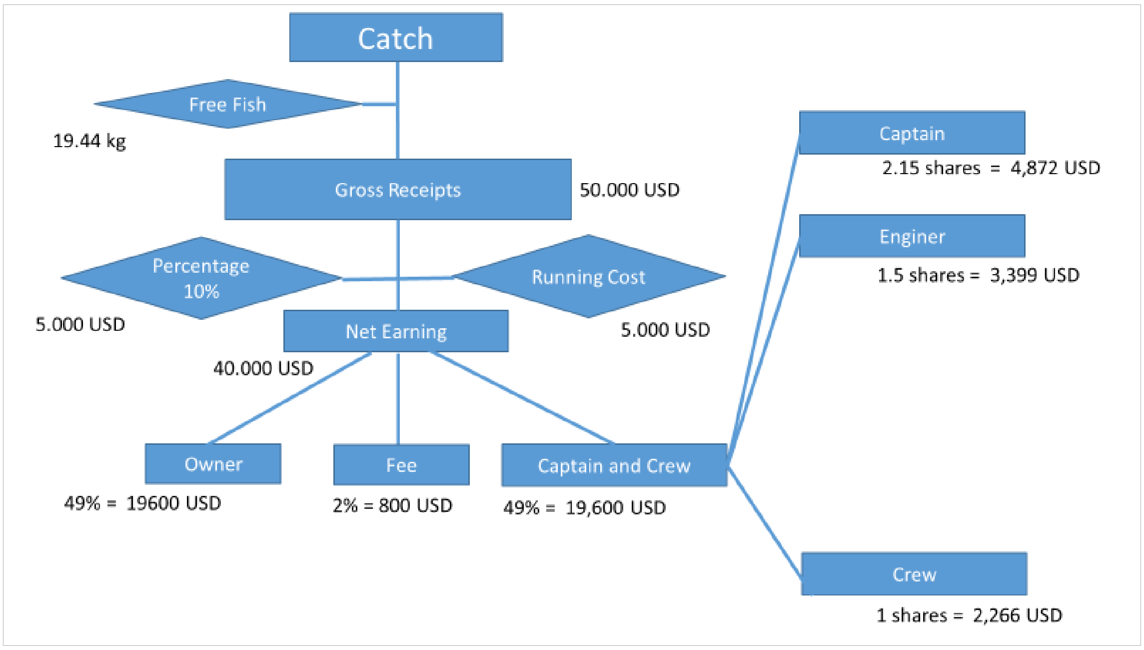

Figure 7.5 c. Sharing system of HL/TL in PPS Kendari

Bio-economic model - Kendari

Catch and effort data

Data on annual catches and effort for the years 2010 - 2014 was compiled from Port Authority of PPSK which collects daily data on landings. As shown in Table 7.6, catch per unit effort (CPUE) was on average highest for PL vessels (average of 6.2 tons per trip), and lowest for the smaller HL/TL vessels (average of 2.75 tons per trip). The highest landings per annum were by the PS fleet at an average of 14,700 tons, whereas landings by the PL fleet and HL/TL fleet averaged 3,981 tons and 871 tons per annum respectively.

Table 7.6. Catch, effort and CPUE for Kendari FAD associated tuna fisheries.

Year	**Purse seine**			**Pole and line**			**Hand line & troll line**		
	Effort (trip)	Catch (ton)	CPUE (ton/trip)	Effort (trip)	Catch (ton)	CPUE (ton/trip)	Effort (trip)	Catch (ton)	CPUE (ton/trip)
2010	3,075	15,544.95	5.06	940	5,032.41	5.35	387	826.85	2.14
2011	2,538	13,856.39	5.46	673	3,805.29	5.65	293	861.26	2.94
2012	2,606	14,450.96	5.55	485	3,419.24	7.05	290	856.42	2.95
2013	2,465	14,904.77	6.05	522	3,561.86	6.82	380	961.60	2.53
2014	2,178	14,589.88	6.70	683	4,083.78	5.98	267	847.25	3.17
Average	**2,572**	**14,669.39**	**5.76**	**661**	**3,980.52**	**6.17**	**323**	**870.68**	**2.75**

Source: Landing monitoring report from PPS Kendari Port Authority.

Cost and revenue

Using information obtained in the survey interviews with vessel owners and captains in Kendari, cost functions were constructed for each vessel type, including investment costs (vessel and FAD), fixed costs and variable costs. As shown in Table 7.7, total costs were highest for PL vessels (USD 97,300), with costs for PS vessels only slightly lower. Costs associated with investing in and operating HL/TL vessels were much lower, at only USD 15,200.

Table 7.7 Cost variables of the tuna fishing fleets.

Cost variables	Unit	Purse seine	Pole and line	Hand and troll line
Total Cost (Capital+Fixed+Variables)	USD	**86,846.1**	**97,284.8**	**15,250.7**
Capital investment		**79,856.1**	**88,242.6**	**12,509.3**
Boat	USD	48,881.5	74,794.3	8,601.3
Engine	USD	9,844.8	10,512.0	2,842.2
Auxiliary 1	USD	792.5	804.0	828.1
Auxiliary 2	USD	544.0	-	-
Fishing gear	USD	17,763.6	102.4	88.1
Permit	USD	149.6	149.6	149.6
FAD	USD	1,880.2	1,880.2	-
Fix cost		**5,357.7**	**7,127.3**	**1,904.2**
Maintenances				
Boat	USD	2,508.7	4,038.9	448.8
Main Engines	USD	1,656.8	2,772.4	568.4
Auxiliary	USD	586.4	284.2	56.1
Fishing gear	USD	605.8	31.8	224.4
Variable cost		**1,632.3**	**1,914.9**	**837.1**
Fuel	USD	642.9	472.7	349.2
Lubricant	USD	40.6	88.3	33.1
Bait	USD	-	56.1	22.7
Ice	USD	203.5	113.7	95.2
Logistic	USD	696.7	558.7	278.8
Wages	USD	-	-	15.0
Spare part	USD	48.6	74.8	43.2

Source: Interviews with vessel owners and captains in 2014 and 2015.

Stochastic frontier

A stochastic frontier model for the FAD associated tuna fisheries in Kendari was done using data for the year 2015. This includes observations on catches (kg) per trip, as well as information on vessel size, number of crew, days at sea, the amount of ice and water used on each trip, as well as information on the captain, fishing ground and gear used. A total of 2598 data from the 2015 landings were used for the technical efficiency analysis. Summary statistics are shown in Table 7.8.

There are four dummy variables indicating how many fishing trips each captain made during the year 2015. DumCap1 takes a value of 1 if the captain made less than 2 trips a year, and zero otherwise. DumCap2 takes a value of 1 if the captain made 2-6 trips a year, and zero otherwise. DumCap3 takes a value of 1 if the captain made 6-12 trips a year, and zero otherwise. DumCap4 takes a value of 1 if the captain made more than 12 trips a year, and zero otherwise. As shown in Table 7.8, the average values of the four captain dummy variables were in the range 0.19 - 0.29, indicating that each captain category contained 19 - 29% of all observations. The captain dummy variables are used as a proxy variable for experience.

Table 7.8. Summary statistics for variables included in stochastic production frontier and technical efficiency models for FAD associated tuna fisheries in Kendari. Source: landing monitoring in Kendari Fishing Port, 2015.

			Summary statistics			
Variables	**Description**	**Measurement**	**Mean**	**Std dev**	**Min**	**Max**
n = 2598						
Output and input variables						
Y(Catch)	Catches	Kg	3,632.8	2,640.6	204	23,256
Crew	Number of crew	person	14.3	5.2	3.0	30.0
Dim	Size of vessel (length x wide x depth)	m^3	83.31	63.13	7.7	270.46
DAS	Day spent at sea	days	5.4	2.7	1.0	45.0
Ice	Quantity of ice	ice block	84.5	49.6	11.0	900.0
Water	Quantity of water	1000 litres	1.3	0.7	0.1	7.5
Fuel	Quantity of fuel	litre	674.0	427.3	30.0	15,000
Vessel specific variables						
DumCap1	2 trips or fewer	dummy	0.19	0.39	0	1
DumCap2	2 - 6 trips a year	dummy	0.25	0.43	0	1
DumCap3	6 - 12 trips a year	dummy	0.27	0.44	0	1
DumCap4	More than 12 trips a year	dummy	0.29	0.45	0	1
Dum1	Fishing ground grid 1	dummy	0.02	0.15	0	1
Dum2	Fishing ground grid 2	dummy	0.06	0.24	0	1
Dum6	Fishing ground grid 6	dummy	0.09	0.29	0	1
Dum8	Fishing ground grid 8	dummy	0.02	0.16	0	1
Dum4B	Fishing ground Grid 4B	dummy	0.80	0.40	0	1
DumFG1	Hand line and Troll Line	dummy	0.18	0.38	0	1
DumFG2	Pole and line	dummy	0.01	0.10	0	1
DumFG3	Purse seine	dummy	0.81	0.39	0	1
DSoff	Off season period (Oct, Nov, Dec, Jan, Feb)	dummy	0.43	0.49	0	1
DSpeak	Peak season period (March, April, May)	dummy	0.33	0.47	0	1
DStrans	Transition period (June, July, Aug, Sep)	dummy	0.24	0.43	0	1

In all, it was possible to identify 29 different fishing grounds where the vessels fished in 2015 based on the landing records. The identification was done on the basis of 1x1 degree grids, but finer grips of 0.5 x 0.5 degrees were also used. Most of the fishing (over 80%), took place in a single grid, which is represented by the dummy variable Dum4B.

Three dummy variables were defined for the fishing gear used in the Kendari tuna fishery; DumFG1 takes a value of unity if the vessel used HL or TL, and zero otherwise. DumFG2 takes a value of unity if the vessel used PL, and zero otherwise. DumFG3 takes a value of unity if the vessel employed PS, and zero otherwise. Just over 80% of the vessels in the sample used PS.
Three variables were also used to indicate whether the vessels were operating during the peak season or off season, or during a transition period. DSoff takes a value of unity if the fishing trip was made during the off season (October - February), and zero otherwise. DSpeak takes a value of unity if the trip

was made during the peak season (March - May), and zero otherwise. DStrans takes a value of unity if the trip was made during the transition period (June - September).

Harvest function

The following details the results of the bio-economic model outlined in Section 7.3 using the data discussed above. Ordinary least squares was used to estimate equation (9), using the data on costs and revenue to construct cost, revenue and profit functions. The data on catches and effort for the years 2010 - 2014 were aggregated to annual data, and harvests expressed as catch per unit effort then estimated as a function of effort.

The estimated harvest function is defined as

$$\frac{h}{E} = \propto + \beta E + \varepsilon \qquad (9a)$$

where *h* denotes harvest and *E* effort, *α* and *β* are parameters to be estimated and *ε* a random error term. The ratio $\frac{h}{E}$ is also defined as catch per unit effort.

The results for the estimated harvest function for each fleet segment (PS, PL, HL/TL) are shown in Table 7.9. These results should be viewed with some caution as they are based on only 5 observations, and the number of degrees of freedom was accordingly very small (= 3). The R^2 from the regression of this data set ranged from 0.84 for the PL and 0.91 for the HL/TL data, indicating that the model explains a considerable amount of the variation of CPUE.

Table 7.9. Harvest function for the 3 gears types at Kendari.

Gear	b_0	t stat	P-value	b_1	t stat	P-value	R square
Purse Seine	10.3456	8.8874	0.0030	0.0018	-3.9634	0.0287	0.8396
Pole and Line	8.6545	13.3348	0.0009	0.0038	-3.9361	0.0292	0.8378
Hand Line & Troll line	5.0251	11.9529	0.0013	0.0070	-5.4840	0.0119	0.9093
Accumulated Model	9.8459	10.4725	0.0005	0.0012	-3.9590	0.0167	0.7967

Multiplying through both sides of equation (9a) by the effort variable yields the following harvest function

$$h = \propto E + \beta E^2 \qquad (9a)$$

The plots of the resultant harvest function for each gear type are presented in Figures 7.7 – 7.9. As shown in Figure 7.7, actual effort in the PS tuna fishery was less in 2013 and 2014 than in 2010 and 2011.

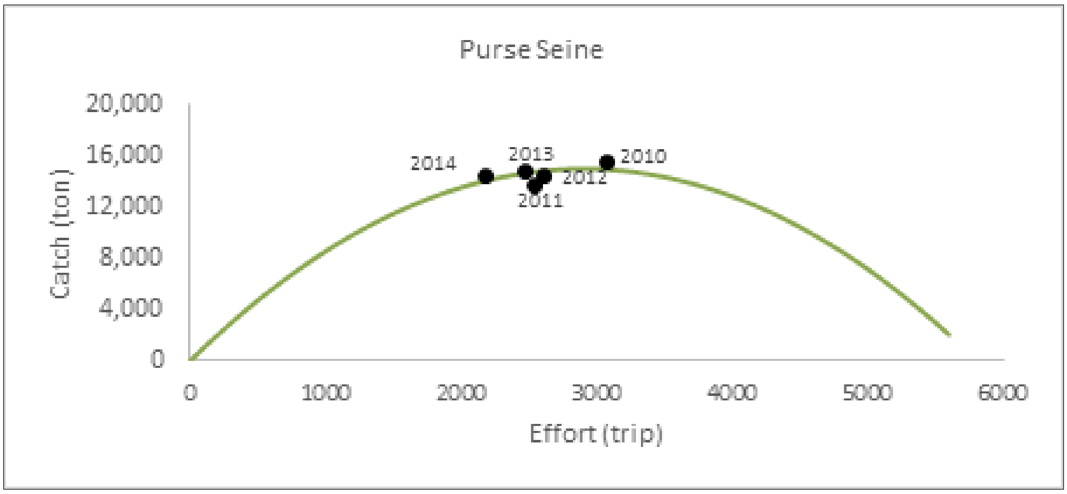

Figure 7.7. Actual PS catch effort in 2010-2014 at Kendari.

Actual catch effort for the PL fishery (Figure 7.8) was highest in 2010 but reduced significantly in 2011 and 2012, before increasing again during 2013 and 2014. Efforts during these most recent years were still less than at the maximum point.

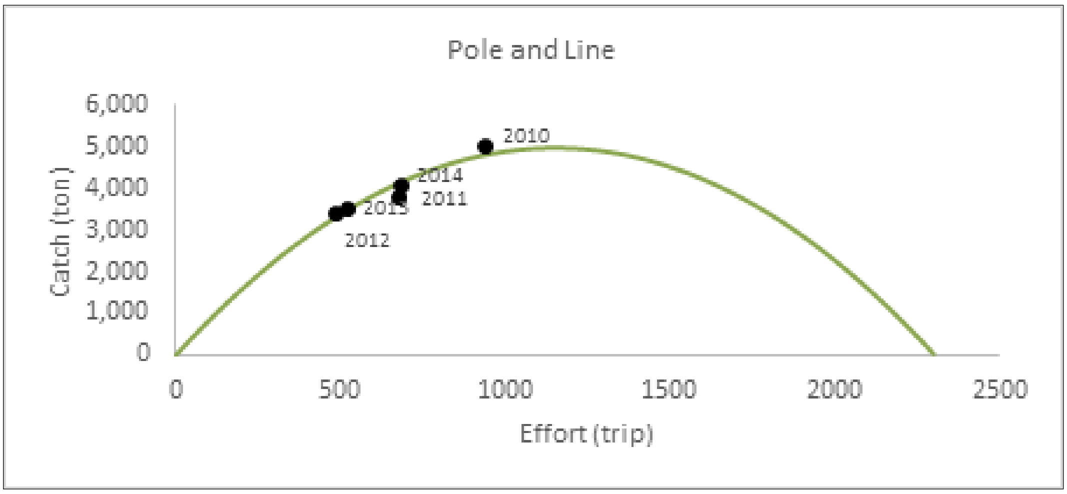

Figure 7.8. Actual PL catch effort in 2010-2014 at Kendari.

Actual catch effort for the HL/TL fishery (Figure 7.9) was lower in 2011 and 2012 than in 2010 but at a similar level in 2013 as in 2010. In 2014, effort was significantly reduced.

Figure 7.9. Actual HL/TL catch effort in 2010-2014 at Kendari.

Cost variables and function

Cost functions were developed using the data presented above. For each gear type - PS, PL, and HL/TL – total costs were constructed from individual vessel data. The total cost function was then used to estimate profits. The total cost function is the sum of capital costs, fixed cost, cost of free fish and variable cost. Capital cost is defined as the part of revenue accruing to the vessel that is shared between the vessel, vessel owner, crew and with FAD owners if a FAD-user fee is required (see section "Socio economic aspects of FAD tuna fishery" above on share arrangements). For the PS fleet, the capital cost is defined as 10.4% of catches and this value is multiplied by harvests (h) and average price of the harvests (p). Fixed costs are defined as maintenance of the boat, engine and fishing gear. The cost of free fish is the cost of giving part of the harvest free of charge to the crew. For the PS vessels this 'free fish' amount was calculated to be an average of around 176 kg per trip and the opportunity cost per trip thus equals this amount of free fish times the average price of the catches (*p*). Annual costs associated with the free fish are calculated as costs per trip multiplied by the number of trips (*f*). Variable cost per trips is defined as the sum of fuel, ice, water and other logistics. In the case of HL/TL vessels, variable costs also include wages paid to crew over and above what the crew gets through the share system. These additional wages are low. For the PS vessels, variable costs averaged USD 1,632 per trip. Total costs are defined as the sum of fixed costs, free fish costs, capital costs and variable costs. Total costs are calculated both for vessels which are completely inactive, in which case the number of trips (f) equals zero, and for active vessels in which case the number of trips is greater than zero. In the latter case, the fixed cost is divided by the number of trips undertaken per year; 43 for the PS vessels, 20 for the PL vessels, and 30 for the HL/TL vessels.

The cost functions thus developed are as follows:

Purse seine:
$C (f) = (5357.7) + (176.25 * p) * f + (0.104 * h * p) + (1632.3 * f)$, for $f = 0$
$C (f) = 5357.7/n_{trip/year}*f + (176.25 * p) * f + (0.104 * h * p) + (1632.3 * f)$, for $f = 1 \ldots N$

Pole and line:
$C (f) = (7127.3) + (30 * p) * f + (0.10 * h * p) + (1914.9 * f) +$ for $f = 0$
$C (f) = (7127.3/ n_{trip/year})*f + (30 * p) * f + (0.10 * h * p) + (1914.9 * f) +$, for $f = 1\ldots N$

Hand and troll line:
$C (f) = (1904.2) + (19.44 * p) * f + (0.1078 * h * p) + (837.1 * f)$, for $f = 0$
$C (f) = (1904.2/ n_{trip/year})*f + (19.44 p) * f + (0.1078 * h * p) + (837.1 * f)$,for $f = 1\ldots N$

Where:
C = cost (USD)
p = fish price (USD/kg)
f = effort (trip)
h = harvest/catch

Fish price and revenues function

Revenues function for each fishing gear type was developed from the fish price and catch composition. Average fish prices for the year 2015 data are presented in Table 7.10, where prices are broken down into fish groups similar to the catch composition of each gear type. There were some differences in price between each fishing gear for the same fish group, e.g. skipjack tuna caught by HL/TL vessels had a higher price than tuna caught by PS vessels and PL vessels. This information was then used to calculate total revenues functions for the each fishing gear. As shown in Table 7.11, the calculated average revenue was highest for the HL/TL vessels and PL vessels, or USD 936 and USD 913 respectively, but significantly lower for the PS vessels, or USD 796.

Table 7.10 Average fish price and estimated revenues for 3 different tuna fishing fleets. Figures shown are USD per ton of catch.

Species	Purse seine	Pole and line	Hand and troll line
Skip Jack	924.58	907.85	938.34
Yellowfin Tuna	957.83	924.43	993.63
Scads	897.84		897.53
Mackerel tuna	663.15		698.31
Big Eye Tuna	1,009.52		1,095.87
Others	1,128.83		782.79
Estimated revenues USD/ton*	**795.53**	**912.59**	**936.14**

Sources: 2015 landing monitoring data. *In accordance with the catch composition.

Static Equilibrium

Results from estimating the harvest function, outlined above, were used to determine the effort (number of trips) corresponding to MSY. Letting *b0* and *b1* represent the intercept and slope coefficient in the harvesting equation, the MSY level of effort may be defined as:

$$E_{MSY} = \frac{b_0}{2b_1}$$

Effort levels corresponding to Maximum Economic Yield (MEY) and Open Access Yield (OAY) were calculated using the goal solver in MS Excel. In the former case the solver was set to maximise profits, while in the latter case the solver was set for zero profits. Revenue was calculated on the catch composition and average prices for each gear type, as discussed above, and costs using the total cost function.

The results from the biological and economic analysis for the static equilibrium for the three different gear types are presented in Table 7.11 and Figures 7.10 – 7.12. The level of effort applied to the tuna fisheries in all three cases was very close to the effort level corresponding to MEY. For the PS vessels, the level is slightly above MEY, but for the PL vessels and HL/TL vessels the levels were just below that corresponding to MEY. This indicates that the tuna fishery was, at that time, enjoying considerable profits, but at the same time, because of these good profits, there was a risk that investments in the fisheries – both FADs and boats – could increase in future years. Prudent management would be needed to curb those likely increases. It should be noted that the profits shown in Table 7.11 refer to nett profits, the true benefit for the boat owner i.e. profits after the shares, and benefits after the revenues were subtracted, with the cost function subtracted by the shares (total 51% for the crews and fees, including unloading fee).

Table 7.11. Static equilibrium for the FAD associated tuna fishery in Kendari.

	Effort (trip)	Catch (Ton)	Revenues USD	Benefit USD	Benefit/ effort
Purse Seine					
Maximum economic (MEY)	2,147	13,996	11,134,593	2,868,934	1,336
Maximum sustainable (MSY)	2,902	15,014	11,944,145	2,513,509	866
Open access (OAY)	4,294	11,565	9,200,070	6	0
Existing condition	2,178	14,079	11,199,976	2,868,330	1,317
Pole and Line					
Maximum economic (MEY)	779	4,461	4,066,478	916,205	1,176
Maximum sustainable (MSY)	1,152	4,983	4,542,491	706,283	613
Open access (OAY)	1,558	4,364	3,977,832	0	-
Existing condition	683	4,158	3,790,444	902,347	1,321
Hand and Troll Line					
Maximum economic (MEY)	278	852	797,734	222,374	801
Maximum sustainable (MSY)	357	896	838,805	204,418	573
Open access (OAY)	555	618	578,153	0	-
Existing condition	267	839	785,831	222,043	832

As shown in Figure 7.10, MEY for the PS vessels is equal to USD 2.9 million which is only slightly above the level of profits in 2015. The optimal number of trips is 2,147 but the number of actual trips undertaken in 2015 was 2,178. Profits per trip would at the maximum point equal to USD 1,336. The OAY level for the PS vessels is reached when the level of effort equals 4,294 trips. Total revenue would then equal USD 9.2 million, but profits would be almost zero. These results indicate that the PS fishery was, at the time, still in good condition and still providing high benefits.

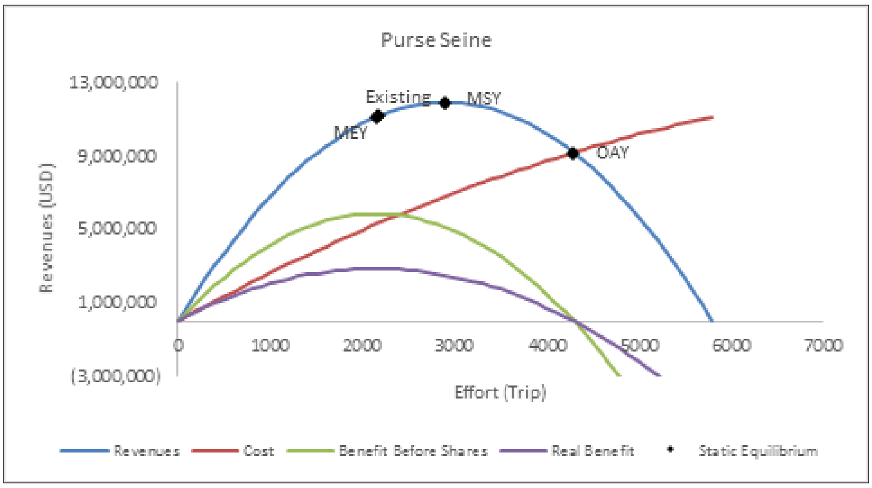

Figure 7.10. Static equilibrium of the bio economic model for PS fishery.

For the PL fishery (Figure 7.11) MEY is obtained when effort equals 779 trips. Profits are then USD 916,000. Effort in 2015 was lower than this, at only 683 trips per year. The effort level corresponding to MSY is reached at 1,152 trips with total revenue of USD 4.5 million. The OAY level for the PL fleet will be reached if the level of effort is 1,558 trips with total revenue of around USD 4 million and zero profit. The PL fishery was also still in the good condition and still providing high benefits.

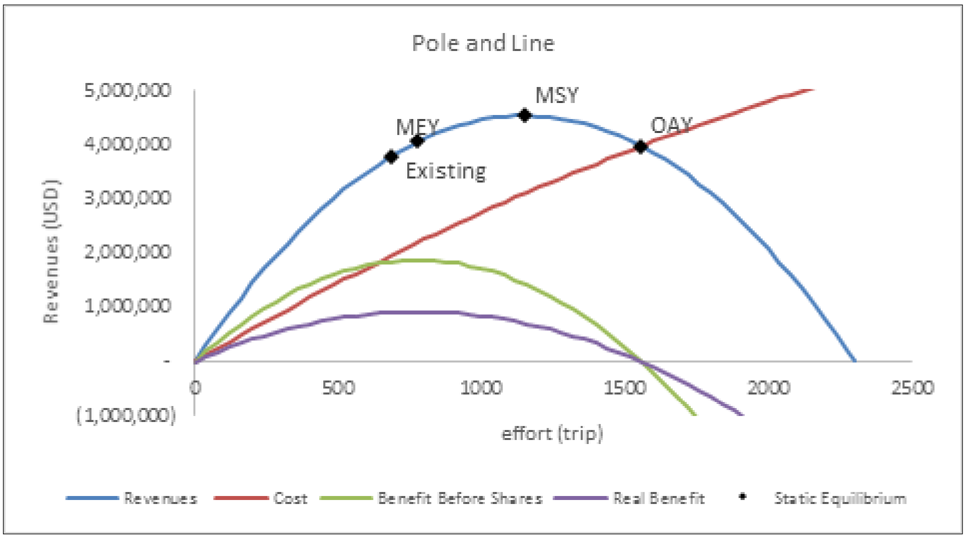

Figure 7.11. Static equilibrium of the bio economic model for PL fishery.

In the HL/TL fishery (Figure 7.12), the MEY will be reached with effort levels corresponding to 278 trips. Profits at this level total USD 800,000. This is slightly above the level of exploitation in 2015. MSY is obtained at effort levels equalling 357 trips and total revenues of USD 840,000, while the OAY level will be reached when level of effort equals 555 trips. Total revenues will then amount to USD 580,000 but there will be no profits. The HL/TL fishery was also still in the good shape and still providing high benefits.

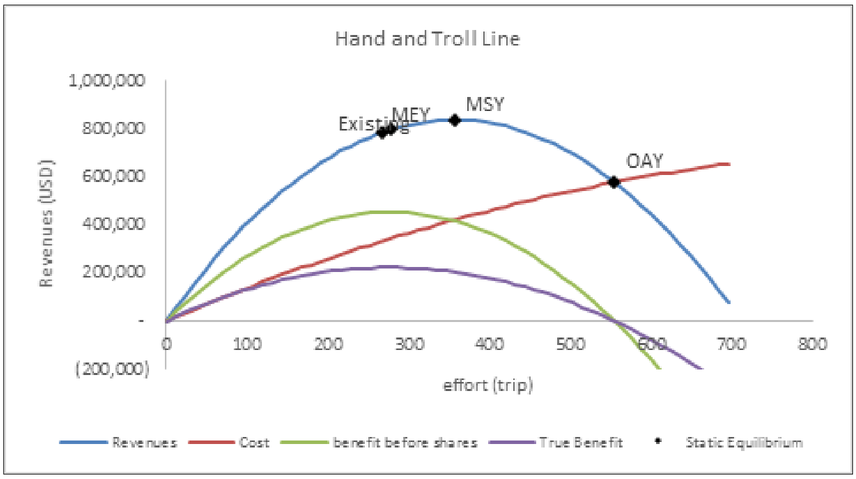

Figure 7.12. Static equilibrium of the bio economic for the HL/TL fishery.

These results indicate that the level of effort in 2015 was similar to that expected to hold when MEY is obtained. There are good profits to be enjoyed by all three gear types, and therefore, there were strong incentives for further investment, both in FADs and vessels, but also in auxiliary gear like GPS or echo sounders. Such investments could push the fishery towards the Open Access point (OAY), where there are no profits to be had. Management authorities should therefore keep a close watch on investments in these tuna fisheries.

From the MEY level in Table 7.11 we can see that the actual vessel owner benefit portion from the total revenues is considerably low at only 22% for the PL fishery (USD 916,205 from USD 4,066,478 total revenues), 25% for the PS fishery (USD 2,868,934 from the USD 11,134,593 total revenues) and 27% for the HL/TL fishery (USD 222,374 from USD 797,734 total revenues). Most of the total revenue is going on the shared income costs, with an average 10% portion going on investment for the vessel, engine, fishing gear and also FADs. This also explains the reason behind the extensive investment in fishing fleet and auxiliary gear.

Stochastic production function

Following Battese and Coelli (1995), the model used for estimating the stochastic production frontier is given by:

$$\ln Catch_i = \beta_0 + \beta_1 \ln(Dim)_i + \beta_2 ln\,(Crew)_i + \beta_3 ln\,(DAS)_i + \beta_4 ln\,(Ice)_i + \beta_5 ln\,(Water)_i + V_i - U_i$$

where the technical inefficiency effects are defined as a function of dummy variables:

$$U_i = \delta_0 + \delta_1 DumCap2 + \delta_2 DumCap3 + \delta_3 DumCap4 + \delta_4 Dum4B + \delta_5\, DumfFG3 + \delta_6\, DSoff + \delta_7\, DSpeak + W_i$$

Here, the β's and δ's are parameters to be estimated, while V_i and W_i are well-behaved random error terms and *i* indicates individual vessels.

The model was estimated using maximum likelihood. For this purpose the frontier R package developed by Coelli & Henningsen, (2013) was employed. Use was also made of the plm R package developed by Croissant & Millo (2008).

The results from estimating the model are presented in Table 7.12. As all variables are in logarithmic form, the parameter estimates can be interpreted as elasticities which show by how much catches will increase if the use of each input is increased by 1%. All the parameters in the model are statistically significant at the 1% level or better, with the exception of the parameter relating to the variable days at sea (DAS). This parameter takes a negative value, indicating that lengthening the fishing trip will lead to reduced catches. The increased utilisation of FADs can lead to vessels spending more time transiting between FADs in search of suitable fish aggregations, thus reducing the time actually spent fishing. The negative value of the DAS-parameter appears to be picking up this effect. All the other variables have a significant positive impact on catches.

All the dummy variables in the inefficiency equation have a negative effect on inefficiency – and thus increase the efficiency of the vessels – as can be seen from the fact that all the estimated parameters in the inefficiency equation take a negative value. However, three of the parameters are not statistically significant from zero; those related to DumCap2, DumCap4 and Dum4B. The DumCap2 and DumCap4 variables refer to instances where the captain of the vessel did 2 - 6 fishing trips, or more than 12 fishing trips, in 2015. The results therefore indicate that the efficiency of vessels with such captains was no different from the efficiency of captains who only did 1 or 2 fishing trips in that year. To avoid multicollinearity the dummy variable pertaining to cases where the captain did fewer than 1 or 2 trips per year (DumCap1) was not included in the regression model. However, having captains that went 6 - 12 trips a year has a positive effect on efficiency.

The choice of fishing grounds does not appear to have a significant influence on efficiency, but the PS vessels appear as more efficient. Efficiency is also higher both in the off-peak season and the peak season, than in the transitory period.

Table 7.12. Estimation results, output elasticities, and technical inefficiencies.

Item	Estimate	Std. Error	z-value	Pr(>|z|)	
Stochastic frontier model					
(Intercept)	6.0487	0.2109	28.6785	< 2.20E-16	***
log(Crew)	0.2349	0.0411	5.7179	1.08E-08	***
log(Dim)	0.0685	0.0140	4.9060	9.30E-07	***
log(DAS)	-0.0804	0.0373	-2.1558	0.0311	*
log(Ice)	0.4275	0.0297	14.4009	< 2.20E-16	***
log(Water)	0.2001	0.0194	10.2966	< 2.20E-16	***
Ineffieciency fator					
(Intercept)	1.2583	0.1284	9.7983	< 2.20E-16	***
DumCap2	-0.0810	0.0788	-1.0284	0.30374	
DumCap3	-0.2005	0.0949	-2.1132	0.03458	*
DumCap4	-0.0254	0.0916	-0.2768	0.78192	
Dum4B	-0.0240	0.0688	-0.3485	0.72748	
DumFG3	-0.4924	0.0875	-5.6263	1.84E-08	***
DSoff	-0.2693	0.0622	-4.3315	1.48E-05	***
DSpeak	-0.4152	0.0896	-4.6361	3.55E-06	***
sigmaSq	0.4473	0.0534	8.3776	< 2.20E-16	***
gamma	0.7070	0.0247	28.6620	< 2.20E-16	***

Significance codes: 0 (***), 0.001 (**), 0.01 (*), 0.05 (.), 0.1 ( ), 1

In Table 7.13, estimated technical efficiency is calculated across vessel/gear types. Technical efficiency is highest for PS vessels (0.58 on average), but significantly lower for both PL and HL/TL vessels. The least efficient vessels have a similar efficiency score for all three gear types, but the most efficient PS vessels and HL/TL vessels are far more efficient than vessels using PL.

Table 2.13. Summary statistics of the efficiency

Parameter	All	Purse seine	Pole and line	Hand and troll line
n	2598	2107	26	466
Average	0.5431	0.5764	0.3707	0.4018
Min	0.0934	0.0989	0.0994	0.0934
Max	0.9061	0.9061	0.7165	0.8718
Stdev	0.1737	0.1653	0.1378	0.1308

In the plot of frequency of estimated technical efficiency of the tuna fishing fleet in Kendari (Figure 7.13), the distribution is skewed to the right, showing that the estimated technical efficiency of 40% of the vessels is below the average. The estimated efficiency of 20% of the vessels is in the 0.7 - 0.8 range while the efficiency of more than 21% of the vessels is estimated as greater than 0.8.

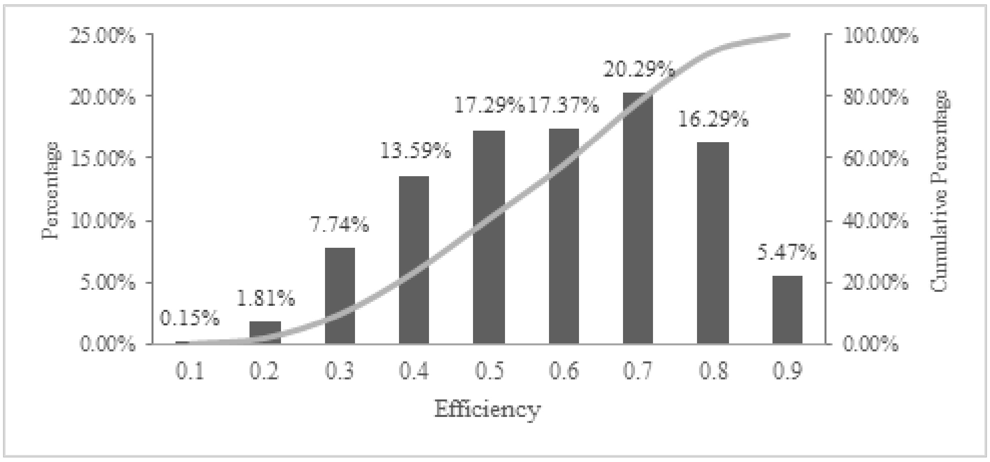

Figure 7.13. Frequency distribution of the estimated technical efficiency (for all gear types combined).

In Figure 7.14 and Table 7.14 the seasonality of the estimated technical efficiency is analysed in more detail. The dark black line in Figure 7.14 represents the estimated technical efficiency of vessels active during the peak season (March - May) while the grey line represents the efficiency of vessels during the off season (October - February). The dotted line shows estimated efficiency of vessels in the transitory season (June - September). Estimated efficiency is highest during the peak season, but overall there is not a large difference between the technical efficiency of vessels operating during the peak season and the off season. The frequency distribution during the three different periods also shows different patterns, with the distribution of the peak season being more skewed to the right than in the distributions for the other seasons.

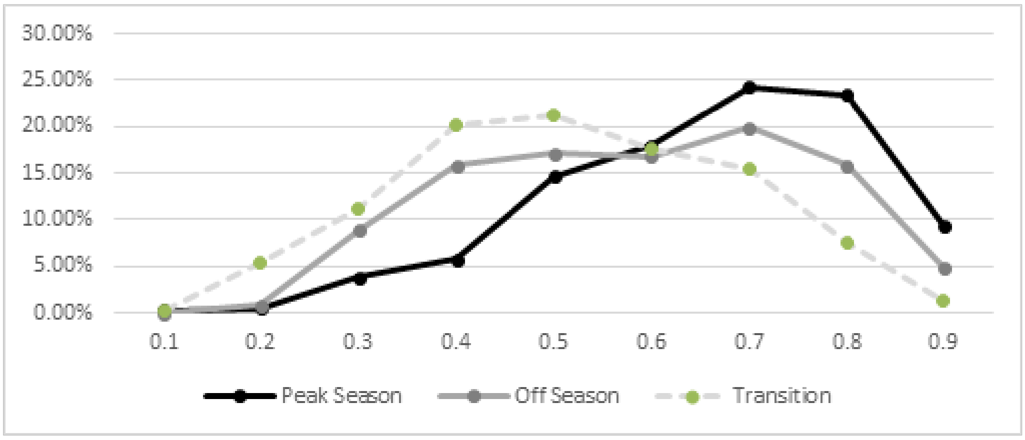

Figure 7.14. Efficiency frequency distribution for different seasons.

As evident from Table 7.14, it is clear that average efficiency is highest during the peak season and the standard deviation lower. However, the difference between the peak and off seasons is not large. This is rather surprising, as one would expect efficiency to be higher during the peak season when the fish are more abundant and catches higher.

Table 7.14. Efficiency distribution and summary for 3 seasons.

Efficiency Range	Peak Season		Off Season		Transition	
[0.0, 0.1)	3	0.35%	0	0%	2	0%
[0.1, 0.2)	5	0.58%	9	1%	34	5%
[0.2, 0.3)	33	3.85%	98	9%	70	11%
[0.3, 0.4)	49	5.71%	176	16%	128	20%
[0.4, 0.5)	125	14.57%	190	17%	134	21%
[0.5, 0.6)	154	17.95%	186	17%	111	18%
[0.6, 0.7)	209	24.36%	221	20%	98	16%
[0.7, 0.8)	200	23.31%	176	16%	47	7%
[0.8, 0.9)	80	9.32%	54	5%	8	1%
Average	0.6068		0.5383		0.4652	
Min	0.0989		0.1020		0.0934	
Max	0.9061		0.8733		0.8723	
Stdev	0.1562		0.1715		0.1667	

Results from estimating the stochastic production frontier indicated that the length of the trip, as measured by days at sea, had a negative but statistically insignificant effect on catches. In Figure 7.15 the relationship between trip length and estimated efficiency is analysed in more detail. The figure clearly shows that vessels that spend many days at sea tend to have rather lower efficiency. Indeed, most of the points corresponding to those longer trips lie below the average level.

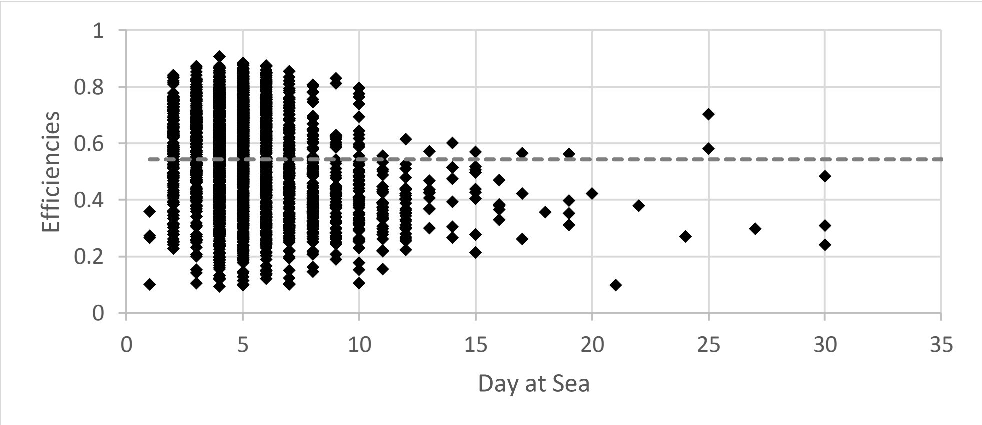

Figure 7.15. Technical efficiency according to length of fishing trip.

There were no clear patterns in the relationship between the vessel dimensions and crew size on the one hand and technical efficiency level on the other. Figure 7.16 does appear to show a non-linear relationship between crew size and estimated efficiency. Technical efficiency is lower for vessels with small crews and largest crews, but higher for vessels with crews of 10 - 20 individuals.

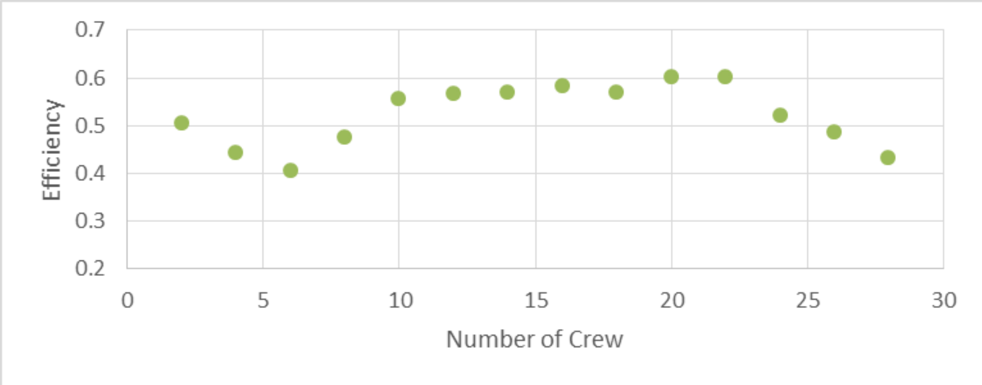

Figure 7.16. Average technical efficiency according to the size of vessel's crew (all gear types combined)

The available data also allows for comparison of technical efficiency of the same vessels between individual fishing trips. Figure 7.17 shows the distribution of estimated technical efficiency of the tuna vessels according to the number of trips undertaken by each vessel. Vessels that made fewer than 12 trips a year were excluded from this comparison. Seven vessels were identified has being very efficient. The efficiency of these vessels was estimated to be much higher than the average and the spread of estimated efficiency, as measured by the difference between maximum and minimum efficiency scores, was quite narrow. As these vessels were not always captained by the same individual, the efficiency of the vessels must first and foremost be related to the vessel's specification and use of inputs. Other vessels are shown as always performing poorly; the estimated efficiency is low and the variations of efficiency scores high. These vessels might need more skilled captains or try to operate more often during the peak fishing season and fish where catches can be expected to be higher.

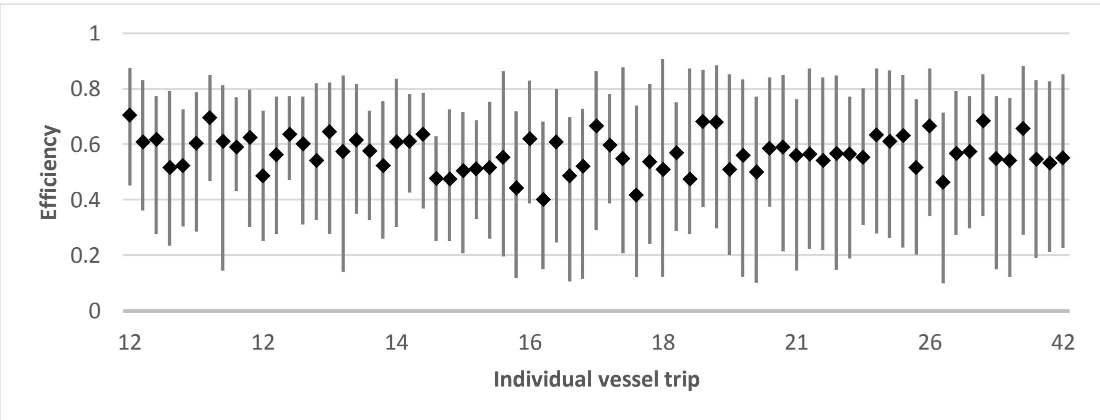

Figure 7.17. Spread of technical efficiency of individual vessels, based on number of trips done for one year.

Socio-economic aspects

Socio economic aspects have been of increasing concern for both policymakers and researchers in regards to fisheries management. Understanding the behaviour and social structure of the fishers will enable good policy recommendations, to achieve successful fisheries management. This is in line with the Hilborn (2007) statement about "managing fisheries is managing people". Most of the fishers engaged in the FAD associated tuna fisheries are highly dependent on the fisheries sector. Only a few of the captains or vessel owners have alternative incomes outside of the fisheries sector. Some of the alternative livelihoods are not outside the fisheries sector because they still have connection with the fishing activities. This includes activities such as fishing equipment, stores for spare parts, engine repair workshops, and fish catch transportation.

Using the average benefit per trip from the bio-economic model and the shared socio-economic data, we were able to estimate the individual income for the crews. For the existing conditions the PL fleet provided the highest shares among the three fisheries. The PL fishery showed an average income of USD 1,321 per trip. The amount of the shares for each crew are presented in Table 7.15. Each crew of the PL vessels received on average USD 67 per trip, with the average number of trips of the PL vessels being 20 per year. In total, the crew of the PL vessels earn an estimated USD 1,344/year (USD 112/month).

Table 7.15. Simulation of the shares for 3 fishing fleets

Position	Purse Seine	Pole and Line	Hand & Troll line	Purse Seine	Pole and Line	Hand & Troll line
Captain	3.64	2.54	2.15	237	171	207
Engineer	2.08	1.96	1.5	135	132	144
Fishing Master	1.5	2.31		98	155	
Boy-boy (bait thrower)		1.85			124	
Net Thrower	1.5			98		
Diver	1.5			98		
Crew	1	1	1	65 (10)	67 (11)	96 (5)
TOTAL	20.22	19.66	8.65	731	649	447

Total shares; PS = USD 1,317, PL = USD 1,321, HTL = USD 832, number of crew PS = 15, PL = 15, HTL = 7

The revenue to be shared in the PS fishery is USD 1,317 per trip per vessel for the existing conditions, if we use the same calculations as for the PL vessels and assume an average crew of 15 for the PS vessels. Using the average shares allocation for the PS vessels the crew will each receive USD 65 per trip. On average, PS vessels make 30 trips per year so the total annual shares are USD 1,950 (USD 162 per month).

The income shares for the HL/TL vessels were lowest, at an average of only USD 832 per trip. By using the same calculation methods as above and assuming a crew of 7 persons per HL/TL vessel and the average shares allocation, it was estimated that the crew will receive USD 96 per trip. The HL/TL vessels make, on average, 30 trips per year so annual income shares for each crew would amount to USD 2,880 (USD 240 per month). The crew of HL/TL vessels receive the highest share amount compared to that received by crew of the other two fishing fleets. Crew of the PL vessels received the lowest share amount.

In the study by Bailey et al.(1987) the shares for the HL vessel crew were estimated at only USD 87 per month. If we accommodate the changes in exchange rate between 1985 and 2015 using the value of Gold Price in dollar during that time we can use 3.98 as an adjustment factor, meaning the USD 87 figure equates to USD 348 per month in 2015 terms. For the *payang* (i.e. Danish seine) vessels, not too dissimilar to PS vessels, that study estimated the crew shares to be even smaller at only USD 73 per month, or in adjusted terms, USD 294 per month.

From the 2015 Kendari statistics report, information is available on the labour incomes in Kendari city industries. In 2015 the minimum salary for the labour was USD 134 per month. This minimum salary is low compared with the monthly incomes from the PS and HL/TL fishing fleets but it still higher than the monthly income from the PL fishing fleet. In general, the fisheries industry, and especially the FAD associated tuna fisheries in Kendari, still offer higher incomes for the crew than from other labour sectors. As the fisheries also require intensive use of labour, some of the fishers come from another places outside the Kendari or Sulawesi Island. This also explains the reason why the extensive investment in FAD fisheries has occurred. The results here are very similar to those obtained by Gaffar

(2015) on the contribution of the modernized fishing technology on socio-economic status in south Sulawesi. Gaffar (2015) stated that the modernization of the fishing technology improved the socio-economic status of the fishers.

The relatively good income offered by the fisheries sector acts as a strong incentive for young men to leave school after elementary school and to start work as fishermen at an early age, in order to help provide for their families and also to prepare for starting their own families in the future. They depend on fisheries for their sole income as they spend most of their time going at sea on fishing trips. They consider that the good income offered by the fisheries sector will be sufficient to support their lives and that they don't necessary need other sources of income.

Static equilibrium of bio economic model

Our bio-economic model for the FAD associated tuna fisheries based in Kendari was developed using the Schaefer (1957) surplus production model. The static equilibrium estimates from the bio-economic model showed that exploitation level in 2015 was below the MSY level, and the profit per trip for all the fishing gears was still high. Simulations were conducted to explore the effects of changes in fish price, fuel price and number of trips in a year. Result of these simulations are presented in Figure 7.18. In one scenario it was assumed that fuel increased in price by 40%, fish prices decreased by 10% and effort (fishing tips per year) decreased by 20%. In all three cases, the point representing MEY shifted to a lower level of effort and profits were reduced for all three gear types. PL vessels were most severely impacted in this scenario, as profits reduced by 34%. This can be explained by the fact that PL vessels use a large amount of fuel, far more than the other two vessel types. The average number of trips per year for the PL vessels is also less compared to the other fishing fleets, so the reduction of the number of trips per year will result in increases in their fixed costs.

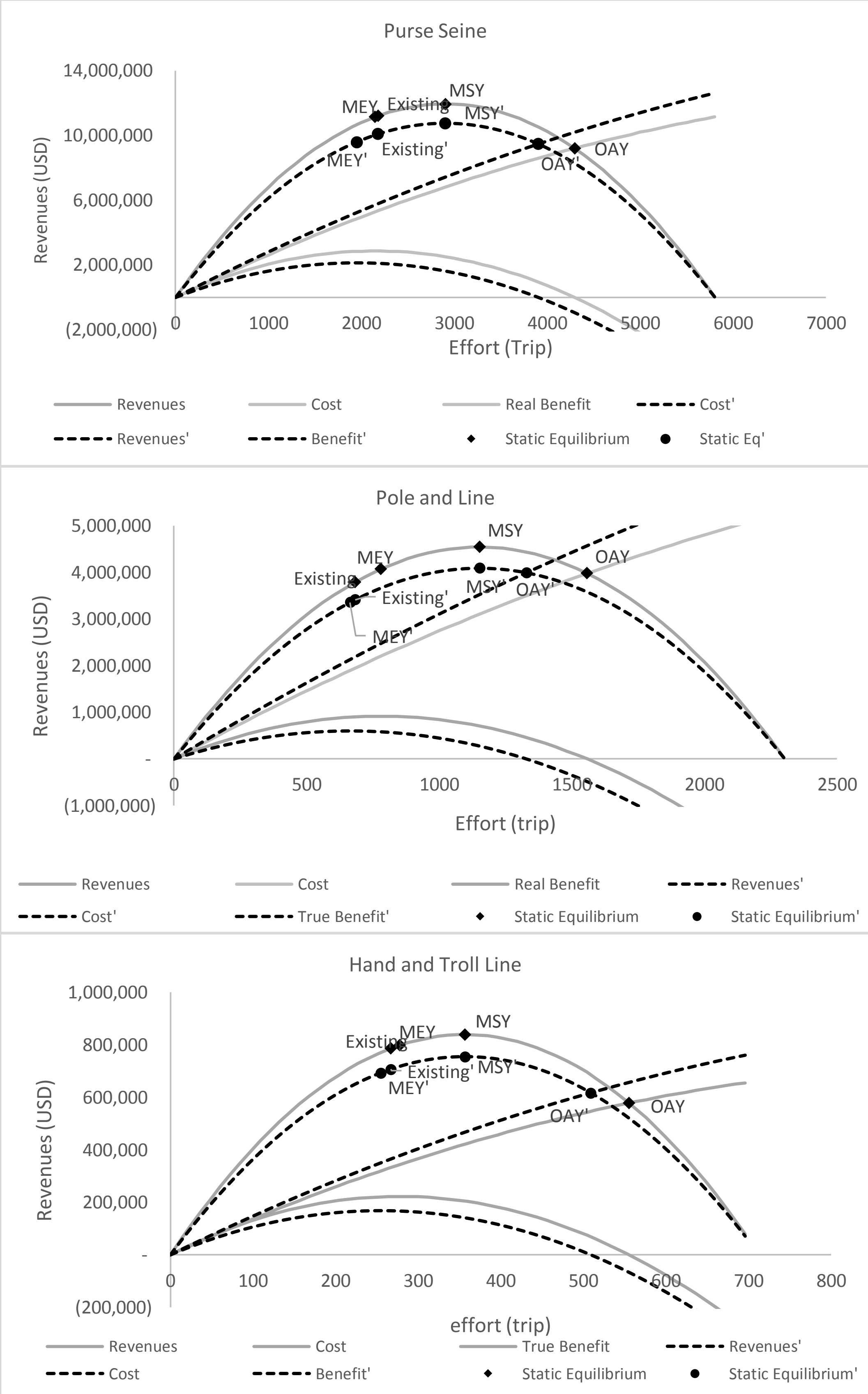

Figure 7.18. Bio-economic simulation for different scenarios for each gear type.

Technical efficiency

The results of the technical efficiency analyses showed a mean efficiency score of 0.5485. This technical efficiency is lower than that reported in the study by Jeon et al. (2006) for the PS fishery in the Java Sea (mean value 0.61), and that reported by Fousekis and Klonaris (2003) for the Greece trammel net (mean value 0.717), and also lower than that reported by Ghee-Thean et al. (2012) for the Malaysian trawl fishery (mean value 0.717 for the SPF and 0.56 for DEA). This showed the ability of the FAD associated tuna fishery in Kendari to convert the input variables into output (catch) is still lower if compared with the PS fishery in Java Sea. Both fishing fleets utilise FADs during their fishing operations.

Seasonality also contributed to the efficiency levels in the FAD associated tuna fishing fleets in Kendari. This is similar to the results obtained by Jeon et al. (2006) who used different dummies for the different fishing seasons to test the effect of the seasonality on technical efficiency. Their study revealed that efficiency is highest during peak season compared to the off season.

Policy implications

The focus of bio-economic and technical efficiency analysis in open access fisheries is to describe the best form of sustainable development and management for the renewable resource stock, and to avoid overcapacity and higher pressures on the fisheries. Bio-economics analyses examine the more broader area of the sustainability of resource stocks and maximising economic resources rent from the fishing activities. The technical efficiency analyses focus more on the efficiency levels of the individual vessels and on avoidance of the overcapacity contributed by the fishing fleets.

Results from both types of analyses done for Kendari showed there is strong need regarding the implementation of FAD regulations to reduce the overinvestment in FAD installations and to maintain the number of FADs at an optimum level. This result supports the implementation of Ministerial Regulation No.26/2014 (which included the regulation of the maximum number of 3 FADs allowed for each vessel). See Section 6.5 for discussion on the status of Indonesia's FAD regulations.

Conclusion - Kendari

This study aimed to provide a preliminary socio-economic and bio-economic analysis of the FAD associated tuna fisheries in Kendari (SE Sulawesi) and estimate the technical efficiency of the tuna fishing fleets. The main constraints during the project were the lack of long-term time series for catch and effort data and insufficient biological data to build a robust biological analysis for the bio-economic model. There was also need for more detailed information about the fishing operations around the FADs to improve the outputs from the technical efficiency analyses. Better data would allow other possibilities in the analyses, such as deriving the long run dynamic equilibrium for the bio-economic model, and also a more detailed stochastic production function frontier analysis. However, the results from this project proved useful for exploring the FAD associated tuna fisheries in Kendari and showed the potential for data analyses that could be done to support the policy planning and implementation.

7.4.2 Palabuhanratu (West Java)

Characteristics of fisheries at PPN Palabuhanratu

Fishery production in PPN Palabuhanratu increased during 2012 - 2014 to 10,000 tons, but decreased to 3,800 tons in 2016 (Figure 7.19). This decrease was the result of fewer landings of catch from purse seine and longline vessels and also to a decline in fishing effort, as a result of MMAF policies regarding transshipments and ex-foreign vessels.

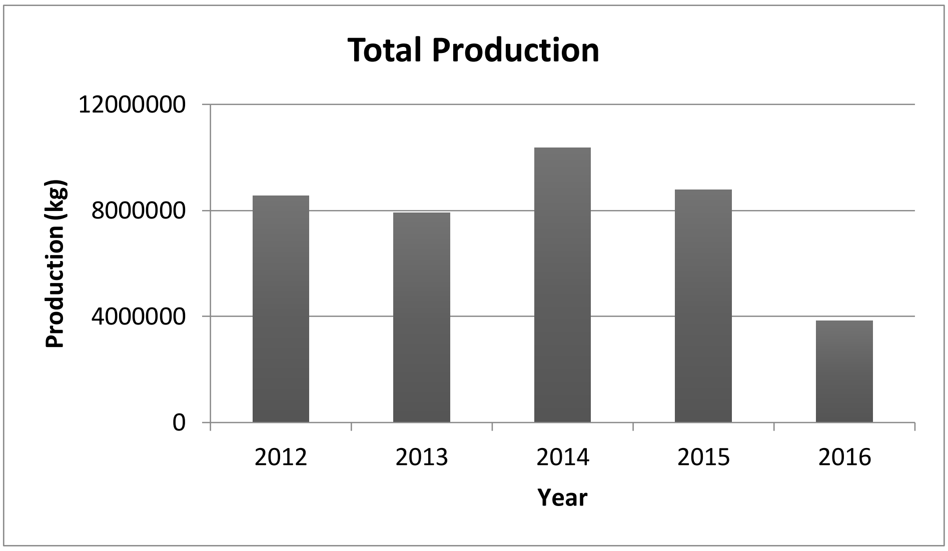

Figure 7.19. Fisheries production at PPN Palabuhanratu during period 2012-2016.
(Source: Landing Report from PPN Palabuhan Ratu 2017).

The Archipelagic (Class B) Fishing Port of Palabuhanratu, PPN Palabuhanratu, is located in southern West Java, and is a landing base for fishing vessels operating in the Indian Ocean. Several different fleets and fishing gears are a feature of PPN Palabuhanratu, including hand-line/troll-line (*kapal tonda*), lift-net (*bagan*), gillnet (*rampus*), longline, Danish seine (*payang*), handline - small vessel (*pancing ulur*), and trammel net (Figure 7.20). Hand-line/troll-line (HL/TL) vessels, which use deepwater anchored FADs in their fishing operations, made up 16.43% of the total number of fishing vessels based at PPN Palabuhanratu in 2016.

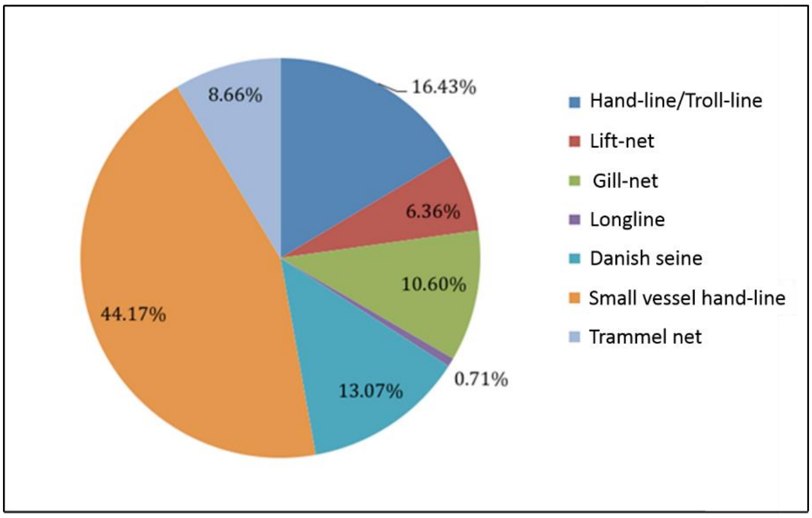

Figure 7.20. Vessels composition by gear at PPN Palabuhanratu in 2016.
(Source: Landing Monitoring Report PPN Palabuhanratu 2017).

Production of the HL/TL fleet decreased from a 800 - 900 tons in 2012 - 2013 to only 326 tons in 2016 (Figure 7.21). This significant decrease was the result of many of the vessels targeting hairtail (Trichiuridae) instead of tuna during hairtail season because it is a more profitable product. Palabuhanratu is a well-known centre of export of hairtail product to China, Korea, and Japan (Nurani et al. 2015). The decrease in production was also caused by the influences of climate and weather.

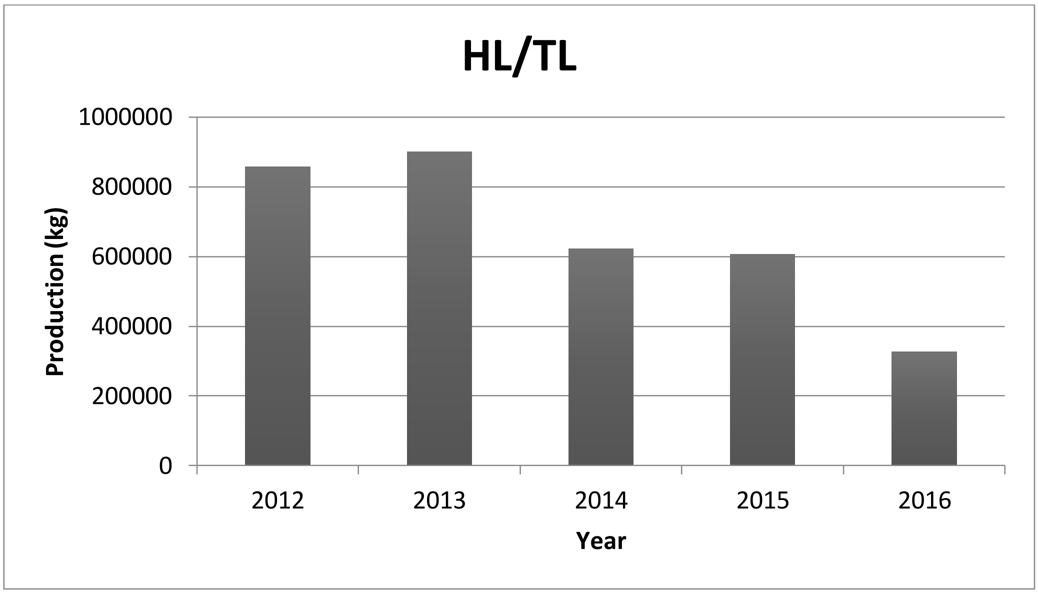

Figure 7.21. Annual catch production of the HL/TL fleet at PPN Palabuhanratu during period 2012-2016. (Source: Landing Report from PPN Palabuhanratu 2017).

The HL/TL vessels (*kapal tonda*) are wooden vessels that have developed at PPN Palabuhanratu since 2004, when they were introduced into the region by Bugis fishermen of southern Sulawesi. At first these vessels (Figure 7.22) operated with gill-nets but then changed to become surface troll-line vessels. They also carry hand-line gear and fish opportunistically with both troll-line and hand-line.

Figure 7.22. A HL/TL vessel departing PPN Palabuhanratu. Photo: M. Natsir 2016

The size of HL/TL vessels vary between 5 - 16 GT with the average being 6.3 GT, and average dimensions of 12.4 m in length, with 2.9 m in width and 1.1 m in depth. The average engine (in-board) size is 158 HP. An average of 4 persons are required to operate on one HL/TL fishing vessel. The details of size of the HL/TL vessels at PPN Palabuhanratu are given in Table 7.16.

Table 7.16. Characteristics of HL/TL vessels at PPN Palabuhanratu.

Fleet		GT	Length	Width	Depth	Engine (HP)	Crew
HL/TL	Maximum	16.00	14.74	4.20	2.50	330.0	6
	Minimum	5.00	10.30	2.30	0.80	23.0	3
	Average	6.27	12.36	2.87	1.05	158.3	4

The tuna fishing areas for the HL/TL vessels based at PPN Palabuhanratu are located in the Indian Ocean, with the majority of FADs being south in the area from the mouth of the port, from Tinjil Island, extending to Pangandaran to the east. The main fishing season for the HL/TL vessels at PPN Palabuhanratu is June to September and the low season being December to March.

Information on catch compositions of the HL/TL vessels is provided in Section 6.2.

Characteristics of Social Society of PPN Palabuhanratu

Characteristics of fishers

Based on data and information obtained through the interviews, the average age of vessel captains in Palabuhanratu was 36 years, with the average period of experience of being a fisherman being 13 years. For the majority of captains surveyed (true for 75% of those surveyed) their formal education was to end of primary school (*sekolah dasar*), with them becoming fishermen directly after leaving school. In general they received no formal training for their profession as a fishermen, and instead received their tuition and knowledge from other fishers and captains. The HL/TL fishers in PPN Palabuhanratu are full-time fishers who rely solely on income from their business at sea. The fishing of tuna around the FADs is done all year round, except during the season when fishing for hairtail (*ikan layur*) is more profitable. From the interview the average income of fishermen in PPN Palabuhanratu is IDR 3 million per month.

Fishers' knowledge

Although their opinions of the condition of fish resources varied, all fishermen interviewed were of the opinion that fish resources had decreased during the last 10 years and that fishing on FADs had not increased their incomes. They largely attributed the decline in fish stocks to the presence of large purse-seine vessels (from Jakarta) and their unregulated catch in the Palabuhanratu region on FADs installed progressively closer to the shore. In common with the fishermen at PPS Kendari, the factor considered to be of most influence on fishing success was the weather. Fishermen of PPN Palabuhanratu are able, through their specific knowledge, to identify the presence of fish resources around the FADs so that the fishing event will be successful. The condition of the currents at the FADs is one a factor that the fishermen can assess to determine likelihood of success. The development of capture technologies have also been a major factor in the success of fishing tuna resources around FADs.

Fishermen in PPN Palabuhanratu were aware of the government policy and regulations about FADs but the implementation of those policies and regulations has not been achieved. The delivery of information and explanations *('sosialisasi')* by the government, about the policies and regulations, had been done to some extent, but the results from the interviews revealed that many fishers remained insufficiently informed. In general, the HL/TL fishermen of Palabuhanratu purposefully installed their FADs in locations well distanced from those of the purse-seine fishers who are from outside the region. The FAD regulations (Ministerial Decree No. 26 / PERMEN-KP / 2014) state that the minimum distance between the anchored FADs should be 10 nm, a measure intended to increase the effectiveness of FAD attraction.

However, there had been occurrences of the purse-seine FADs being installed less than 10 nm from those of the HL/TL fishers.

The use of FADs as a ‘fish collecting tool’ by HL/TL fishers have caused conflicts with longline fishers because there have been many occurrences of longlines becoming entangled on the FADs. Conflicts have also occurred between the purse-seine fishers and HL/TL fishers over the utilization of fish resources around the FADs. However, many of the HL/TL fishers who have not had their own FADs have utilized the purse-seine FADs for their fishing operations. In a system commonly known as *“tuyul”*, the FADs owned by the purse-seine fishers from outside the region have been guarded by the HL/TL fishers from Palabuhanratu. When the purse-seine vessels carry out fishing on the FADs they provide part of their catch to the HL/TL fishers as payment for this ‘guarding service’.

Systems of FAD ownership

There have been three types of ownership and use of FADs for the HL/TL fishers of PPN Palabuhanratu:

1. The owner of a HL/TL vessel owns a FAD or multiple FADs and the fishing by that vessel is done on those FAD(s);
2. The FAD(s) is used by a group of HL/TL vessels under ownership of one ‘business’ (generally one vessel owner who owns multiple vessels);
3. FADs that are installed and owned by purse-seine vessel operators from outside the region.

In general, the interview outcomes showed that fishermen in Palabuhanratu have a high awareness of fisheries management, and all respondents indicated that they would obey the rules set by the government. This is viewed as an opportunity for the government to provide good utilization policies for the tuna resources. However, the fishermen also indicated that they assumed that if the regulations were enforced there would still be fishermen who would conduct fishing activities that were not allowed by the government.

Division of catch and income

The profit sharing system for the HL/TL vessels in Palabuhanratu is illustrated in Figure 7.23. The gross income from the catch is based on the total catch at time of return to port, less the 5 fish per person taken home by crew. Net income is determined by gross income less 20%; 5% for maintenance costs, 3% for tax *(‘retribusi’*), 5% for those persons *(‘juru batu’*) in port who facilitate departure to sea and unloadings of catch, 5% for engine technicians *(‘juru mesin’*), and 2% for others. Accounting for the costs associated with the fishing operations at sea, the average net income is IDR 8 – 9 million. That net income is divided into 2 equal parts; half goes to the vessel owner and the other half is distributed to the vessel’s captain and crew. The half of net income that goes to the captain and crew is further divided according the numbers of persons, with the captain receiving 2 persons worth and each crew member receiving 1 persons worth.

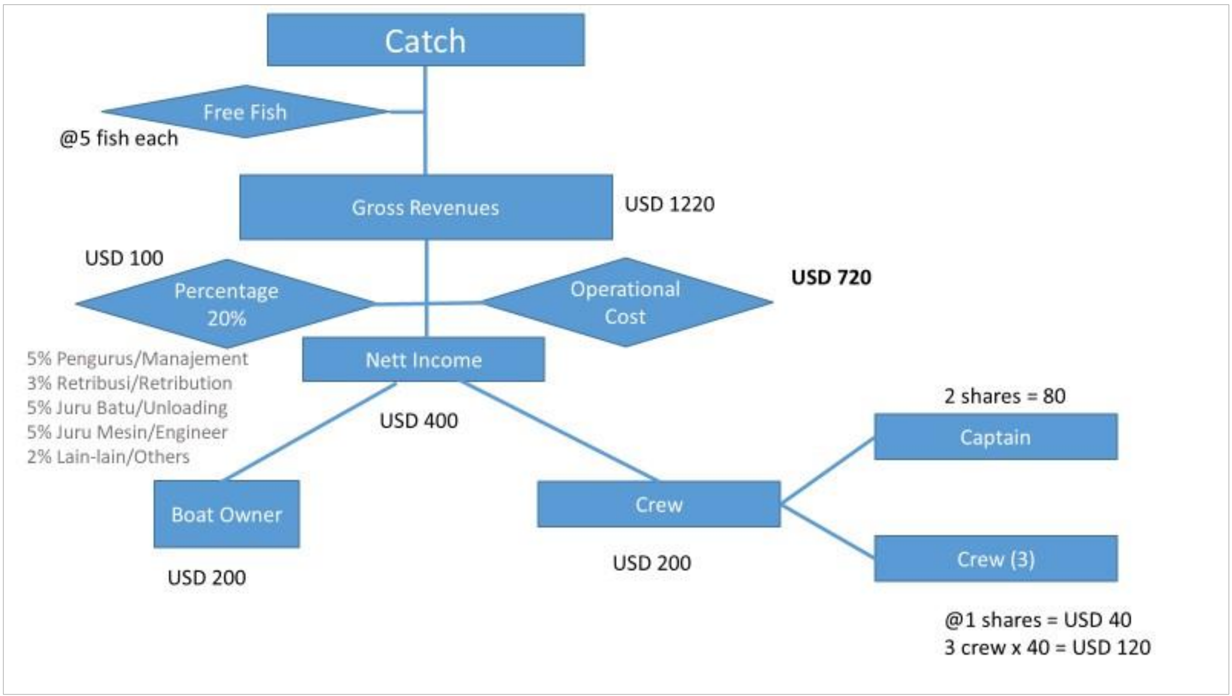

Figure 7.23. Sharing System of PL/HL in PPN Palabuhanratu

Bioeconomic analysis of the FAD-based fishery

FAD construction and installation costs

The overall design of FADs used by HL/TL fishers in Palabuhanratu is similar to that of FADs used by fishermen in PPS Kendari and in other regions, apart from their being no 'live-on' FADs i.e. the type of FADs that occur in some parts of eastern Indonesia that include a bamboo raft (*rakit*) and bungalow as part of the surface structure. For details of design of Indonesian anchored tuna FADs, see Section 5.

The costs of making FADs include: purchasing 100 pieces (i.e. branches) of coconut or nipa palm, with an average price of USD 0.19 – 0.31 per piece and an average total cost of USD 26; the mainline rope with average cost of USD 3615; an average cost for USD 498 for the floats; and an average cost of USD 196 for the anchor weights. The average total cost of making a FAD was USD 4,413, much higher than the average cost of FADs in Kendari. This is because the deeper waters in the fishing grounds of the Palabuhanratu region require a longer and stronger mainline rope, and the rope cost is by far the largest component of the overall costs. The details of the costs for FAD construction are given in Table 7.17.

Table 7.17. Costs associated with FAD construction di PPN Palabuhanratu.

FAD Component	Quantity	Price (USD)	Cost Range (USD)	Average Cost (USD)
Attractor	100 leaf	0.2 - 0.3	19.2 - 30.8	26.2
Rope	7,000 – 10,000 m	0.3 – 0.6	3231 - 3877	3615
Styrofoam (Float)	1 – 3 Rafts	154 - 385	308 - 769	498
Sinker	30 - 37	4.2 - 7.7	131 - 269	196
Labour	1 package	38 - 115	38 - 115	77
Total FAD Cost			**3,727– 5,062**	**4,413**

Catch and Effort data

Data on total catch and total number of fishing trips by the HL/TL vessels by year, obtained from PPN Palabuhanratu Port Authority for the 2008 - 2016 period enabled determination of CPUE in kg/trip (Table 7.18). The lowest CPUE was 461 kg/trip in 2010, the year when total number of trips was the highest. The highest CPUE of this period was in 2008, four years after the commencement of HL/TL operations at Palabuhanratu.

Table 7.18. Trends in effort, catch and CPUE for HL/TL vessels in PPN Palabuhanratu.

Year	Effort (Trips)	Catch (Kg)	CPUE (Kg/trip)
2008	350	292,167	835
2009	940	601,221	640
2010	1,927	888,403	461
2011	1,695	1,023,659	604
2012	1,032	852,040	826
2013	1,287	888,043	690
2014	1,211	613,143	506
2015	902	603,353	669
2016	504	320,855	637

Operational costs

The cost components of the HL/TL tuna fishing business in Palabuhanratu include capital, fixed costs and variable costs (Table 7.19). The average amount of capital invested amounted to USD 20,639. This capital component included the cost of purchasing a vessel (USD 12,820), the main engine (USD 2,186), auxiliary machinery (USD 969), fishing gear (250) and costs FADs construction (USD 4,413). The average fix cost for 1 year was USD 429. The average variable cost of the vessel for one fishing trip, was USD 720.

Table 7.19. Cost components of HL/TL fishing with FADs in Palabuhanratu Fishing Port.

Cost Variable	Unit	Average	Minimum	Maximum
Capital investment	USD	20,639	9,496	37,138
Boat	USD	12,820	3,846	26,923
Engine	USD	2,186	923	3,462
Auxiliary 1	USD	969	923	1,154
Fishing gear	USD	250	77	538
Permit	USD	0	0	0
FAD	USD	4,413	3727	5,062
Fix Cost	**USD**	**429**	**154**	**758**
Boat Maintenances	USD	115	38	231
Main Engines Maintenances	USD	231	77	385
Auxiliary Maintenances	USD	48	15	81
Fishing gear Maintenances	USD	35	23	62

Table 7.19 Continued.

Cost Variable	Unit	Average	Minimum	Maximum
Variable Cost	USD	720	432	1201
Fuel	USD	272	160	446
Lubricant	USD	47	8	146
Spare part	USD	57	3	186
Fishing gear	USD	35	23	62
FAD Maintenances	USD	19	8	31
Stone/Weight	USD	33	31	35
Ice	USD	121	85	135
Logistic/Food	USD	136	115	160
Wage	USD	0	0	0

The results for the estimation of the harvest function for the HL/TL fleet at PPN Palabuhanratu are presented in Table 7.20. These results should be viewed with caution because they were only obtained using 9 observation years and the number of degrees of freedom was very small at only three. The R^2 value of the regression was shown to be 0.44, indicating that the model describes variation of CPUE for 44% of the total data but the remaining 56% of data cannot be explained by the model.

Table 7.20. Harvest function for the HL/TL fishery at PPN Palabuhanratu.

Gear	b_0	b_1	R square
Hand Line & Troll line	829.657	0.1625	0.4353

The plot of the harvest function generated for the HL/TL vessels in PPN Palabuhanratu is shown in Figure 7.24. The actual effort in 2010 - 2011 increased but was still below MSY. CPUE decreased through period 2014- 2016. During this period of observations, the fishery of the HL/TL vessels operating around the FADs appeared to be in 'safe condition', and the addition of more vessels to the fishing fleet appeared to carry no risk to its sustainability.

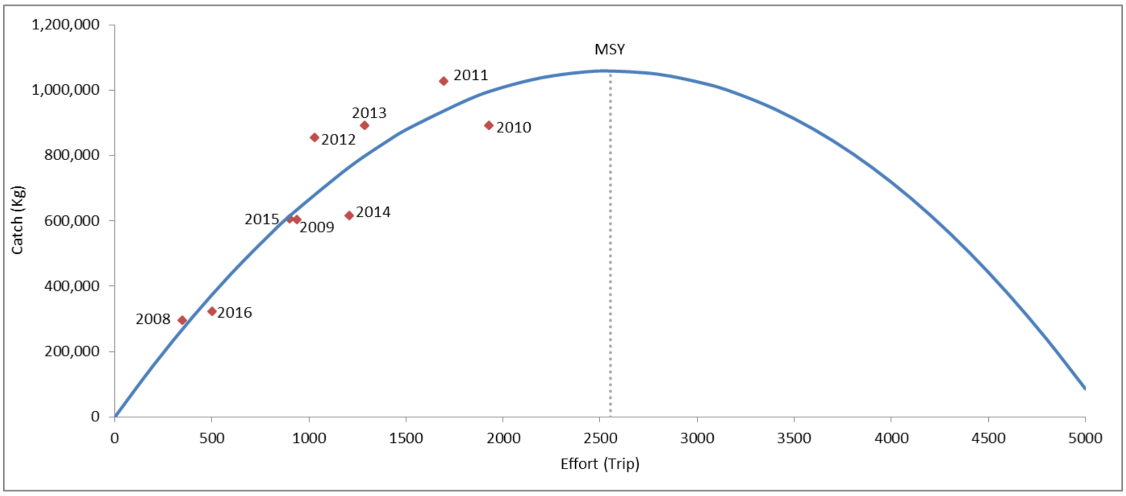

Figure 7.24. Actual HL/TL catch effort during period 2008 - 2016 in PPN Palabuhanratu.

Cost variables and function

A cost function was developed using the data presented in the previous section. For the HL/TL fleet the total cost was obtained from individual vessel data. The total cost function was then used to estimate the profit. Total cost function is the sum of capital costs, fixed costs, 'free fish' costs and variable costs. The cost of capital is defined as part of revenue earned on the vessel because revenue is shared between vessels, vessel owners, crew and sometimes also to owners of the FADs used for fishing. Fixed costs are defined as maintenance of the vessels, engines and fishing gear. The cost of 'free fish' is the cost of giving part of the catch for free to the crew. The annual cost associated with free fish is calculated as the cost per trip times the number of trips (f). The variable cost per trip is defined as the amount of fuel, ice, water and other logistics. In the case of the HL/TL vessels, variable costs also include wages paid to the crew on top of what the crew gets through the share system. The total cost was calculated for both vessels that were completely inactive (in which case the number of trips (f) was equal to zero), and for active vessels where the number of trips was greater than zero.
The cost functions developed are as follows:

Hand-line and troll-line (variables based on average):

$C(f) = (429) + (20 * p) * f + (0.2 * h * p) + (720 * f), \text{ for } f = 0$

$C(f) = (429/ n_{trip/year}) * f + (20 p) * f + (0.2 * h * p) + (720 * f), \text{ for } f = 1 \dots N$

Hand-line and troll-line (variables based on minimum):

$C(f) = (154) + (20 * p) * f + (0.2 * h * p) + (432 * f), \text{ for } f = 0$

$C(f) = (154/ n_{trip/year}) * f + (20 p) * f + (0.2 * h * p) + (432 * f), \text{ for } f = 1 \dots N$

where:

C = *cost (USD)*

p = *fish price (USD/kg)*

f = *effort (trip)*

h = *harvest/catch*

Fish Prices and Revenue Functions

The average fish prices for 2015 are shown in Table 7.21, where prices are given by fish type. This information was then used to calculate the total revenue function for the HL/TL fleet at PPN Palabuhanratu.

Table 7.21. The average fish prices at PPN Palabuhanratu.

Common Name	Average Catch (Kg)	Composition (%)	Average Price/kg USD)
Yellowfin Tuna	294.07	45.40%	2.23
Skipjack	210.53	32.50%	1.06
Striped Marlin	74.03	11.40%	2.38
Big Eye Tuna	38.49	5.90%	2.23
Dolphin Fish	18.47	2.80%	1.27
Others	12.61	2.00%	0.92

Static Equilibrium

The result of the estimated harvest function was used to find the number of trips corresponding to MSY. With *b0* and *b1* to represent the intercept and slope coefficients in the harvesting equation, the effort MSY (F_{MSY}) can be calculate:

$$F_{MSY} = \frac{b_0}{2b_1}$$

Revenue was calculated based on the catch composition and the average price for the HL/TL fleet and costs using the cost function describe above, the benefit defines as revenue minus by cost. The level of effort for the Maximum Economy Yield (F_{MEY}) and Open Access (F_{OA}), was calculated using the program in MS Excel. In MEY case, the solver was set to maximize the benefit, whereas in OA case, the solver was set for zero benefit..

The results of the bio-economic analysis for Static Equilibrium for the HL/TL fleet at PPN Palabuhanratu are presented in Table 7.22 and Figure 7.25. The current level of business applied in this tuna fishery is still far below the level of effort that corresponds to the maximum economic yield (MEY). This suggests that the fishery has been sustainable with good income. However, because of these good profits there is a risk that investment in the fishery, both in terms of vessels and FADs, may increase in coming years, and precautionary management is required to prevent overfishing. It should be noted that the benefit shown in Table 7.22 refer to the total or accumulative benefit, the actual profit for the vessel owner i.e. profit after deductions in the share system.

Table 7.22. Static equilibrium for HL/TL fleet in PPN Palabuhanratu.

	Effort (trips)	Catch (tons)	Revenues USD	Benefit USD	Benefit/ effort
Using Average Cost Function					
Maximum sustainable (MSY)	2,553	1,059	192,115	**(438,246)**	172
Maximum economic (MEY 1)	913	622	112,791	196,349	215
Open access (OAY 1)	1,825	973	176,495	-	-
Existing condition	504	377	68,364	156,995	311
Using Minimum Cost Function					
Maximum sustainable (MSY)	2,553	1,059	192,115	**294,973**	116
Maximum economic (MEY 2)	1,522	886	160,753	545,870	359
Open access (OAY 2)	1,825	973	176,495	-	-
Existing condition	504	377	68,364	301,740	599

As shown in Figure 7.25, we use two different cost function to estimate the benefit, first is using the average cost function and the second one is using the minimum cost function. This calculation was made to understand the impact of cost function to the net benefit. MEY for the HL/TL fleet at PPN Palabuhanratu is USD 196,349 which is just slightly above the existing condition. The optimal number of trips is 913 but the actual number of trips made in 2015 was only 504, and in this condition the total profit from the fishery is USD 156,995. The OAY level is carried out to the level of effort equal to 1,825 trips. The total revenue will then be equal to USD 176,495 million, but the profit is almost zero.

These results indicated that, at time of survey, the HL/TL fishery was still in good condition and was still providing high benefits.

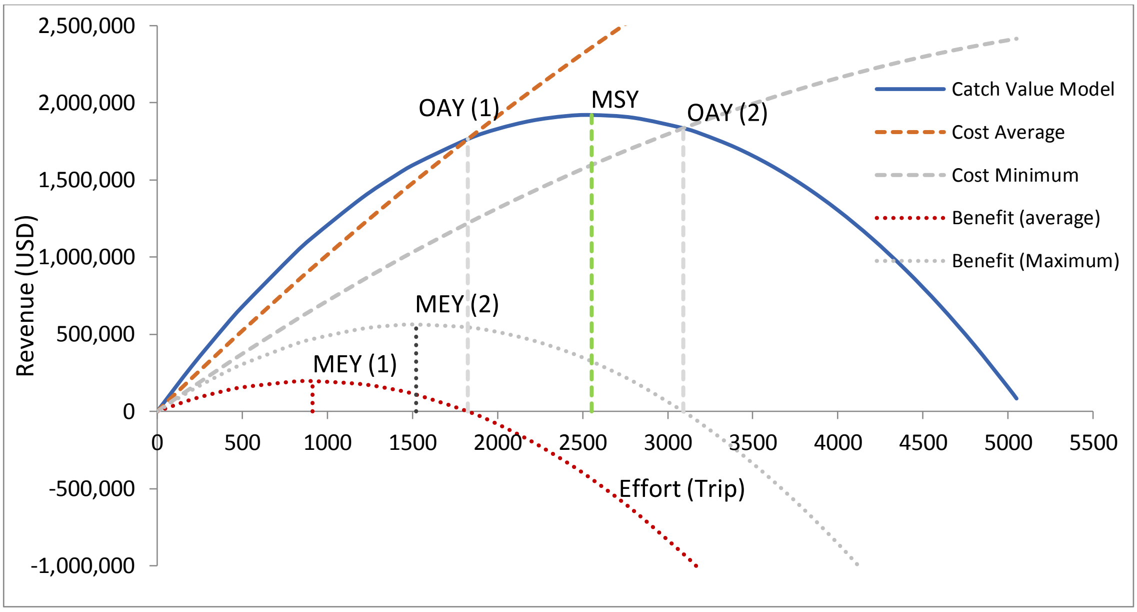

Figure 7.25. Static equilibrium from the bio economic model for the HL/TL fishery in Palabuhanratu.

These results suggest that current levels (i.e. levels at time of survey) of effort are similar to those expected to occur when maximum economic yields are obtained. This level of effort is profitable and therefore there is a strong incentive for further investment, both in number of vessels and FADs, but also in additional equipment such as GPS and echo sounders. Such investments may encourage fisheries to open access routes (OAY), where no or fewer benefits will be obtained. Therefore, those managing the fishery should keep a close watch on the tuna fishery investments.

8. Trial acoustics and video research on fish aggregations on FADs.

Research team: Andria A. Utama, Regi F. Anggawangsa, Ignatius Tri Hargiyatno and Wudianto (all of CFR).

8.1 Research need and Objectives

As one of the largest tuna-producing nations in the world, Indonesia has an obligation to support the sustainable management of tuna fisheries. There is high concern about the ever increasing numbers of anchored Fish Aggregating Devices (FADs) in use by Indonesian tuna fishing vessels, operating in Indian Ocean waters and other maritime regions of Indonesia. The concerns are around the possible negative impacts of the FADs on tuna communities, as they might act as an 'ecological trap'. Achieving a better understanding of the species make-up, behaviour of fish species (their 'aggregation dynamics') on and around FADs is a high priority issue in the eyes of the Regional Fisheries Management Organizations (RFMOs), the Indian Ocean Tuna Commission and the Western and Central Pacific Fisheries Commission. That improved understanding is needed for the scientific basis to develop policies to achieve sustainability of the FAD-based fisheries.

FIS/2009/059 had as one of its original key objectives to "Provide capacity development for Indonesian scientists in areas of tropho-dynamics, reproductive biology, fish ageing and spatial dynamics". However, there was agreement in the project's planning that a decision on which area(s) of capacity development would be pursued would be made during the course of the project. At the project's first Coordination Meeting, in April 2014, all participants agreed that one important area of capacity development would be in the area of examining fish aggregation behaviours on and around the Indonesian tuna FADs, as doing so would marry well with the other activities of the FAD Fisheries Study. It was also agreed as a good value-adding research activity to earlier acoustics research on FADs, done by scientists of RIMF.

The principal objectives of the field work were:

1. To conduct trial research on deepwater anchored tuna FADs, utilising a range of different equipment for acoustic and visual assessment of fish aggregations;
2. To attempt species characterisation and fish biomass estimates of fish aggregations using the aforementioned techniques;
3. To apply this preliminary research towards a better understanding of 'recovery' of fish aggregations following fishing events on FADs;
4. To provide opportunity for capacity building in skills and knowledge associated with the fish aggregation associated research.

8.2 Methodology

Study areas

The study was done in areas located in the Eastern Indian Ocean (FAO area 57), south of the island of Java (Figure 8.1), approximately 50 – 300 nm from the coastline. Depth range was 1,500 – 2,500 m. The study areas are subject to seasonal patterns driven by the northwest monsoon during November – March and the southeast monsoon during June – August. There are also inter-monsoonal periods: Period I April-May and Period II in September-October. Three surveys were done, utilising 5 FADs in two different areas (Figure 8.1, Table 8.1). First survey coincided with the southeast monsoon, while the second and third surveys coincided with the northwest monsoon.

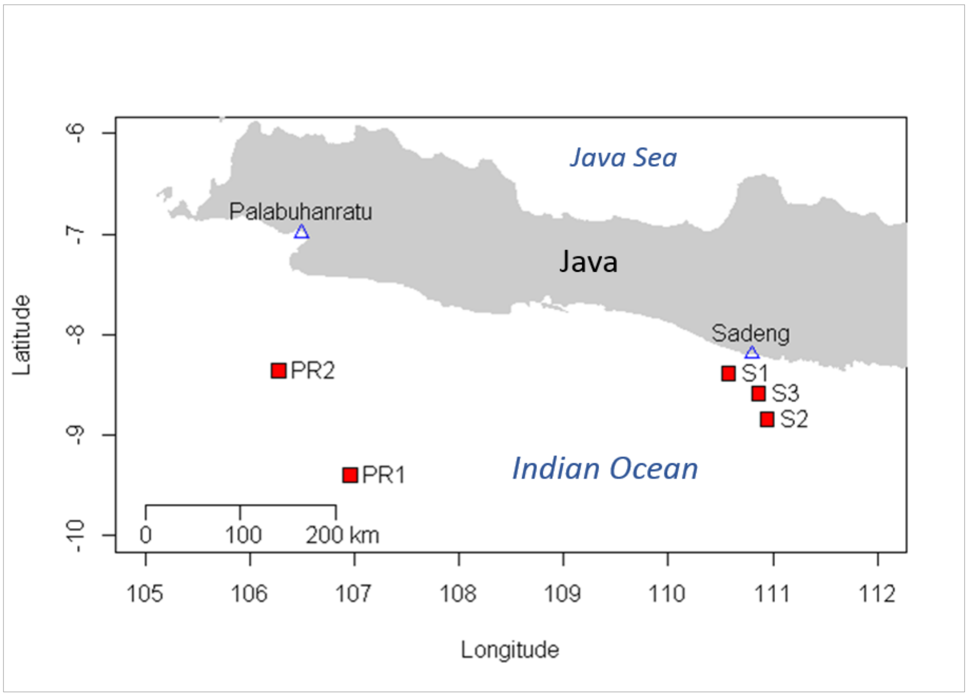

Figure 8.1. The location of FADs during the acoustic surveys (a) Sadeng 1 (S1), (b) Palabuhanratu (PR1,PR2), and (c) Sadeng 2 (S2,S3).

Table 8.1. Details of the survey trips.

Survey	Area	Number of FADs	Dates	FADs coordinates
1	Sadeng	1	23 August 2016	8.3863ºLS, 110.5731º BT
2	Palabuhanratu	2	2 November 2016	9.39897º LS, 106.95673º BT
			3 November 2016	8.35558º LS, 110.27280º BT
3	Sadeng	2	8 December 2017	8.839 º LS, 110.9462º BT
			8 December 2017	8.5874 º LS, 110.8635º BT

Data Collection

The investigations were done on a small scale fishing vessel (handline/troll-line) of 14 m length, equipped with:

- *Multifrequency* SIMRAD EY 60 and EK 80 *scientific echosounder* 38, 200 kHz;
- CTD (conductivity, temperature, and depth) instrument or *mini logger*;
- M4i buoy *trifrequency echosounder* (Marine Instruments);
- 360º GoPro and Nikon Key Mission 360º.

The types of data that were obtained by using various equipment are shown in Table 8.2.

Table 8.2. The type of data obtained using various equipment.

Data type	SIMRAD	M4i	CTD *Mini logger*	GoPro Nikon 360
SA (scattering area) values	✓			
Densities	✓	✓		✓
Spatial distribution	✓	✓		✓
Size distribution				✓
Species discrimination		✓		✓
Length-weight				
Salinity			✓	
Temperature		✓	✓	
Depth	✓	✓	✓	

The types of equipment and fishing vessel used for the study are shown in Figure 8.2.

Acoustic data were collected along a star survey pattern with eight branches, according to method of Josse *et al.* (1999) (Figure 8.3 a). Each branch was 1.2 nm in length, without duplicate tracks and with nominal survey vessel speed of approximately 3 knots. The elementary sampling units were defined by partitioning of the survey area into 45 degree angular sectors (Figure 8.3 b). Therefore, the survey areas were divided into eight horizontal strata with one branch per stratum. Depth categories included one 40 m layer for depths between 10 and 50 m, and nine 50 m layers from depths between 50 and 500 m.

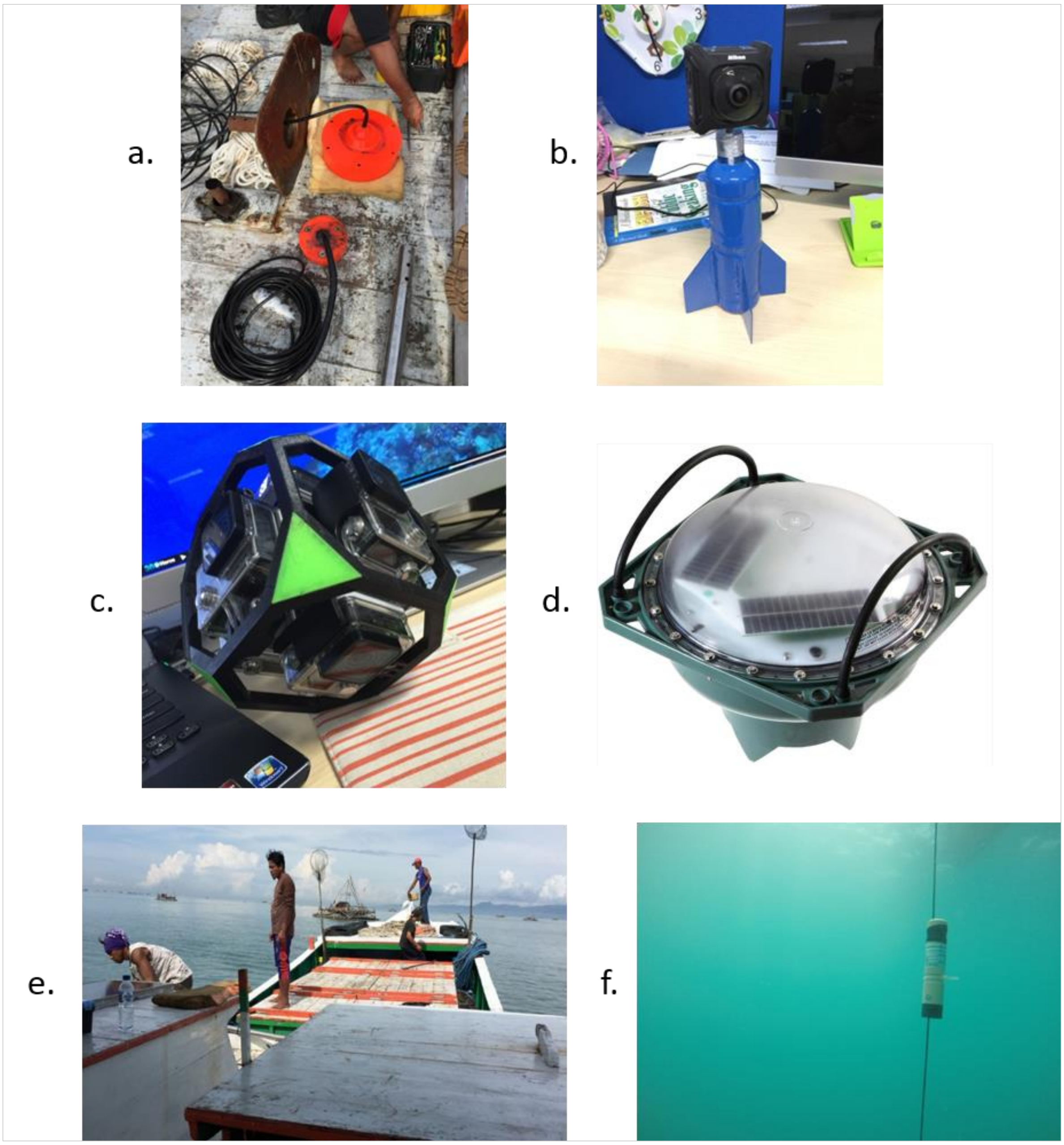

Figure 8.2. Images to illustrate the types of equipment used in this study: (a) echo sounder transducer and receiver units, (b) Nikon Key Mission 360º, (c) Go Pro 360 º set-up, (d) M4i buoy, (e) one of the handline/troll-line vessels used for the surveys, and (f) a CTD mini-logger.

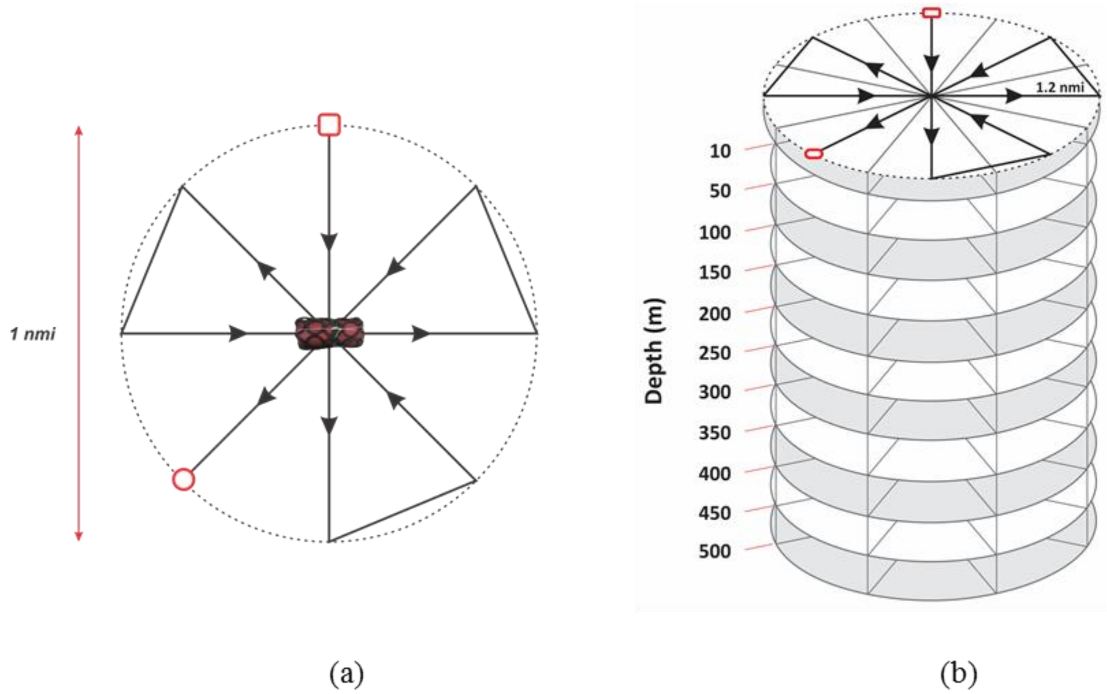

Figure 8.3. (a) Diagram illustrating the survey patterns used during acoustic surveys around FADs; (b) Stratification of survey area. (Modified from Josse et al. 1999).

S_A values corresponding to fish density around FADs were observed based on vertical (depth) and horizontal (distance from FAD) strata. Fish aggregations were not characterized by shape and assemblages criteria. Ground truth validation was only possible down to 30 m depth using GoPro 360° or Nikon Key Mission 360°. Where fish aggregations were detected the GoPro 360° or Nikon Key Mission 360° were set with consideration of the current direction and practical condition of wire. Environment data were collected using CTD (*mini logger*).

Data Analysis

Raw acoustic backscatter data were post-processed using the Large Scale Survey System (LSSS) software. Only 38-kHz data were used for extracting the SA values for all surveys. The S_A values of echo integration were observed at 0.1 nmi intervals. Backscattered hydro-acoustic energy was converted to fish density using the target strength (TS) – fish length function (MacLennan and Simmonds 2013):

$$TS = 10.\log\left(\frac{\sigma}{4\pi}\right) = 20\log L - b\ (dB)$$

where *b* = constant parameter of TS, σ = backscattering cross section, and *L* = fish length (cm). 360° videos were stitched by *Autopano* software to get the complete 6 sided or 360-degree view.

8.3 Results and Discussion

Acoustic trials

A total of 88 fish aggregations were observed, ranging between 0.71 - 42881.66 m^2/nmi^2. Spatial distribution of fish aggregations varied from less than 0.1 to 1.4 nmi from the FAD, while the aggregations were distributed in the depth range of 10 to 245 m. The mean value of S_A in every depth stratum and distance stratum is shown in Table 8.3.

Table 8.3. Mean S_A value per depth and distance from FAD strata.

Depth strata (m)	Distance from FAD (nautical mile)														
	0.0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 1.0	1.0 - 1.1	1.1 - 1.2	1.2 - 1.3	1.3- 1.4	1.4 - 1.5
10 - 50	3018.6	5780.4	6054.3				3204.1	2022	2209.4			2324.2	1217		
50 - 100	2726.2	2646.3			840		12783.7					652			472.4
100 - 150		48.9					3501.6								
150 - 200	3.5														
200 - 250	38.03	10.38													

The density of fish aggregations by depth and distance detected in the surveys are could be found in Figure 8.4. *Target Strength (TS)* values were recorded for every fish aggregation; the lowest TS value was -59.6 and the highest value was -31.44 dB. Due to the high variability of TS values it was not possible to define the fish size without length-weight data, except if we assume a homogeneous distribution of the fish species around the FADs.

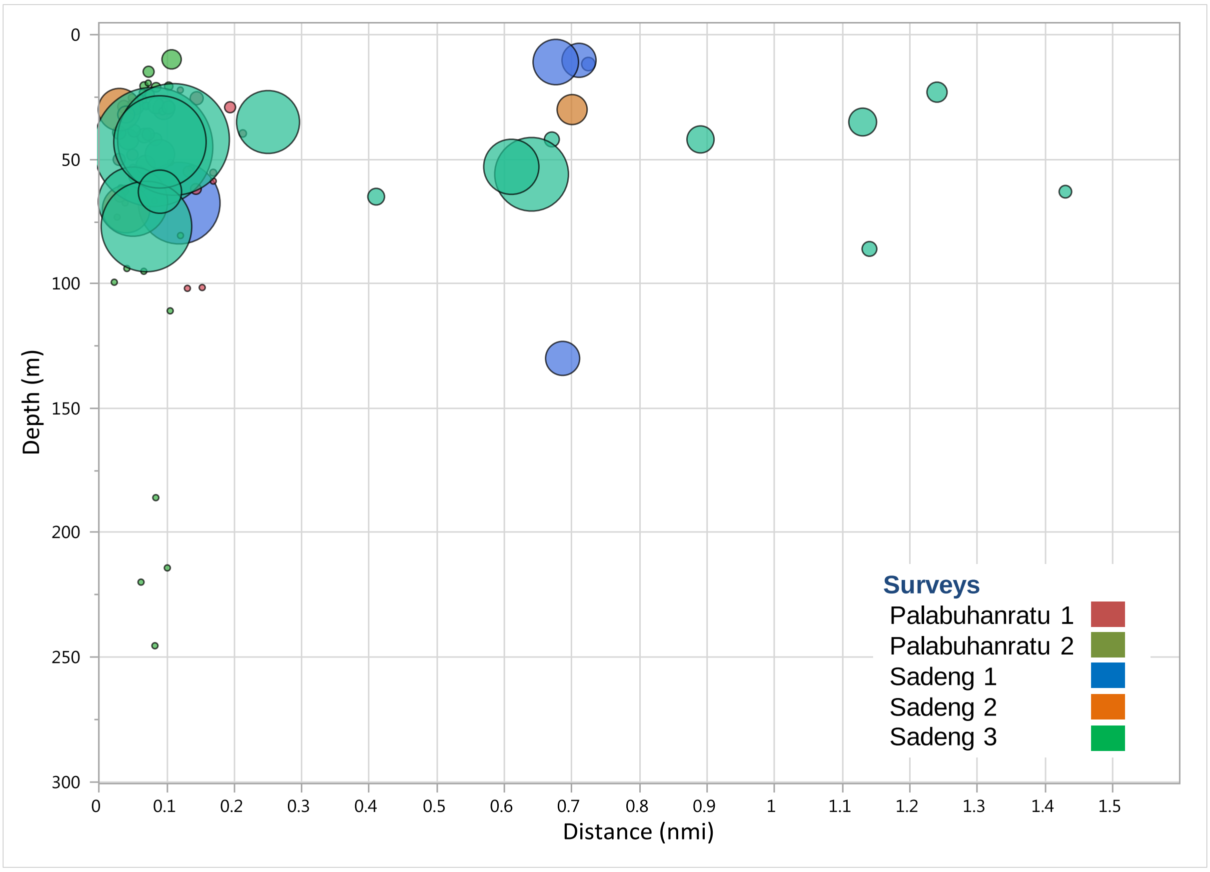

Figure 8.4. All aggregations of fish per depth and distance strata from the FADs.

Generalized linear models (GLMs) analysis showed that the variables of distance, depth, latitude, and longitude appear to be significant in the model and the full model (distance + depth + latitude + longitude) gives the lowest AIC value. The highest density of fish was found less than 0.2 nmi from the FADs and in a relative shallow layer of less than 100 m depth. A high number of fish aggregations were also found between 0.6 - 0.7 nmi from FADs in less than 100 m depth. Details of the fish aggregations of each survey are illustrated in Figure 8.5 and the distribution of area backscatter values as proportional to densities in each survey are provided in Table 8.4.

Table 8.4. The distribution of area backscatter values as proportional to densities in each survey.

Surveys	S_A value range	Mean S_A value	Aggregation number	Aggregation distance from FAD (nmi)
S1	542.34 - 20149.84	6784.47	5	0.6 - 0.8
S2	859.55 - 6827.66	3957.19	4	0.03 - 0.7
S3	472.36 - 42881.66	11744.58	17	0.05 - 1.5
PR 1	38.92 - 1399.36	268.31	19	0.02 - 0.21
PR 2	0.71 -1271.50	341.92	43	0.02 - 0.12

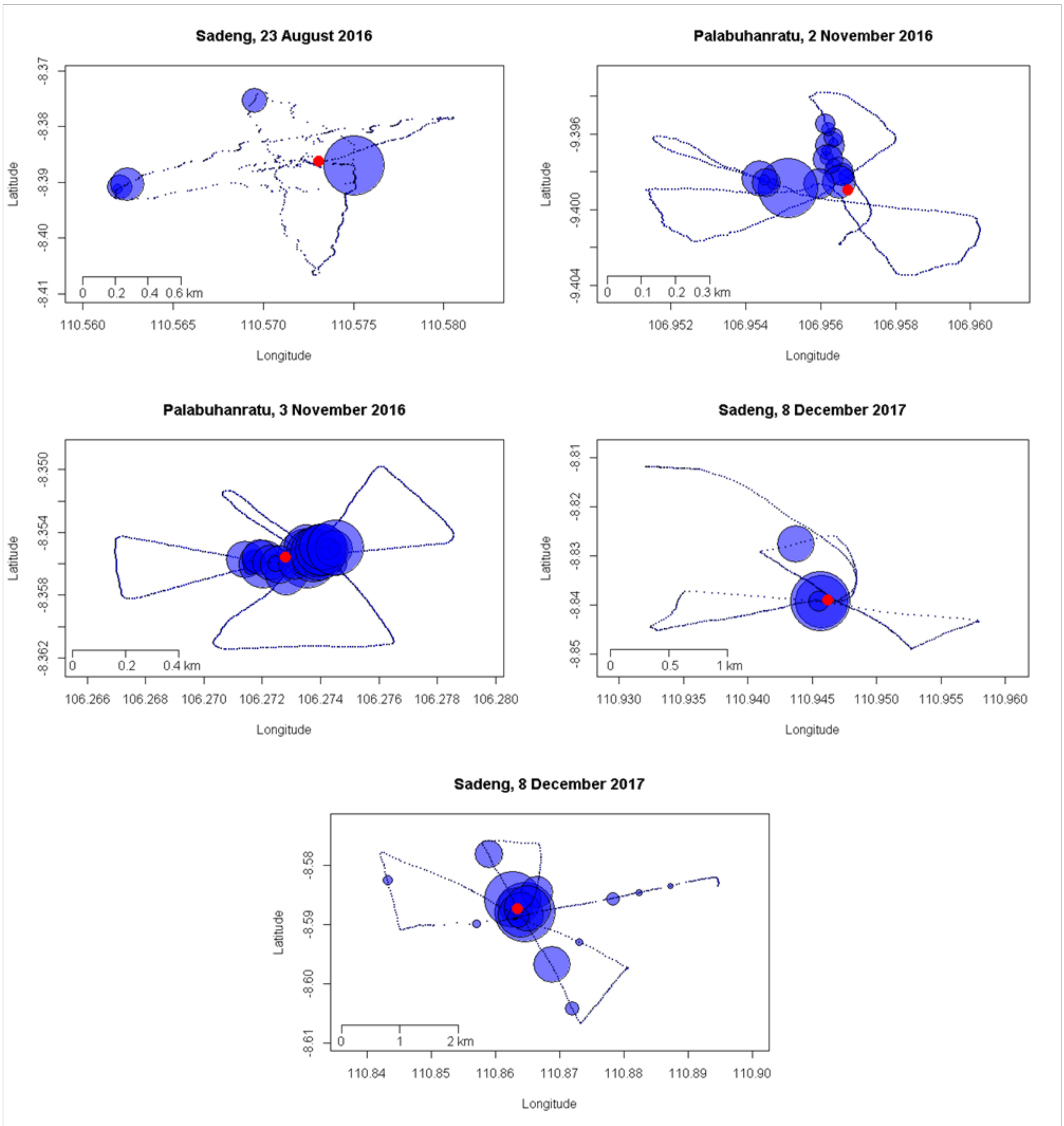

Figure 8.5. Acoustic tracks (blue lines), FADs position (red circles) and fish aggregations (blue-filled circles).

Temperature measurements recorded in the acoustic survey areas indicated the lowest temperature observed was during the Sadeng 1 survey on 23 August 2016 (southeast monsoon), while the other surveys had relatively similar temperature patterns (Figure). The thermocline layer in Sadeng 1 survey was shallower at around 75 m and at 27°C. On average, the thermocline layers for other surveys were deeper than 90 m with temperature at around 28°C. Figure 8.6 also shows that fish prefer to aggregate above and below the thermocline layer, however the highest density aggregations were found above the thermocline layer.

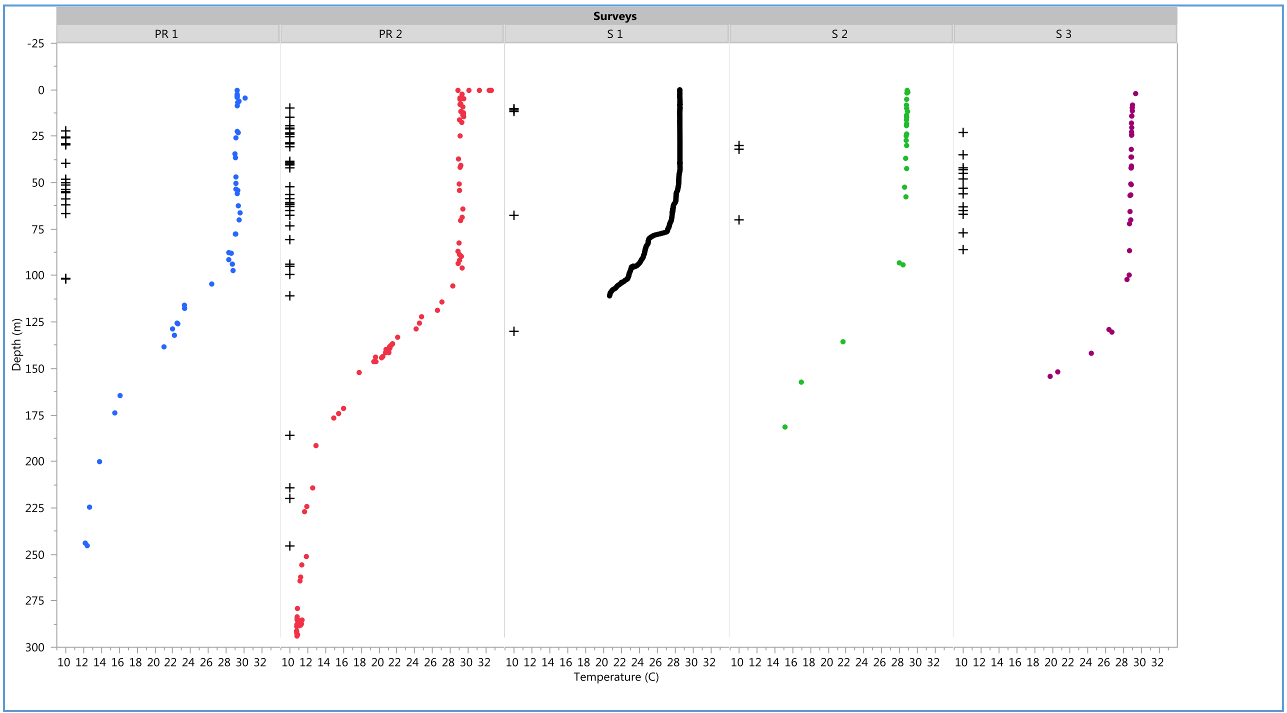

Figure 8.6. Temperature profile in surveys Sadeng 1 2016 (S1), Sadeng 2 2017 (S2), Sadeng 3 2017 (S3), Palabuhanratu 1 2016 (PR 1), dan Palabuhanratu 2 2016 (PR 2). The aggregations of fish by depth in each survey area are marked by "+".

Camera trials

Several species of fish were observed and able to be identified to species in the trials using 360° camera. The species included dolphin fish (*Coryphaena hippurus*), rainbow runner (*Elagatis bipinnulata*), *trigger fish*, scads, and *juvenile* yellowfin tuna (*Thunnus albacares*). Our trials of use of video camera for acoustic data verification showed there were depth limitations, where there is reliance on natural light. The estimate of this limit is around a maximum of 30 m depth, in best conditions. Also, the strong currents in open sea become a significant obstacle during the camera deployment. This was particularly true for the GoPro 360° video camera, where the camera frame rotated in the current as a result of the frame not being a streamlined and this made fish identification quite challenging. The Nikon KeyMission 360° had the advantage of its streamlined shape and it was possible to attach an additional wing to reduce rotations. However, the quality of video from the Nikon KeyMission 360° was poor by comparison to the clearer footage from the GoPro 360° (Figure 8.7). Another negative feature of the Nikon KeyMission 360° is that its underwater lens does not produce a full round field-of-view, with the edge impacted by a dark border (as can be seen in Figure 8.7 b).

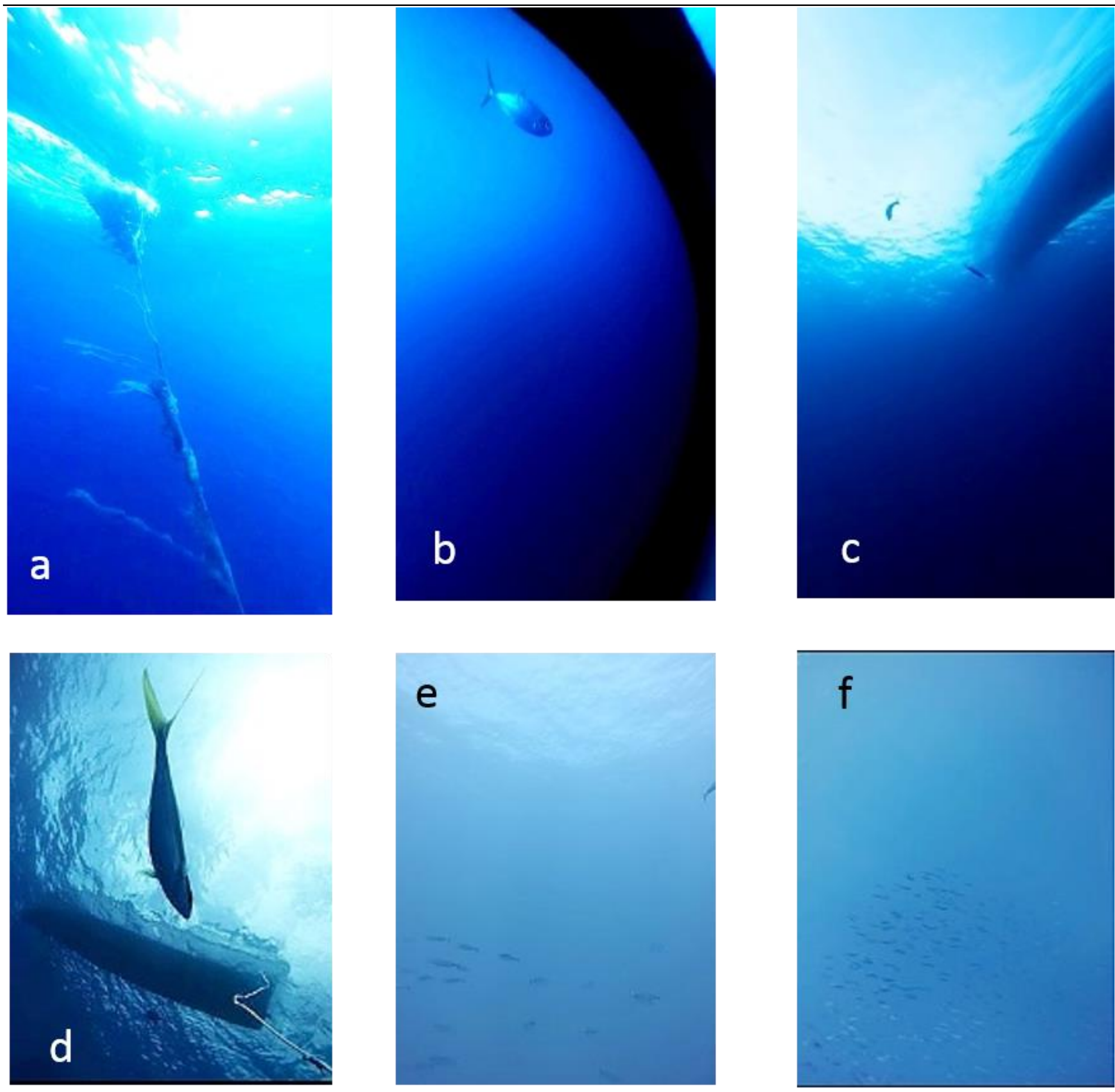

Figure 8.7. Images from video captured by cameras (a,b,c) Nikon KeyMission 360º and (d,e,f) GoPro 360º.

Weather conditions can affect the distribution of FADs in the ocean. The last acoustic survey in Sadeng was conducted during a tropical cyclone. Tropical cyclone "Dahlia" was a 1 – 2 Category cyclone which passed to the south of Java in a south-easterly path during 30 November – 1 December 2017. Based on the positional data before and after the cyclone, we are able to determine that one of FADs had moved approximately 10 nm in the southeast direction under the cyclone's influence.

8.4 Conclusions

Overall, these trials of acoustic and visual survey methods on the FADs were successful in that they demonstrated that:

- With the appropriate equipment, and with a research vessel or with good cooperation from fishing vessel owners, skippers and crew, it should be possible to conduct acoustic and visual assessment of fish aggregations around the FADs;
- More extensive research with acoustic and visual surveys around the Indonesian FADs is recommended to do species characterisations, fish biomass estimates of fish aggregations, examine species' spatial behaviours, residency times, and aggregation 'recovery rates' following fishing events by the various fishing gears. The results of such research would benefit in the development of improved management for the FAD-based fisheries;

- Achieving video of sufficient quality to use as validation of fish species detected in acoustic census will require overcoming the problems of camera stability under influence of the strong water currents commonly experienced in the areas where the anchored tuna FADs are deployed;
- The trials did provide opportunity for capacity building in skills and knowledge associated with the fish aggregation associated research, and this will aid in enabling further research in this area.

9. Overall study conclusions

- The tuna FAD situation in Indonesia is complex; perhaps the most complex of anywhere in the world. Multiple types of anchored FAD, multiple vessel types of various sizes and fishing gears, different forms of FAD ownership and operations, and high rates of FAD turn-over: a truly 'dynamic' FAD environment;
- The FADs are an important efficiency tool for both large-scale (purse-seine, some of the pole & line) and small-scale (smaller pole & line and hand-line/troll-line) fishers. Prohibiting use of the deepwater anchored FADs, or severely restricting their use, is likely to have largest impact to the small-scale fishers who have become heavily reliant on them. The productivity of free-school fishing, as an alternative to FAD-based fishing, for the small-scale vessels requires further study;
- The results of the project's enumeration study confirm observations from other monitoring programs (including the concurrent WPEA program and of MDPI) that juvenile YFT and BET comprise significant proportions of the catch of the gears fishing on Indonesian deepwater anchored FADs; HL/TL in particular;
- As expected, obtaining a good estimate of FAD numbers in Indonesian waters proved difficult in the current unregulated environment (i.e. no accurate registry of operational FADs). This was true for Indonesian waters as a whole but also for smaller regions (e.g. determining the number of FADs within an individual FMA);
- Although Indonesia has had FAD regulations in fisheries law since 1997, with multiple upgrades and additions to the regulations since then (most recent regulations are Peraturan Menteri KP No.26/PERMEN/2016 of 2016), to date these regulations have not achieved adequate implementation nor enforcement. A low level of understanding by the fisher community on how the laws are intended to operate and on the benefits that the laws will achieve for the fishers, through improved sustainability of the fisheries, have been key contributing factors to the lack of 'sign-on' and adherence to them;
- The FAD fisheries study provided opportunity for extending Indonesia's capacity for socio- and bio-economic assessments of fisheries, at a time when such capacity is increasingly in demand (e.g. in current and future tuna harvest strategy development, wider development of fisheries management plans for each FMA);
- The study also provided opportunity for participating scientists to explore methods of assessing FAD-based fishing operations, and to extend earlier research on the dynamics of fish aggregations on deepwater anchored FADs in Indonesian waters.

10. Recommendations

- With increasing recognition of the importance of including socio-economic impacts to fishing communities (in particular impacts to small-scale fishers) in development of new management measures, the capacity development of Indonesian scientists in socio-/bio-economic assessment skills should continue and, if possible, be expanded;
- Similarly, there is need for an ongoing capacity development[16] for Indonesia's fisheries scientists and relevant staff within the Directorates of MMAF in all aspects of developing and implementing harvest strategies, including operating models, Management Strategy Evaluation, and identifying realistic and practical management measures for the complex Indonesian fisheries;

[16] *Also being addressed by the follow-on ACIAR Project FIS/2016/116.*

- Further research on the FAD fisheries is required to determine 'realistic' FAD management options and the likely impacts of FAD-based management measures e.g. restrictions on FAD numbers by region, regulated FAD sharing within and between gear-types, seasonal closures (as has been operating for PNA countries in the Pacific Ocean);
- There is a need to address the question of whether free school (i.e. FAD-free) tuna fishing by 'One by One fishing gears' (pole & line and hand-line/troll-line) is likely to achieve the operational efficiencies, sufficient catch and sustainable incomes for the communities and industries associated with those gears;
- In association with the above, if a move away from FAD-based fishing were to be pursued, capacity development for fishers in free-school fishing techniques is most likely required;
- To extend the preliminary acoustics and visual census research done in this project, research on fish aggregation behaviours on the Indonesian tuna FADs is required to better understand the dynamics of deepwater FAD fishing, and catch success. The outcomes of such may prove to be different to the findings of studies elsewhere. As example, if considering FAD-sharing as a management measure, it is important to determine recovery times following fishing events by the different gears;
- Continued and, ideally, increased participation by vessel owners, skippers and fishers associations in the discussions around new management measures to ensure their 'sign-on';
- Investigate community-based enforcement options to supplement government-based enforcement or even to be the primary method of enforcement/regulation;
- Development of improved designs to achieve FADs that are environmentally friendly, able to comply with fisheries regulations, while maintaining affordability for fishing communities. This could include development of FAD constructions that are more robust and which are less susceptible to loss;
- Research is required to develop effective, affordable methods of FAD detection and monitoring (e.g. new satellite technologies, radar) to enable those enforcing the regulations the ability to monitor FAD numbers and locations in their region;
- With the ongoing 'roll-out' of logbooks by DGCF to the tuna fishing industry, there should be inclusion of information gathering on all aspects of FAD use and catch success;
- In addressing the ever increasing number of deepwater anchored FADs in Indonesian waters, and the little to no current adherence to the regulation of a minimum inter-FAD distance of 10 nmi, fishers need to be better informed of the benefits that will accrue from not having FADs at high density.

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Appendices

Appendix 1: Data recording forms for the enumeration program **99 – 102**

Appendix 2: FAD Fisheries Database (Database Perikanan Rumpon) **103 - 106**

Appendix 3: Questionnaire for socio-/bio-economics surveys **107 - 111**

Appendix 1 Data recording forms for enumeration program

Landings form for purse-seine vessels – page 1 (note: enumerators would normally use the Bahasa Indonesia version).

v3. Sept 2013 ACIAR PROJECT FIS/2009/059 - LANDINGS FORM - PURSE SEINE			
SAMPLING DATE: __ / __ / 201__ TIME:	RECORDER:	LOCATION:	
LANDINGS FORM REFERENCE NO.: ___ - dd / mm / 201y - ___			PAGE __ OF __

VESSEL AND TRIP DETAILS			
VESSEL NAME:		VESSEL REG. :	START DATE: _/_ / 201_
SKIPPER'S NAME:		TOTAL CREW:	FROM PORT:
NAME OF VESSEL OWNER/COMPANY:			RETURN DATE: _/_ / 201_
VESSEL LENGTH: ______ M	VESSEL WEIGHT: __ GT	VESSEL MADE FROM WOOD or FIBER:	TOTAL HOLDS:
MAIN ENGINE: __ HP AUX. ENGINE: __ HP	GPS: Y / N TYPE:	SUPPORT VESSEL: Y / N	SIZE OF SUPPORT VESSEL: __ / __ (M / GT)
FREEZER: Y / N	FREEZER CAPACITY: _____ TON / KG		CAPACITY OF HOLDS (TOTAL): ______ TON / KG

FISHING GEAR AND OPERATIONS		
DIMENSIONS OF NET LENGTH OF FLOAT LINE: ___ M	DEPTH OF NET: ___ M	MESH SIZE: ______ CM
NET MATERIAL:	TOTAL NUMBER SETS:	MAX DEPTH OF FISHING: ______ M
TOTAL FISHING DAYS:	TOTAL FADs VISITED:	TOTAL FADs SUCCESSFUL:
CATCH AREA: GRID#	FAD TYPE(S): PONTOON BAMBOO BAMBOO + BUNGALOW OTHER:	
TIME(S) OF FISHING: SUNRISE MORNING LATE MORN-EARLY AFTERNOON LATE AFTERNOON SUNSET NIGHT		
AVERAGE SEA CONDITIONS DURING FISHING: CALM SLIGHT MODERATE ROUGH VERY ROUGH		
PROBLEMS EXPERIENCED DURING TRIP: ENGINE DECK EQUIP. WHEEL-HOUSE EQUIP. INJURY/ILLNESS OTHER		

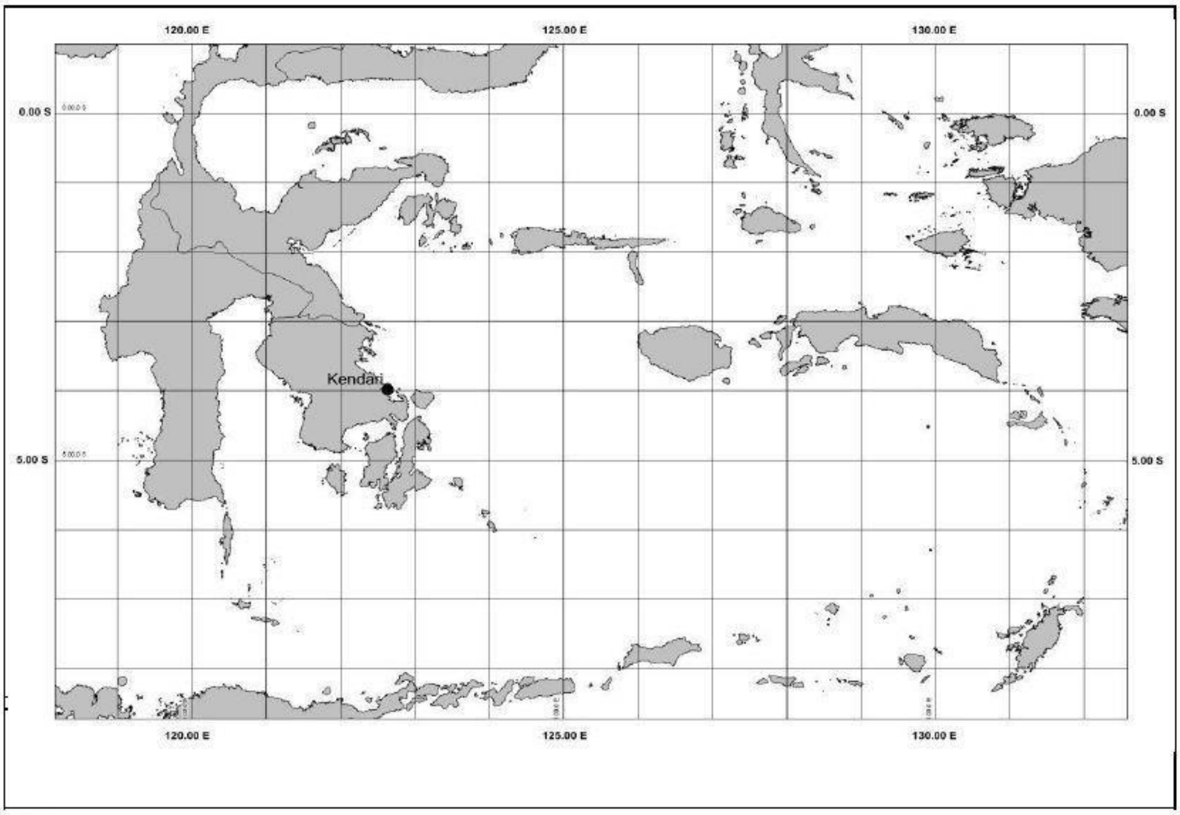
CATCH SUMMARY*

TYPE OF FISH	FAO CODE	TOTAL KG	NUMBER OF FISH	METHOD STORAGE/HANDLING		
				FRESH	FROZEN	NOT KEPT
SKIPJACK (*Katsuwonus pelamis*)	SKJ					
YELLOWFIN TUNA (*Thunnus albacares*)	YET					
BIGEYE TUNA (*Thunnus obesus*)	BET					
DOLPHIN FISH (*Coryphaena hippurus*)	DOL					
RAINBOW RUNNER (*Elagatis bipinnulata*)	RRU					
EAST. LITTLE TUNA (*Euthynnus affinis*)	KAW					
BULLET & FRIGATE MACKEREL (*Auxis rochei & A. thazard*)	FRZ					
OTHER:						
TOTAL CATCH: ______________ TON / KG						

*INFORMATION SOURCE(S): SKIPPER FISHING MASTER AGENT COMPANY OTHER:

INFORMATION RECORDED ON THIS FORM WILL ONLY BE USED FOR RESEARCH PURPOSES AND ALL WILL BE KEPT CONFIDENTIAL.

Landings form for purse-seine vessels – page 2 (note: enumerators would normally use the Bahasa Indonesia version).



COMMENTS:

This page was similar for all gear types. The map was different for each of the 4 sampling ports. The enumerators would seek as best information as possible from the vessel skipper for catch location(s). Most often this would be a "X" in one or more of the 1 deg x 1 deg squares. The information was then entered into the FAD Fisheries Database (see Appendix 2) using grid numbers allocated to each 1 deg x 1 deg square.

Landings form for pole & line vessels – page 1 (note: enumerators would normally use the Bahasa Indonesia version).

v3. Sept 2013 ACIAR PROJECT FIS/2009/059 - LANDINGS FORM - POLE & LINE

SAMPLING DATE: __ / __ / 201__ TIME:	RECORDER:	LOCATION:	
LANDINGS FORM REFERENCE NO.: ___ - dd / mm / 201y - ___			PAGE ___ OF ___

VESSEL AND TRIP DETAILS

VESSEL NAME:		VESSEL REG. :	START DATE: _/ _ / 201_
NAME OF SKIPPER:		TOTAL CREW:	FROM PORT:
NAME OF VESSEL OWNER/COMPANY:			RETURN DATE: _/ _ / 201_
VESSEL LENGTH: _______ M	VESSEL WEIGHT: __ GT	VESSEL MADE FROM WOOD or FIBER:	TOTAL HOLDS:
MAIN ENGINE: ___ HP AUX. ENGINE: ___ HP	GPS: Y / N TYPE:	BAIT CAPACITY: _____ BUCKETS	CAPACITY OF HOLDS (TOTAL): ______ TON / KG

FISHING GEAR AND OPERATIONS

NO. OF FISHERS (AV.):	NO. OF POLES CARRIED: POLE CONSTRUCTION:	SIZE / NO. OF HOOKS:
BAIT: SELF CAUGHT OR FROM LIFT-NET VESSELS	AREA OF BAIT CAPTURE / PURCHASE : GRID#	AMOUNT OF BAIT: _____ BUCKETS
TOTAL FISHING DAYS:	TOTAL FADs VISITED:	TOTAL FADs SUCCESSFUL:
CATCH AREA: GRID#	FAD TYPE(S): PONTOON BAMBOO BAMBOO + BUNGALOW OTHER:	

TIME(S) OF FISHING: SUNRISE MORNING LATE MORN-EARLY AFTERNOON LATE AFTERNOON SUNSET NIGHT

AVERAGE SEA CONDITIONS DURING FISHING: CALM SLIGHT MODERATE ROUGH VERY ROUGH

PROBLEMS EXPERIENCED DURING TRIP: ENGINE DECK EQUIP. WHEEL-HOUSE EQUIP. INJURY/ILLNESS OTHER

CATCH SUMMARY*

TYPE OF FISH	FAO CODE	TOTAL KG	NUMBER OF FISH	METHOD STORAGE/HANDLING		
				FRESH	FROZEN	NOT KEPT
SKIPJACK *(Katsuwonus pelamis)*	SKJ					
YELLOWFIN TUNA *(Thunnus albacares)*	YFT					
BIGEYE TUNA *(Thunnus obesus)*	BET					
DOLPHIN FISH *(Coryphaena hippurus)*	DOL					
RAINBOW RUNNER *(Elagatis bipinnulata)*	RRU					
EAST. LITTLE TUNA *(Euthynnus affinis)*	KAW					
BULLET & FRIGATE MACKEREL *(Auxis rochei & A. thazard)*	FRZ					
OTHER:						
TOTAL CATCH: ______________ TON / KG						

*INFORMATION SOURCE(S): SKIPPER FISHING MASTER AGENT COMPANY OTHER:

INFORMATION RECORDED ON THIS FORM WILL ONLY BE USED FOR RESEARCH PURPOSES AND ALL WILL BE KEPT CONFIDENTIAL.

Landings form for hand-line/troll-line vessels – page 1 (note: enumerators would normally use the Bahasa Indonesia version).

v3.Sept 2013 ACIAR PROJECT FIS/2009/059 - LANDINGS FORM - TROLL-LINE / HAND-LINE			
SAMPLING DATE: __ / __ / 201__ TIME:		RECORDER:	LOCATION:
LANDING REFERENCE NO.: ___ - dd / mm / 201y - ___			PAGE ___ OF ___
VESSEL AND TRIP DETAILS			
VESSEL NAME:		VESSEL REG. :	START DATE: _/_ / 201_
NAME OF SKIPPER:		TOTAL CREW:	FROM PORT:
NAME OF VESSEL OWNER/COMPANY:		VESSEL MADE FROM WOOD or FIBER:	RETURN DATE: _/_ / 201_
VESSEL LENGTH: ______ M	VESSEL WEIGHT: __ GT	CARRYING SMALL CRAFT: Y / N NO. SMALL CRAFT: ____	TOTAL HOLDS:
MAIN ENGINE: __ HP AUX. ENGINE: __ HP	GPS: Y / N TYPE:	SIZE SMALL CRAFT: ____ M WITH ENGINE: Y / N	CAPACITY OF HOLDS (TOTAL): ______ TON / KG
FISHING GEAR AND OPERATIONS			
FISHING GEAR (TROLL-LINE AND HAND-LINE) CARRIED:			
TOTAL FISHING DAYS:	TOTAL FADs VISITED:		TOTAL FADs SUCCESSFUL:
CATCH AREA: GRID#	FAD TYPE(S): PONTOON BAMBOO BAMBOO + BUNGALOW OTHER:		
TIME(S) OF FISHING: SUNRISE MORNING LATE MORN-EARLY AFTERNOON LATE AFTERNOON SUNSET NIGHT			
AVERAGE SEA CONDITIONS DURING FISHING: CALM SLIGHT MODERATE ROUGH VERY ROUGH			
PROBLEMS EXPERIENCED DURING TRIP: ENGINE DECK EQUIP. WHEEL-HOUSE EQUIP. INJURY/ILLNESS OTHER			

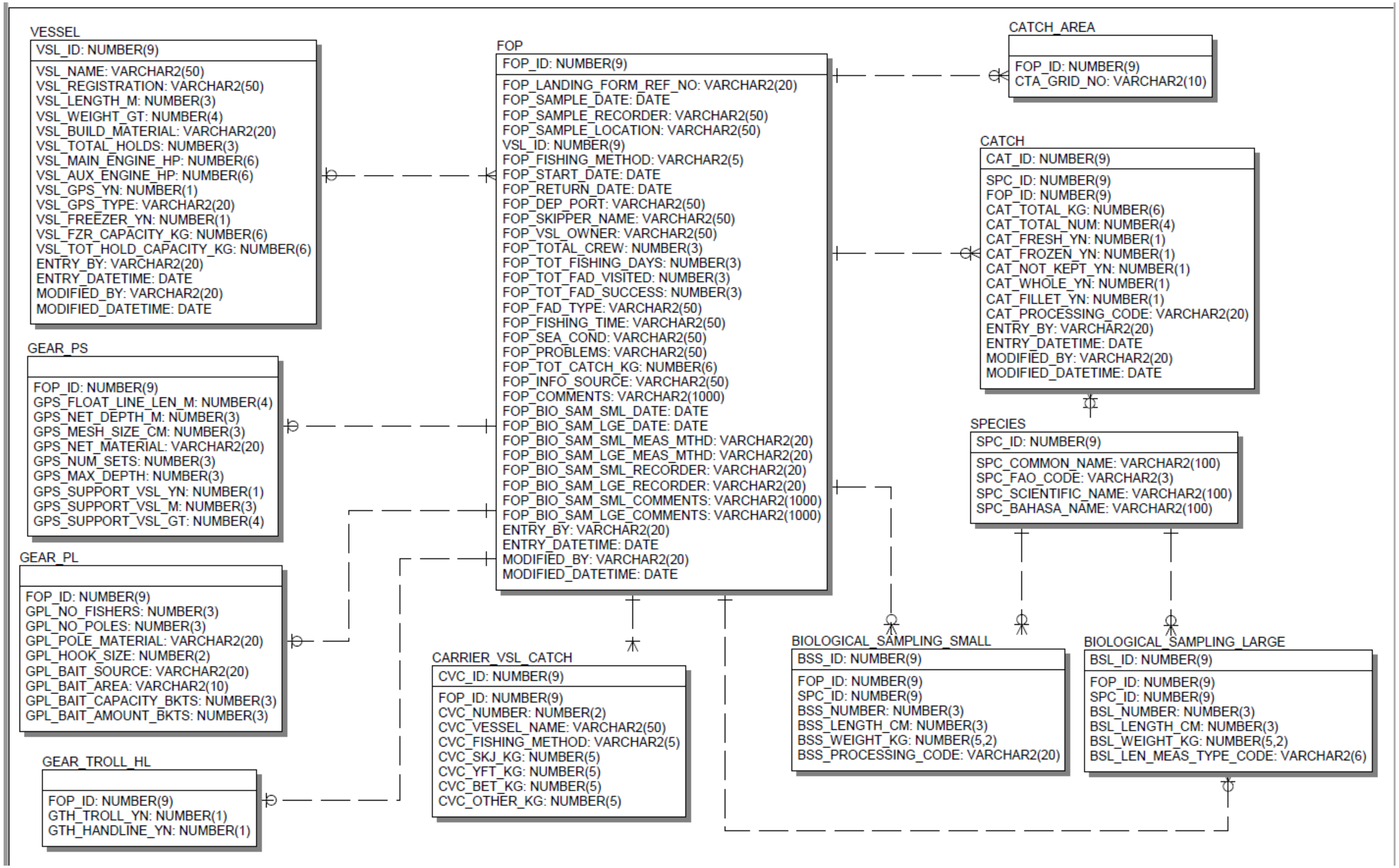
CATCH SUMMARY*				
TYPE OF FISH	FAO CODE	TOTAL KG	NUMBER OF FISH	CODE STORAGE / HANDLING: S, B, U, F, TS
SKIPJACK (*Katsuwonus pelamis*)	SKJ			
YELLOWFIN (*Thunnus albacares*) - *SMALL (BY TROLL)*	YFT			
BIGEYE (*Thunnus obesus*) - *SMALL (BY TROLL)*	BET			
YELLOWFIN (*Thunnus albacares*) - *LARGE (BY H-LINE)*	YFT			
BIGEYE (*Thunnus obesus*) - *LARGE (BY H-LINE)*	BET			
BLACK MARLIN (*Makaira indica*)	BLM			
BLUE MARLIN (*Makaira nigricans*)	BUM			
STRIPED MARLIN (*Tetrapturus audax*)	MLS			
SWORDFISH (*Xiphias gladius*)	SWO			
SHARK (TYPE =)	SHK			
EAST. LITTLE TUNA (*Euthynnus affinis*)	KAW			
BULLET & FRIGATE MACKEREL (*Auxis rochei & A. thazard*)	FRZ			
DOLPHIN FISH (*Coryphaena hippurus*)	DOL			
RAINBOW RUNNER (*Elagatis bipinnulata*)	RRU			
OTHER:				
TOTAL CATCH: __________ TON / KG				

*INFORMATION SOURCE(S): SKIPPER FISHING MASTER AGENT COMPANY OTHER:

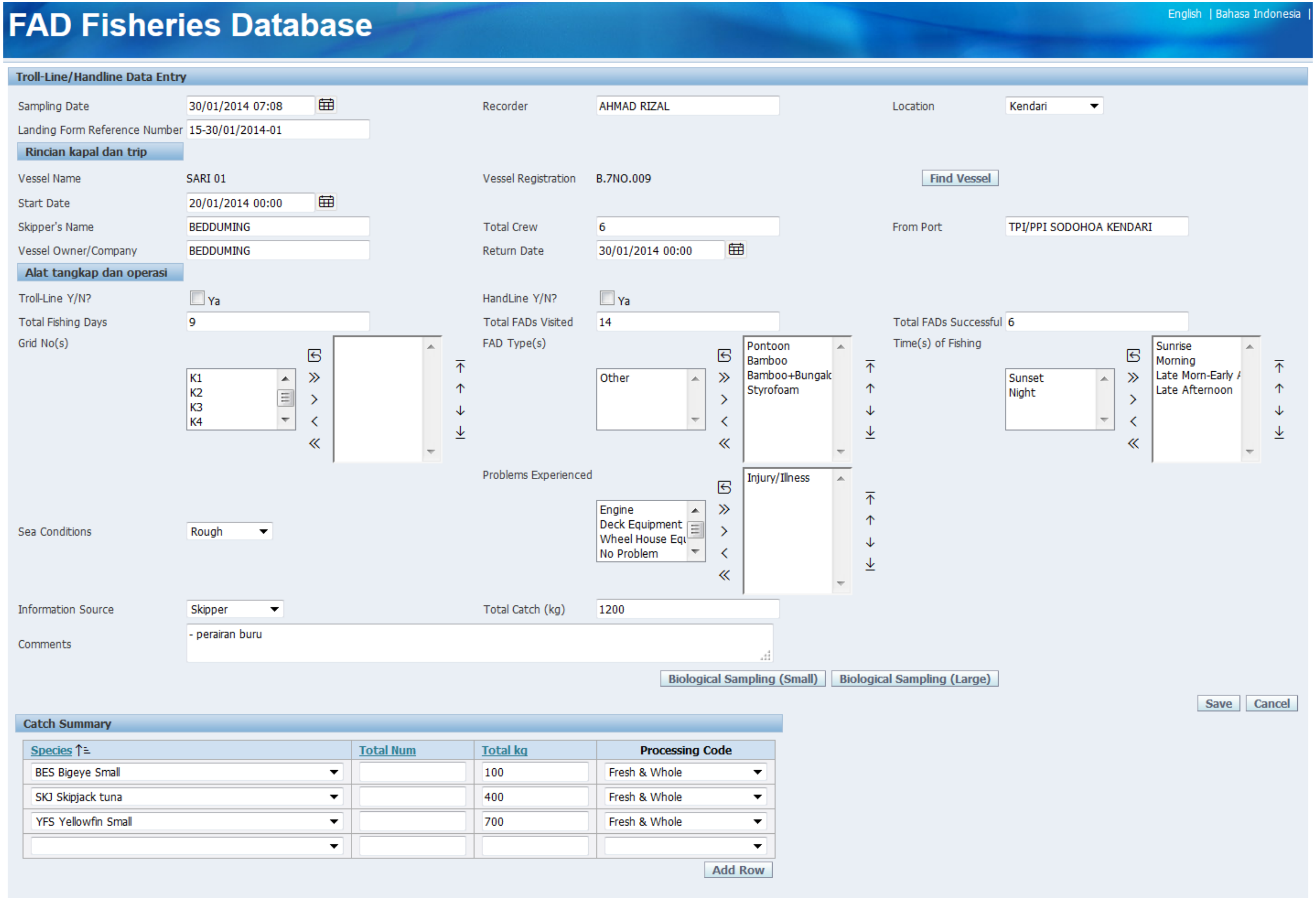
INFORMATION RECORDED ON THIS FORM WILL ONLY BE USED FOR RESEARCH PURPOSES AND ALL WILL BE KEPT CONFIDENTIAL.

Appendix 2. FAD Fisheries Database (Database Perikanan Rumpon)

Diagram to illustrate the components of the relational database:



A 'screen-grab' from the database, showing an example of data entries from a hand-line/troll-line vessel landings form. The data entry personnel would normally use the full Bahasa Indonesia version of the portal:



FAD Fisheries Database

English | Bahasa Indonesia |

Troll-Line/Handline Data Entry

Sampling Date 30/01/2014 07:08
Recorder AHMAD RIZAL
Location Kendari
Landing Form Reference Number 15-30/01/2014-01

Rincian kapal dan trip

Vessel Name SARI 01
Vessel Registration B.7NO.009
Find Vessel
Start Date 20/01/2014 00:00
Skipper's Name BEDDUMING
Total Crew 6
From Port TPI/PPI SODOHOA KENDARI
Vessel Owner/Company BEDDUMING
Return Date 30/01/2014 00:00

Alat tangkap dan operasi

Troll-Line Y/N? Ya
HandLine Y/N? Ya
Total Fishing Days 9
Total FADs Visited 14
Total FADs Successful 6
Grid No(s) K1 K2 K3 K4
FAD Type(s) Other | Pontoon Bamboo Bamboo+Bungalc Styrofoam
Time(s) of Fishing Sunset Night | Sunrise Morning Late Morn-Early A Late Afternoon
Problems Experienced Engine Deck Equipment Wheel House Equ No Problem | Injury/Illness
Sea Conditions Rough
Information Source Skipper
Total Catch (kg) 1200
Comments - perairan buru

Biological Sampling (Small) Biological Sampling (Large)

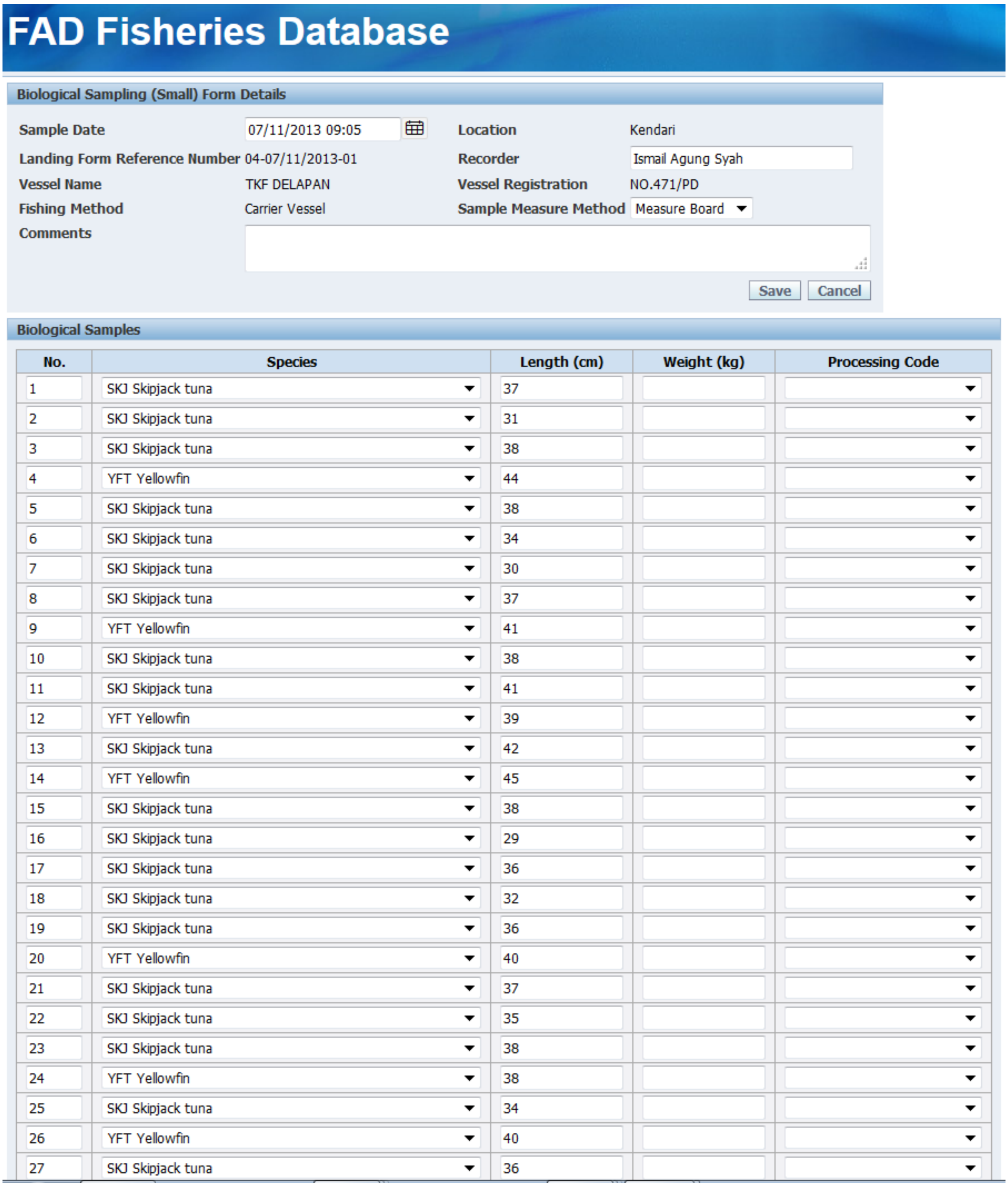
Save Cancel

Catch Summary

Species	Total Num	Total kg	Processing Code
BES Bigeye Small		100	Fresh & Whole
SKJ Skipjack tuna		400	Fresh & Whole
YFS Yellowfin Small		700	Fresh & Whole

Add Row

A 'screen-grab' from the database, showing an example of data entries for biological sampling (small fish) from a carrier vessel landing. The data entry personnel would normally use the full Bahasa Indonesia version of the portal:



FAD Fisheries Database

Biological Sampling (Small) Form Details

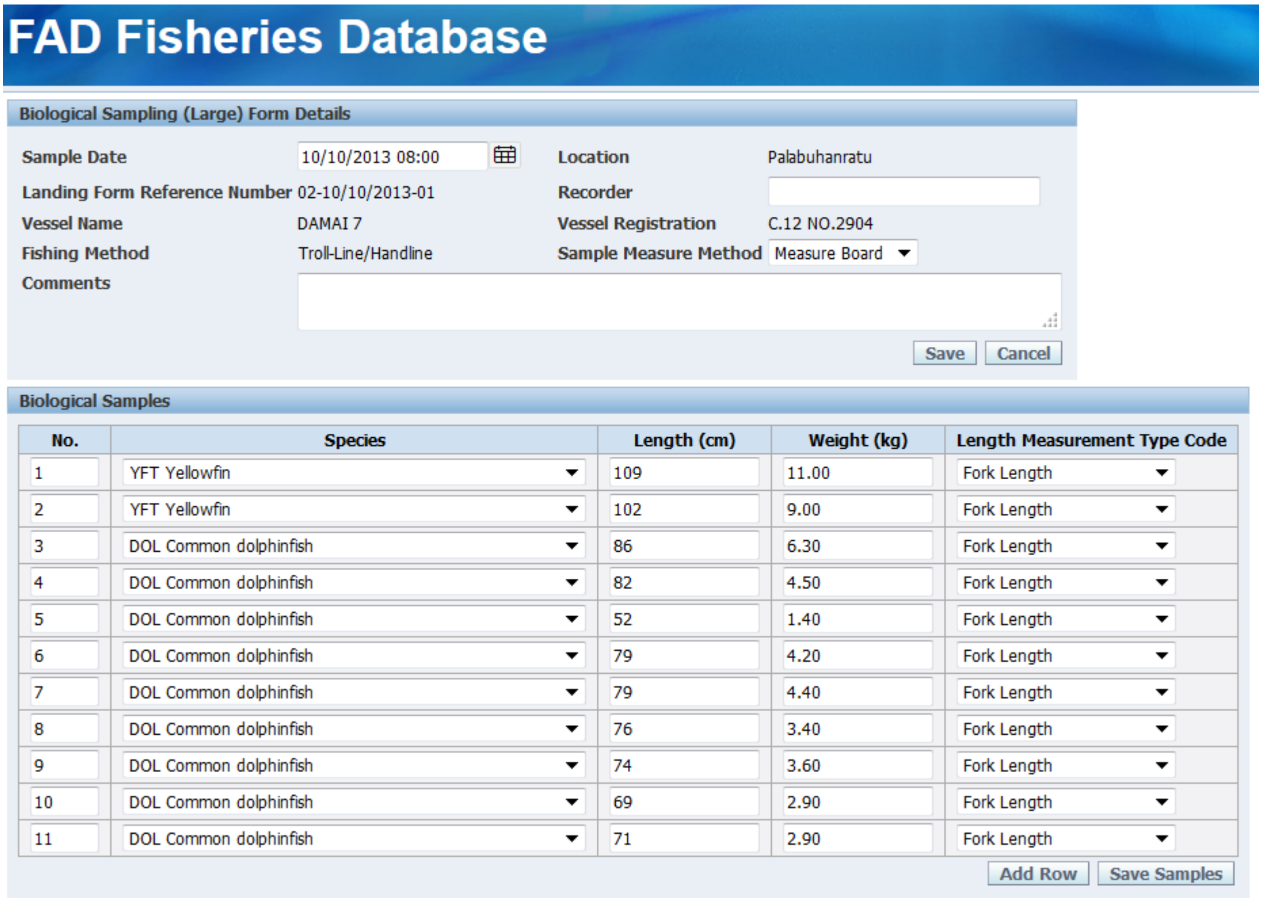
Sample Date	07/11/2013 09:05	Location	Kendari
Landing Form Reference Number	04-07/11/2013-01	Recorder	Ismail Agung Syah
Vessel Name	TKF DELAPAN	Vessel Registration	NO.471/PD
Fishing Method	Carrier Vessel	Sample Measure Method	Measure Board
Comments			

Save Cancel

Biological Samples

No.	Species	Length (cm)	Weight (kg)	Processing Code
1	SKJ Skipjack tuna	37		
2	SKJ Skipjack tuna	31		
3	SKJ Skipjack tuna	38		
4	YFT Yellowfin	44		
5	SKJ Skipjack tuna	38		
6	SKJ Skipjack tuna	34		
7	SKJ Skipjack tuna	30		
8	SKJ Skipjack tuna	37		
9	YFT Yellowfin	41		
10	SKJ Skipjack tuna	38		
11	SKJ Skipjack tuna	41		
12	YFT Yellowfin	39		
13	SKJ Skipjack tuna	42		
14	YFT Yellowfin	45		
15	SKJ Skipjack tuna	38		
16	SKJ Skipjack tuna	29		
17	SKJ Skipjack tuna	36		
18	SKJ Skipjack tuna	32		
19	SKJ Skipjack tuna	36		
20	YFT Yellowfin	40		
21	SKJ Skipjack tuna	37		
22	SKJ Skipjack tuna	35		
23	SKJ Skipjack tuna	38		
24	YFT Yellowfin	38		
25	SKJ Skipjack tuna	34		
26	YFT Yellowfin	40		
27	SKJ Skipjack tuna	36		

A 'screen-grab' from the database, showing an example of data entries for biological sampling (large fish) from a hand-line/troll-line vessel landing. The data entry personnel would normally use the full Bahasa Indonesia version of the portal:



FAD Fisheries Database

Biological Sampling (Large) Form Details

Sample Date	10/10/2013 08:00	Location	Palabuhanratu
Landing Form Reference Number	02-10/10/2013-01	Recorder	
Vessel Name	DAMAI 7	Vessel Registration	C.12 NO.2904
Fishing Method	Troll-Line/Handline	Sample Measure Method	Measure Board
Comments			

Save Cancel

Biological Samples

No.	Species	Length (cm)	Weight (kg)	Length Measurement Type Code
1	YFT Yellowfin	109	11.00	Fork Length
2	YFT Yellowfin	102	9.00	Fork Length
3	DOL Common dolphinfish	86	6.30	Fork Length
4	DOL Common dolphinfish	82	4.50	Fork Length
5	DOL Common dolphinfish	52	1.40	Fork Length
6	DOL Common dolphinfish	79	4.20	Fork Length
7	DOL Common dolphinfish	79	4.40	Fork Length
8	DOL Common dolphinfish	76	3.40	Fork Length
9	DOL Common dolphinfish	74	3.60	Fork Length
10	DOL Common dolphinfish	69	2.90	Fork Length
11	DOL Common dolphinfish	71	2.90	Fork Length

Add Row Save Samples

Appendix 3. Questionnaire for socio-/bio-economics surveys

Pertanyaan (Questions)	Catatan (Note)
Identifikasi dan Kepemilikan Kapal ***Vessel identification and ownership***	
Identitas kapal (Nama, Negara, Nomor Pendaftaran, Kode Panggil *Vessel identification (name, state registration number, radio callsign)*	Nama Kapal *Name of Vessel*
	Nomor Regristrasi *Registration Number*
	Kode Panggil Radio *Call Sign*
	Nomor SIPI *SIPI Number*
Identitas Pemilik (Nama, Alamat, Telepon, No KTP) *Owner(s) (name, address, telephone, ID number)*	Nama Pemilik Kapal *Owner Name*
	Alamat (No Telefon) *Address (Telephone):*
Tipe Kepemilikan (Pribadi, Kerjasama, Operator dari Pemilik) *Ownership Type*	Nama Kapten *Captain Name*
	Alamat (No Telefon) *Address (Telephone):*
Pelabuhan Asal *Port of registry*	
Pelabuhan Pendaratan *Port of Landing*	
Seperti apakah jalur pemasaran hasil tangkapan dari kapal saudara (semua dijual di TPI, ke perusahaan, ke perusahaan koperasi, dijual kepada pengepul/pengumpul yang kemudian menjual kembali, dll What are the normal market pathways for catches from your vessel(s) - all sold through local TPI at landing place, sold directly to company, sold directly to company as part of mitra kolaborasi system, sold to middleman who then sells onto other companies/buyers etc.?	
Apa yang terjadi dengan hasil tangkapan selain tuna? Dijual di pasar lokal? Dan kepada siapa? What happens to the bycatch species from your vessel(s)? – all sold locally? And to who?	
Seberapa sering anda memasang rumpon dan berapa kali anda mengganti attraktor atau bagian dari rumpon yang rusak How often do you install new FADs and how often do you replace	

the under-surface attractor material on existing FADs?	
Apakah anda melakukan pengelolaan rumpon bersama dengan group atau perusahaan lain Are you in a FAD sharing arrangement with other companies/vessels?	
Jika iya, bagaimana pengaturan dalam operasi bersama dengan perusahaan tersebut If so, how does that arrangement operate?	
Apakah ada mekanisme rolling dari pengawasan rumpon untuk menghindari perusakan dan pemanfaatan dari rumpon Do you use ‘rolling system’ for your FADs to make sure they are guarded from use/abuse by other vessels?	

Deskripsi Kapal dan alat Tangkap *Description of vessel and equipment*	
Tipe Kapal (Berdasarkan Alat Tangkap) *Type of vessel (principal gear)*	
Tahun Pembuatan *Year of construction*	Tahun Pembuatan *Year of Built*
	Tahun Pembelian *Year of Purchase*
Dimensi Kapal: Dimension: Panjang, Lebar, Dalam (m) *Length, Breadth, Depth (m)*	Panjang/LOA=
	Lebar/B=
	Dalam/D=
Total GT/*Gross tonnage*	GT=
Bahan Material Kapal *Hull construction material*	(kayu, fiberglass, besi):
Jumlah dan Kapasitas Palka *Hold capacity*	Jumlah dan Kapasitas Palka Ikan: (buah) (ton) *Total Number and Fish Hold/Box Capacity:*
	Bahan material Palka (kayu, fiberglass, besi): *Fish hold construction material*
	Kapasitas Fasilitas Pembekuan/Es: *Capacity*
	Dimensi Palka: *Fish Hold Dimension:*
	Panjang/*Length* (m):
	Lebar/*Width* (m):
	Dalam/*Depth* (m)
	Kapasitas/*Capacity*: (ton):

Deskripsi Mesin (Merk, umur, kekuatan mesin, jenis bahan bakar) *Engine(s) descriptors (brand, age, horsepower, fuel type)*	Mesin Utama: *Main Engine*
	Jenis Mesin (Marine/ Mesin Mobil (Truk)/ Lain) *Engine Type (Marine/Truck or Automotive*
	Merk/*brand:*
	Umur/*age:*
	Kapasitas Mesin; HP/PK (Tenaga Kuda/Horsepower): *Engine Capacity*
	Jenis Bahan Bakar *(Type of Fuel):*
	Mesin Pembantu/Tambahan: *Auxilary Engine*
	Merk: *Brand*
	Umur: *Age*
	HP/PK (Tenaga Kuda): *Horse Power*
	Jenis Bahan Bakar: *Type of Fuel*

Perawatan/*Docking Maintenances*	
Bodi Kapal *Hull*	Docking Tahunan: Biaya: Rp. *Annual Docking* *Cost*
	Docking Besar (4 tahunan): Biaya: Rp. *Annual Docking* *Cost*
Mesin Utama (Suku cadang dan Biaya Bengkel) *Main Enggine Maintenances*	Perawatan Tahunan : Biaya Total: Rp. *Annual Maintenances* *Total Cost:*
	Jumlah Perbaikan dalam satu tahun: *Number of repairs in a year*
	Biaya Perbaikan Tahunan: *Cost of repairs*
	Bongkar Mesin/Perbaikan Besar/*Overhau*l:
Mesin Tambahan (Suku cadang dan Biaya Bengkel) *Auxiliary Engine (spare part and labor)*	Perawatan Tahunan : Biaya Total: Rp. *Annual Maintenances* *Total Cost:*
	Jumlah Perbaikan dalam satu tahun: *Number of repairs in a year*
	Biaya Perbaikan Tahunan: *Cost of repairs*
	Bongkar Mesin/Perbaikan Besar/*Overhaul*:
Variables:	
Jumlah ABK *Number of Crew*	
Tanggal Berangkat *Departure Date*	
Tanggal Pulang *Date of return*	
Daerah Penangkapan *Fishing Ground (Grid Number)*	
Nama Pencatat *Recorder Name*	
Tanggal Sampling *Sampling Date*	

Logistik/*Logistic*:	
Jumlah Bahan Bakar *(Fuel)*	
Pelumas *(Lubricant)*	
Suku Cadang/*Sparepart*	
Kebutuhan Mesin Pendingin *Refrigerantion system needs (freon,etc.)*	

Alat Tangkap *Fishing Gear:*			
Jenis Alat Tangkap: *Type*			
Umur/Masa Pemakaian: *Lifetime* (saat semua bagian alat tangkap sudah terganti)			
Alat bantu penangkapan *Fishing Support Devices*	Mekanik/*Mechanical:*		
	Electronic		
Alat Tangkap *Fishing gear*			
	Umur/Masa Pemakaian: *Lifetime*		
	Pole:	*Lines*	
	Umur *lifetime*	Umur pemakaian	
	Jaring/*net:*	Tali/*rope*:	Pemberat/*singker*
	Umur	Umur	Umur
Jumlah rumpon total *Number of FAD*			
Rumpon FAD	Jumlah Daun Kelapa: *Coconut leaf number*	harga *price/cost*	
	Panjang Tali Rumpon *Rope*	harga *price/cost*	
	Ponton atau Rakit *Ponton or Raft*	harga *price/cost*	
	Wire *Wire*	harga *price/cost*	
	Swivel *Swivel*	harga *price/cost*	
Alat-alat untuk menangani hasil tangkapan *Fish Handling equipment/fasilities on board*			

POLE AND LINE, Handline, Troll line	
Jumlah Rumpon yang dikunjungi/ditangkap *Number of FAD Visited*	
Tipe Rumpon *FAD Type* (Ponton/Bambu/Combination)	
Kedalaman Perairan *water depth*	

Pemilik Rumpon *FAD Owner* *(Private/government)*		
Jumlah ABK *number of crew*		
Jumlah Mata Pancing Yang dibawa: *Total hooks*		
Asal Umpan (Bagan/Tangkap Sendiri) *Bait sources (Purchase/own catch)*		
Jumlah Umpan yang dibawa (Bucket) *Number of Bait*		Harga/price
Lokasi Bagan *(Bait Area)*		Jarak dan tenaga kerja *Distance and labor*
Jumlah PALKA / Kapasitas *Number of fish hold*		
Jumlah Es yang dibawa (Block) *Number of Ice block*		Harga/price
Bentuk (Blok atau serutan) *Ice form (Block or crunch)*		Harga/price
Biaya Perbaikan Pancing, Per Trip/bulanan/Tahunan *Fishing gear repairs cost*		