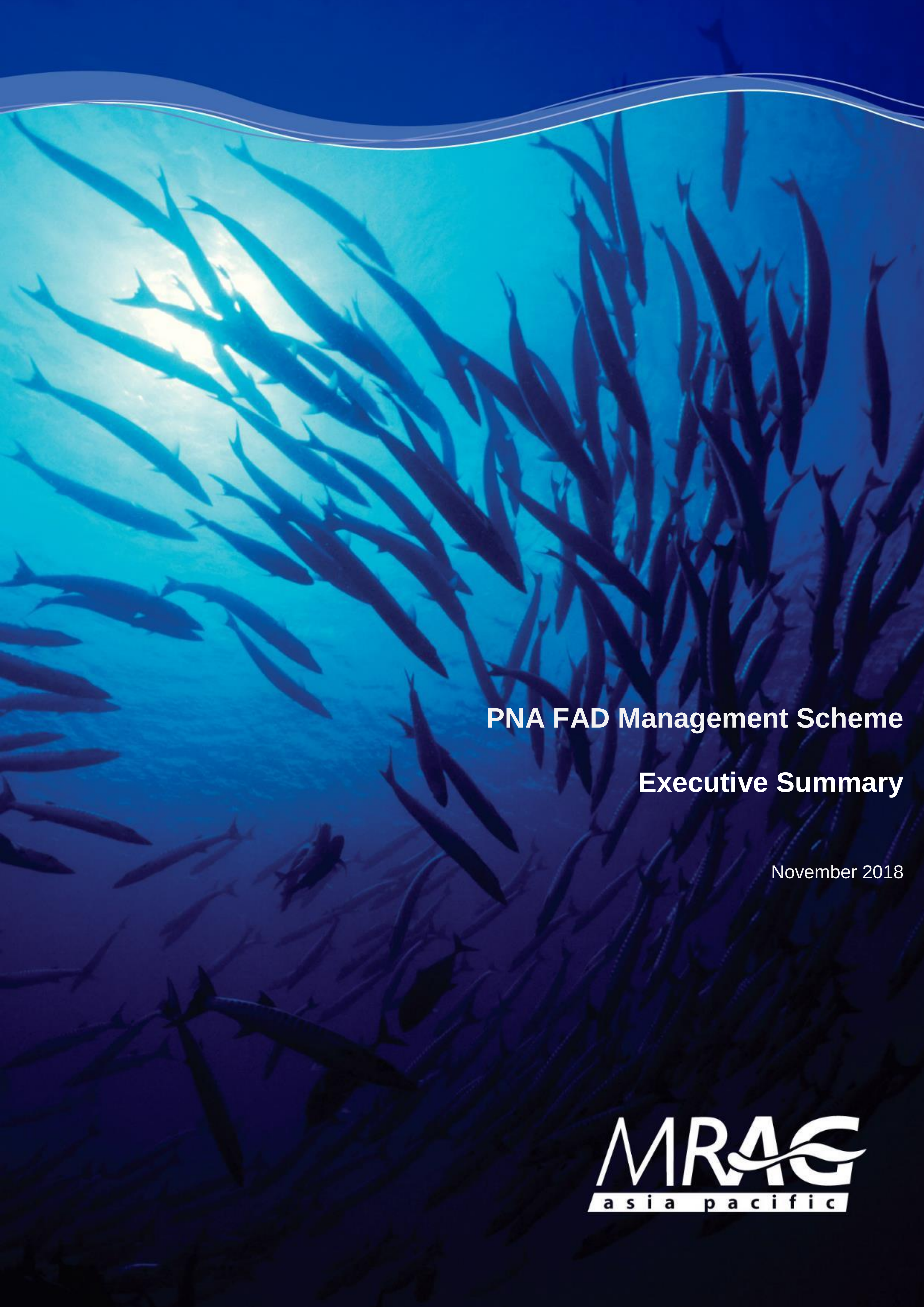

PNA FAD Management Scheme

Executive Summary

November 2018

MRAG asia pacific

About MRAG Asia Pacific

MRAG Asia Pacific is an independent fisheries and aquatic resource consulting company dedicated to the sustainable use of natural resources through sound, integrated management practices and policies. We are part of the global MRAG group with sister companies in Europe, North America and the Asia Pacific.

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Acknowledgements

Thanks go to all those who contributed to the preparation of these reports. Particular thanks go to those fishing companies and satellite buoy suppliers who agreed to participate in the project for providing helpful insights about FADs and FAD usage in the WCPO. Thanks also go to SPC for providing very helpful background data on FAD usage in PNA Party waters. Particular thanks also go to PNA Parties and staff at the PNA Office for providing very helpful feedback on drafts of the various reports.

Executive summary

Background and context

The use of man-made fish aggregation devices (FADs) has become an increasingly important component of the fishing strategies of tuna purse seine fleets across most ocean basins since the mid-1990s. Fishing on FADs offers a number of advantages over fishing on free schools of tuna. In particular, catch rates of tuna are typically higher (Williams and Reid, 2018), the practice of encircling the fish is operationally easier (leading to fewer unsuccessful or 'skunk' sets) and the aggregative nature of FADs combined with the ability to track the location of FADs makes fishing more predictable and can reduce both time and money spent searching for fish. The increasing use of FADs has been paralleled and facilitated by substantial improvements in FAD buoy technology. Anecdotal information suggests the widespread availability and uptake of sophisticated echosounder technology is causing rapid changes in fishing strategy and fleet behaviour, with the potential to be a 'gamechanger' for purse seine fisheries and their management.

Despite the acknowledged importance of FADs in the operation of modern purse seine fisheries, our understanding of FAD usage and impacts in the WCPO is patchy at best. Good information exists on the number of FAD sets and associated species composition through logbooks and observer reports, however limited information is available on the total number of FADs deployed within the WCPO as well as FAD distribution and density. There is also a limited understanding of many of the operational aspects of FAD use by industry including the logistics of deployment and FAD ownership, trading and leasing arrangements.

In that context, the PNA (through FFA, and with funding through the World Bank Ocean Partnerships Project) contracted MRAG Asia Pacific to undertake an assessment of FAD usage and future management options in the WCPO. The overall objectives of the assignment were to consolidate existing information on FAD usage in the WCPO and to evaluate options to constitute a future PNA adaptive FAD management scheme. While the initial Terms of Reference were focused on examining one particular option - a commercial FAD leasing scheme under which PNA would deploy and lease FADs (or their locations) to industry – early discussions with PNA requested the project team assess a broader range of options.

The project was broadly structured in three sequential phases:

1. The **first phase** is focused on reviewing and consolidating existing information on FAD usage in the WCPO, and the preliminary identification of possible future management options;
2. The **second phase** is intended to assess the strengths, weaknesses, opportunities and threats associated with the future management options, including a commercial leasing scheme, to determine the economic and environmental merit of the concepts and the legal implications;
3. The objective of the **third phase** is to develop a business case for the most attractive future management option (or combination of options).

Phase 1: Existing information on FAD use

The Phase 1 report consolidates existing information on FAD usage in the WCPO including information on the history of FAD use and level of FAD dependence, catch and catch rates on FADs in comparison to free schools, the number of FADs deployed and their density and distribution, FAD design and tracking systems, the logistics of deployment and ownership, leasing and trading arrangements.

Our general conclusion from Phase 1 was that, although there were areas in which demonstrably effective action on FAD management had been taken (e.g. FAD bans have served to reduced bigeye mortality), overall the PNA (and the broader WCPO) is generally 'behind the 8 ball' on FAD management across a range of areas.

In particular, despite the acknowledged potential for increased FAD usage (and in particular widespread uptake of latest generation echosounder buoys) to substantially alter the efficiency, operational character and economics of the purse seine sector, relatively basic information and systems to support effective management and track impacts over time are lacking. This includes, for example:

- a lack of good information on number of FADs deployed and actively monitored;
- a lack of information on FAD distribution and density, as well the absence of a fishery-wide system to register and track the real-time location of FADs (although FIMS has proven itself technically capable of tracking FADs, non-compliance and geofencing have weakened the utility of the data); and
- an absence of good information on FAD deployment and retrieval.

Importantly, there is currently no obligation on industry to report information on FAD use to management authorities, other than to provide an indication of set type in logsheets. Given the rapid evolution of FAD usage and technology in the past decade, this has ultimately meant that industry's understanding of FAD usage and its impact on economics is likely to be well ahead of PNA Parties at present.

Against that background, our overall view is that the general 'architecture' of FAD management in the WCPO is in need of significant strengthening across a range of areas (e.g. strengthening information, better registration, marking and monitoring, environmental measures, etc). To that end, the project team worked with the PNA Office to develop a background paper setting out a broad framework of management reform options that was considered by Parties at a workshop held in Brisbane in June 2018.

Phase 2: SWOT Analysis

Building on the management reforms identified in the joint PNAO/MRAG AP paper, the Phase 2 report undertook a strengths, weaknesses, opportunities and threats (SWOT) analysis of nine possible options for the future management of FAD use in Parties' waters. The analysis took into account the outcomes of the Brisbane workshop, as well as an analysis of existing FAD rights and economics within the current management regime. A high level summary of the options and SWOT outcomes are set out below:

Management Option	SWOT Outcomes
Charge for 'FAD Days'	• focuses on key management issue - setting on FADs • Challenge is that FAD fee is 'stab in the dark' in the absence of an effective 'price discovery' process

	• Promising approach, but requires considerable design work
Charge for 'Buoy days'	• likely to cannibalise VDS revenue • effectively a deployment charge, but main issue to manage is not deployment but setting on FADs
Limit number of FAD sets	• direct mechanism to manage impacts associated with FAD sets • BUT selling Day rights and FAD setting rights separately limits the ability of Parties to use market mechanisms to discover the 'proper' price for either Day or FAD setting rights
Charge for FAD sets	• potentially an excellent approach • main handicap is that existing single-zone Day 'markets' are not competitive enough to generate good price information
Limit number of FADs	• not the key thing requiring management (assuming FAD density does not substantially influence stock dynamics) • FAD deployment rights under this option are valuable rights conferred on harvesters – currently owned by Parties
Charge for each FAD deployed	• does not address the key issue (FAD setting) • separate charging for FAD deployment is almost certain to be cannibalistic of Day revenues
Rebate for free school days	• really the same as a scheme for charging for FAD setting but with key disadvantages • more expensive to administer; • higher finance costs for free school harvesters (suppresses Day price)
PNA FAD leasing scheme	• Potentially 'innovative' idea, but major disruption to current operation of WCPO PS fishery – economic consequences for vessels/Parties uncertain • Considerable risks: (i) vessel efficiency, profitability and VDS revenues, (ii) legal and reputational risks associated with being FAD owners and (iii) compliance challenges
Status quo (+Baseline management reforms)	• necessary first step in establishing a longer term management regime • But on their own these measures do not allow Parties to directly control the environmental impacts of (or optimise revenue from) FAD setting

Key observations and conclusions from the Phase 2 analysis which should guide the development of a future FAD management scheme include:

- **Need for clear objectives** – there is a need for the precise objectives underpinning any future PNA FAD management scheme to be discussed an agreed amongst Parties at the outset;
- **Parties should avoid the establishment of two competing instruments or rights** – Parties should avoid the creation of a separate FAD right in the fishery which undermines the efficient operation of the VDS market, and/or cannibalises VDS rents. Global fisheries history is littered with real world examples of tension between two competing rights constraining overall economic returns from the fishery and/or undermining management effectiveness;
- **Parties should oppose FAD charging by any other management agency** – The right to deploy and set on a FAD in PNA waters is currently, in effect, a sub-right (or freedom) of the PNA licensing regime. Charging for FAD usage by other agencies (WCPFC, flag State, etc) will alter the nature

of existing right and will, all other things being equal, expropriate potential revenues currently collected through the VDS;

- **Parties should only allow FAD fishing if they are adequately compensated for all environmental and economic risks** – any future PNA FAD management regime should seek to ensure that (a) environmental risks are minimised to the extent practical and (b) Parties are adequately compensated for all economic risks associated with FAD use;
- **The PNA FAD management framework should recognise, and manage, the two distinct sources of environmental and economic cost associated with FAD use**:
  - Costs associated with <u>FAD deployment</u> (e.g. incidental entanglements, marine debris beaching, impacts on stock dynamics); and
  - Costs associated with <u>setting on FADs</u> (e.g. impacts on vulnerable tuna species; impacts on non-target species such as sharks).

  The first group of costs is best dealt with by measures which seek to directly mitigate impacts such as changes in gear design. The second set of impacts is best dealt with through a regime which limits (and optimises economic returns from) FAD setting.

- **From an economic point of view, the thing of most interest to Parties is FAD sets -** the main focus of any future PNA FAD management regime should be to control and manage FAD sets, not FAD deployments (assuming FAD density is not sufficient to substantially alter stock dynamics on a broad scale). This presupposes that the environmental impacts of FAD deployment can be largely mitigated through gear design;
- **The commercial leasing scheme envisaged in the original TORs is likely to be challenging to implement in practice and carries with it considerable risks to Parties** – although its undoubtedly an innovative, 'thinking outside the square' idea, a broad scale commercial FAD leasing scheme which would see Parties (either solely or with a JV partner) take responsibility for FAD deployment in the WCPO offers limited and uncertain benefits to Parties and carries with it considerable risks;
- **Need to consider practical implementation and sequencing** – there is a need to consider sequencing the proposed reforms, and importantly the correct order of implementation. As a general rule, there will be a range of base level reforms required to provide better information on, and control over, FAD use before progressing with a more sophisticated FAD setting regime to optimise VDS returns.

PHASE 3: 'BUSINESS CASE'

Broadly, the Phase 2 report concluded that the optimal approach to the design and implementation of an effective FAD management regime has three inter-related parts that are sequential:

1. Gather greater information on the actual levels of FAD deployment and setting in the WCPO as well as any information on the relative economics of FAD versus free-school fishing under the VDS. Generate 'guestimates' of the environmental costs and risks that can be attributed to FAD deployment and FAD setting respectively.
2. Develop a <u>preferred regulatory instrument</u> for managing the issues associated with FAD deployment. These are expected to take the form of

specifications for non-entangling and biodegradable FADs and work with other agencies such as WCPFC to ensure that only FADs meeting those specifications are deployed in the WCPO.

3. Develop a complementary economic instrument for managing the issues associated with FAD setting. The FAD setting regime for the VDS would be under the exclusive control of the Parties collectively and would add value to the VDS (Day revenues under the FAD setting regime would more than compensate for any estimated environmental costs and risks associated with the level of FAD setting authorised).

The Phase 3 report analyses the commercial imperatives of PNA in future FAD management and examines measures to refine the VDS to better manage the effects of FAD use on VDS revenues. In particular, Phase 3 examines measures to integrate FAD right pricing into the VDS and proposes the use of a 'price discovery' process through a multizone Day auction to elicit information on industry's willingness to pay a premium for FAD Days over non-FAD Days and ensure that Parties are adequately compensated for the cost and risks associated with FAD use in the fishery. The report then examines the relationship between multizone and single zone FAD Day pricing and explores alternative options for the practical implementation of a FAD Day regime. Phase 3 concludes with a brief overview of the next steps required for the implementation of the recommended FAD management 'business'.

PNA FAD Management Scheme

Phase 1 Report

August 2018

MRAG asia pacific

About MRAG Asia Pacific

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Contents

LIST OF FIGURES .... **II**

LIST OF TABLES .... **II**

1 INTRODUCTION **1**

2 OVERVIEW OF CURRENT FAD ACTIVITY IN THE WCPO **3**

2.1 FAD CATCH AND EFFORT 3
2.1.1 History of FAD use *3*
2.1.2 Level of FAD dependence *4*
2.1.3 Catch *5*
2.1.4 Catch rates *6*
2.2 DENSITY AND DISTRIBUTION OF FADS 8
2.3 NUMBERS DEPLOYED 10
2.4 FAD DESIGN AND MANUFACTURE 13
2.5 FAD TRACKING SYSTEMS 16
2.5.1 Satellite Buoy Manufacturers *16*
2.5.2 Satellite Buoy Models *17*
2.5.3 Technical Operation *19*
2.5.4 Satellite Buoy Usage *21*
2.5.5 Buoy management comments *22*
2.6 LOGISTICS OF DEPLOYMENT 23
2.7 OWNERSHIP, LEASING AND TRADING ARRANGEMENTS 27

3 OPTIONS FOR FAD MANAGEMENT **28**

4 REFERENCES **31**

ANNEX 1: MANAGEMENT OPTIONS PAPER **33**

List of Figures

FIGURE 1: PROPORTION OF TOTAL WCPO PURSE SEINE CATCH BY SET TYPE, 1980-2017. 3
FIGURE 2: PROPORTION OF ASSOCIATED SETS BY TYPE, 1980-2017. 3
FIGURE 3: NUMBER OF SETS IN THE WCPO BY TYPE, 2000-2017. NOTE, DFAD SETS ARE A SUBSET OF ASSOCIATED SETS. 4
FIGURE 4: RELATIVE LEVEL OF ASSOCIATED SET DEPENDENCE (LEFT PANEL) AND TOTAL NUMBER OF ASSOCIATED SETS (RIGHT PANEL) BY FLAG STATE IN WCPO BETWEEN 2013 AND 2015. (DATA SOURCE: PNAO) 5
FIGURE 5: TOTAL REPORTED PURSE SEINE CATCH (T) IN THE CORE AREA OF THE WCPO FISHERY, 1980 – 2017. 5
FIGURE 6: TOTAL CATCH BY SET TYPE (LEFT PANELS) AND PROPORTION OF TOTAL CATCH BY SET TYPE (RIGHT PANELS) FOR SKIPJACK (TOP), YELLOWFIN (MIDDLE) AND BIGEYE TUNA (BOTTOM), 1980 – 2017. 6
FIGURE 7: TRENDS IN CATCH RATES (TOTAL TONNES/SET) BETWEEN DFAD AND FREE SCHOOL SETS, 2000-2017. DOTTED LINES ARE THREE YEAR MOVING AVERAGES. 7
FIGURE 8: TRENDS IN CATCH RATES (TONNES/SET) BETWEEN DFAD AND FREE SCHOOL SETS FOR SKJ (UPPER LEFT), YFT (UPPER RIGHT) AND BET (LOWER LEFT), 2000-2017. DOTTED LINES ARE THREE YEAR MOVING AVERAGES. TRENDS IN SKJ CATCH RATES ACROSS ALL MAJOR SET TYPES, 2000-2017 (LOWER RIGHT). 7
FIGURE 9: POSITION OF UNIQUE FADS TRANSMITTING AS PART OF THE PNA FAD TRACKING TRIAL (FROM ESCALLE ET AL, 2017). THE COLOUR OF THE TRACK CORRESPONDS TO THE MONTH OF THE REPORT (LIGHT ORANGE IN JANUARY TO THE DARKEST SHADE IN DECEMBER). 9
FIGURE 10: 'HEATMAP' SHOWING DENSITY OF FADS TRANSMITTING AT LEAST ONCE PER 1^{o} GRID CELL DURING 2016 (TOP) AND 2017 (BOTTOM) (FROM ESCALLE ET AL 2018A). POSITIONS OF ASSOCIATED SETS AS RECORDED IN OBSERVER DATA ARE INDICATED AS BLACK DOTS. COLOUR SCALE CORRESPONDS TO THE PROPORTION OF TRANSMITTING PER 1° CELL. 9
FIGURE 11: IMPACT OF INCREASED FAD DENSITY ON SCHOOL SIZE AND ASSOCIATION WITH TIME (FROM MAUFROY ET AL, 2017) ... 10
FIGURE 12: ESTIMATES OF THE TOTAL NUMBER OF FAD DEPLOYMENTS IN THE WCPO USING DIFFERENT ESTIMATION METHODS BASED ON OBSERVER DATA ONLY (BLACK LINES) AND USING A COMBINATION OF PNA FAD TRACKING DATA AND OBSERVER DATA (ORANGE LINES) (FROM ESCALLE ET AL, 2018B). 11
FIGURE 13: ESTIMATED NUMBERS OF FAD DEPLOYMENTS IN THE PNA FAD TRACKING TRIAL DATA FOR KNOWN VESSELS, 2016 (RED) AND 2017 (BLACK). (FROM ESCALLE ET AL, 2018A) 12
FIGURE 14: OBSERVER DRAWINGS OF COMMONLY USED FAD DESIGNS IN THE WCPO. 13
FIGURE 15: PROPORTION OF DFADS CONSTRUCTED OF NATURAL (NAT) OR ARTIFICIAL (ART) MATERIALS, AS RECORDED BY OBSERVERS, 2011-2018 (FROM ESCALLE ET AL, 2018C). 14
FIGURE 16: USE OF NET MATERIAL IN DFAD RAFTS AND APPENDAGES, AS RECORDED BY OBSERVERS, 2011-2018. (FROM ESCALLE ET AL, 2018C) 15
FIGURE 17: ISSF RANKING OF FAD DESIGNS FROM HIGHEST TO LOWEST RISK OF ENTANGLEMENT (FROM ISSF, 2015B) 15
FIGURE 18: BUOY SERIAL NUMBER PREFIX AMONGST 'UNASSIGNED' BUOYS REGISTERED IN FIMS WITH A COMMENCEMENT DATE IN 2018 (N=4188). 22
FIGURE 19: PROPORTION OF 'ISL+' BUOYS (LEFT PANEL) AND 'P' BUOYS (RIGHT PANEL) REGISTERED TO VESSELS OF EACH FLAG STATE. 22
FIGURE 20: 'HEATMAP' OF BUOY DEPLOYMENTS PER 1^{o} GRID CELL IN 2016 (TOP) AND 2017 (BOTTOM). POSITION OF FAD/BUOY DEPLOYMENT AS RECORDED BY OBSERVERS IS INDICATED AS BLACK DOTS (2017 DATA INCOMPLETE). THE MAXIMUM NUMBER OF DEPLOYMENTS PER CELL IN 2016 WAS 140 AND 300 IN 2017. (FROM ESCALLE ET AL, 2018A) 25
FIGURE 21: CURRENT DIRECTION AND STRENGTH IN THE EQUATORIAL WCPO, AS AT 1ST AUGUST 2018 (SOURCE: WWW.EARTH.NULLSCHOOL.NET). 25
FIGURE 22: DENSITY OF FAD BEACHING EVENTS BY 1^{o} GRID CELL BETWEEN JANUARY 2016 AND MARCH 2018 (LEFT PANEL; FROM ESCALLE ET AL, 2018). FAD BEACHED ON THE COOK IS SUWARROW ATOLL (RIGHT PANEL; WWW.RADIONZ.CO.NZ). 26
FIGURE 23: SATELLITE BUOYS MARKED WITH VESSEL IDENTIFICATIONS MARKINGS. 27

List of Tables

TABLE 1: PROPORTION OF PURSE SEINE CATCH TAKEN IN FREE SCHOOLS ACROSS MAJOR OCEANS (2014-16 AVERAGE) (DATA SOURCES: RFMOS) 4
TABLE 2: TECHNICAL SPECIFICATIONS OF THE MAIN SATELLITE BUOYS CURRENTLY IN USE BY THE INTERNATIONAL TUNA FLEET. 17

1 Introduction

The use of man-made fish aggregation devices (FADs) has become an increasingly important component of the fishing strategies of tuna purse seine fleets across most ocean basins since the mid-1990s. Fishing on FADs offers a number of advantages over fishing on free schools of tuna. In particular, catch rates of tuna are typically higher (Williams and Reid, 2018), the practice of encircling the fish is operationally easier (leading to fewer unsuccessful or 'skunk' sets) and the aggregative nature of FADs combined with the ability to track the location of FADs makes fishing more predictable and can reduce both time and money spent searching for fish. The increasing use of FADs has been paralleled and facilitated by substantial improvements in FAD buoy technology. Whereas FAD radio buoys in the early 1990s were limited to transmitting simple position information only, the most recent generation of buoys are fitted with sophisticated echosounders which can transmit detailed information on biomass underneath buoys. Anecdotal information suggests the widespread availability and uptake of sophisticated echosounder technology is causing rapid changes in fishing strategy and fleet behaviour, with the potential to be a 'gamechanger' for purse seine fisheries and their management.

In the Western and Central Pacific Ocean (WCPO), the increasing use of FADs, together with improved buoy and general fishing technology and increases in fishing effort, has seen the purse seine catch of the main target species – skipjack tuna – increase by over 70% between 1995 and 2017 (Williams and Reid, 2018). While the latest assessment indicates the stock remains in a healthy position (McKechnie et al, 2016), the increasing use of FADs has not come without its costs. In particular, bycatch of bigeye and yellowfin tuna in FAD sets has substantially increased total fishing mortality on these stocks, and there is concern around the impacts on other non-target species (e.g. silky sharks, sea turtles). While the most recent assessment of bigeye tuna is more optimistic than previous assessments, there remains substantial concern that the capacity to optimise catches of skipjack (and therefore revenues to the PNA Parties) will be constrained by the need to impose restrictive conservation measures to protect the bigeye stock. There is also considerable concern that existing measures to manage the impact of FADs – primarily a three-month prohibition on setting and deploying FADs – are 'blunt instruments' which place disproportionate burden for conservation on PNA Parties.

Despite the acknowledged importance of FADs in the operation of modern purse seine fisheries, our understanding of FAD usage and impacts in the WCPO is patchy at best. Good information exists on the number of FAD sets and associated species composition through logbooks and observer reports. Moreover, the introduction of 100% observer coverage in the WCPO since 2009 has substantially improved our understanding of FAD design and construction, electronics used to track FADs and the nature of FAD interactions. Nevertheless, very important information gaps remain. For example, estimates of the total number of FADs deployed within the WCPO are uncertain and information on their distribution and density remains limited. The absence of a permanent, unique identifier on both the FAD and associated buoy means there is limited capacity to track the full 'life history' of FADs and assesses, for example, the aggregative capacity and ecosystem impacts of different designs. There is also a limited understanding of many of the operational aspects of FAD use by industry including the logistics of deployment and FAD ownership, trading and leasing arrangements.

In that context, the PNA (through FFA, and with funding through the World Bank Ocean Partnerships Project) contracted MRAG Asia Pacific to undertake an assessment of FAD usage and future management options in the WCPO. The overall objectives of the assignment were to consolidate existing information on FAD usage in the WCPO and to evaluate options to constitute a future PNA adaptive FAD management scheme. While the initial Terms of Reference were focused on examining one particular option - a commercial FAD leasing scheme under which PNA would deploy and lease FADs (or their locations) to industry – early discussions with PNA requested the project team assess a broader range of options.

The project is broadly structured in three sequential phases:

1. The **first phase** is focused on reviewing and consolidating existing information on FAD usage in the WCPO, and the preliminary identification of possible future management options;
2. The **second phase** is intended to assess the strengths, weaknesses, opportunities and threats associated with the future management options, including a commercial leasing scheme, to determine the economic and environmental merit of the concepts and the legal implications;
3. The objective of the **third phase** is to develop a business case for the most attractive future management option (or combination of options).

This report sets out the results of the first phase. Although the use of anchored FADs (aFADs) is locally important to some fleets in the WCPO, particularly the domestically-based fleets operating in the archipelagic waters of PNG and the Solomon Islands, the majority of the FAD sets in the WCPO are made on man-made drifting FADs (dFADs). To that end, this report focuses on consolidating existing information on, and future management of, dFADs (hereafter simply referred to as 'FADs').

Broadly, the information in this report was generated through four main sources:

1. Pre-existing published material – these were largely analyses prepared by SPC and other groups for consideration by the WCPFC, together with independent (e.g. NGO) analyses of FAD usage;
2. Information recorded by fisheries observers – detailed recent operational information was available for FSMA fleet, including information on satellite tracking technology used, FAD design and materials and the nature of FAD interactions including the origin of FADs set or inspected. Aggregated information was also provided for the wider WCPO fleet based on information collected in observer GEN-5 forms. This form collects information on FAD design and materials, interactions with FADs and deployment and retrieval.
3. Information provided by fishing companies – this source was highly variable; some companies provided very good information, while others opted not to participate. In the former case, companies took the mature view that any future management option should be based on accurate information, and developed collaboratively with industry to ensure practicality. In the latter case, companies and representative associations expressed concern that any information provided may be 'used against them'. To that end, gaps remain in our understanding of some operational aspects of FAD usage. These gaps will ultimately need to be filled – ideally through a collaborative, inclusive process in which industry is a willing participant and sees the benefits from being involved, but if not, through regulatory requirements to provide information.
4. Information provided by commercial satellite buoy manufacturers – this was largely technical information on current buoy designs and generic information on markets and buoy usage.

This report is broadly structured in three parts. Following this introduction, section 2 consolidates existing information on FAD usage in the WCPO according to the issues outlined in the TOR. Section 3 then discussed in broad terms preliminary management options that will be assessed in more detail in Phase 2.

2 Overview of current FAD activity in the WCPO

2.1 FAD catch and effort[1]

2.1.1 History of FAD use

The association between the major tropical tuna species and floating objects has long been known across each of the world's major oceans. In the WCPO, associated sets (primarily on logs) dominated catches in the early years, with over 80% of reported catches taken in association with floating objects (Figure 1).

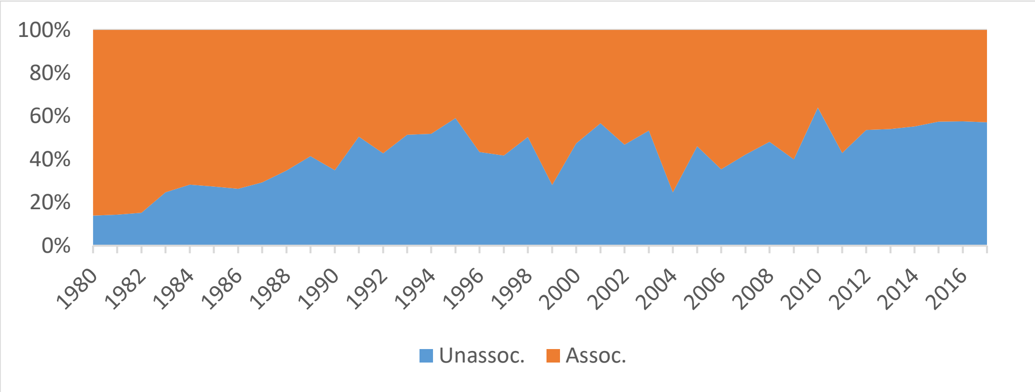

Figure 1: Proportion of total WCPO purse seine catch by set type, 1980-2017.

The fishery on floating objects started based on random encounters with objects of different types (mainly natural debris such as logs), but evolved towards the fishers modifying the encountered objects (e.g. tying two together) and adding radio equipment to relocate them. By the mid-1990s, sets on man-made dFADs began to replace log sets, driven by increased predictability of tracked, man-made versus free floating objects, as well as a capacity to tailor the construction and deployment of the FAD according to operational preferences (FAD materials, depth, deployment location). Since the late 2000s, sets on dFADs have dominated overall associated set effort, accounting for more than half of all associated sets since 2008 and around ¾ of all associated sets since 2014 (Figure 2). By contrast, the proportion of effort on aFADs has remained relatively stable at between 10-20% of total associated sets since the early 1990s.

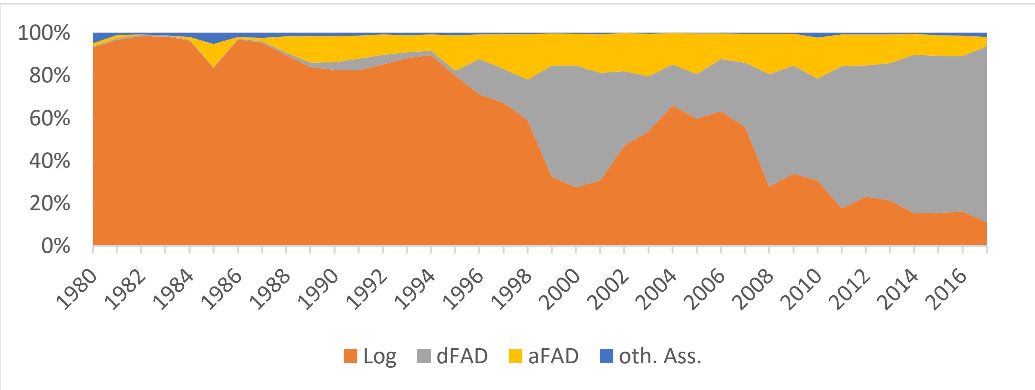

Figure 2: Proportion of associated sets by type, 1980-2017.

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[1] Note – the data used for graphs in this section (except Fig. 4) is drawn from WCPFC public domain data for the area of the WCPFC-CA between 10ºN and 10ºS and east of 140ºE. This could be considered the 'core' area of the WCPO PS fishery. Data coverage after 2000 is >90%, although coverage in the earlier years (closer to 1980) is less comprehensive and should be interpreted with some caution.

Despite the rise in the number and technological capacity of dFADs in recent decades, it is worth noting that the WCPO has not followed a similar path to ocean basins where overall catch is now dominated by associated sets. Indeed, in recent years, the proportion of catch taken in free schools in the WCPO has grown with improved harvesting technology, market-based incentives and regulation on FAD use such that catches taken in free schools have accounted for more than half of the total catch since around 2012 (Figure 1). This contrasts with other ocean basins where less than ¼ of the catch is taken in free schools (Table 1).

Table 1: Proportion of purse seine catch taken in free schools across major oceans (2014-16 average) (data sources: RFMOs)

WCPO	EPO	Indian	Atlantic
54.7%	20.1%	21.4%	24.3%

The dominance of free school fishing in the WCPO is even more pronounced in terms of effort. While the total number of associated sets (including dFADs, logs, aFADs) has remained relatively stable at between 10,000 – 20,000 sets since 2000, the number of free school sets has roughly doubled in the same period (Figure 3). The major rise in the number of free school sets commenced around 2008/09, coinciding with the introduction of the 3-month FAD closure under the PNA Third Implementing Arrangement (3IA) and subsequent mirroring in WCPFC's CMM 2008-01. The overall increase in free school catch has not increased in proportion to the number of sets, however, because free school fishing results in more unsuccessful sets and a lower catch per unit effort (CPUE) than associated sets. In 2017, the proportion of dFAD sets was higher than in recent years (27% of total sets Vs 21–24% between 2012-2016) perhaps related to skipjack tuna being less available in free school sets (Williams and Reid, 2018).

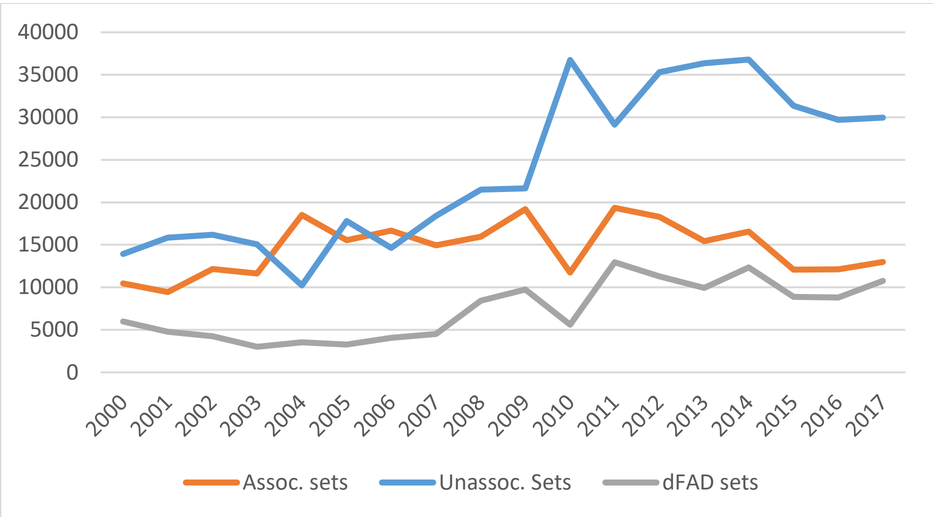

Figure 3: Number of sets in the WCPO by type, 2000-2017. Note, dFAD sets are a subset of associated sets.

2.1.2 Level of FAD dependence

While the overall number of associated sets has remained relatively stable across the fishery in recent years, the usage of FADs is not uniform across the purse seine fleet. Figure 4 shows the relative level of associated set dependence by vessels flag between 2013 and 2015. Fleets flagged to the El Salvador, Spain, the European Community and the Solomon Islands had the highest levels of associated set dependency, while fleets from Korea, Japan, Tuvalu and Kiribati had the lowest.

Nevertheless, taking into account fleet size and effort, the United States, Taiwan and PNG accounted for the highest absolute number of associated sets (Figure 4). Fleets flagged to the European Community, Vanuatu, El Salvador, New Zealand and Tuvalu accounted for <2% of total associated sets collectively.

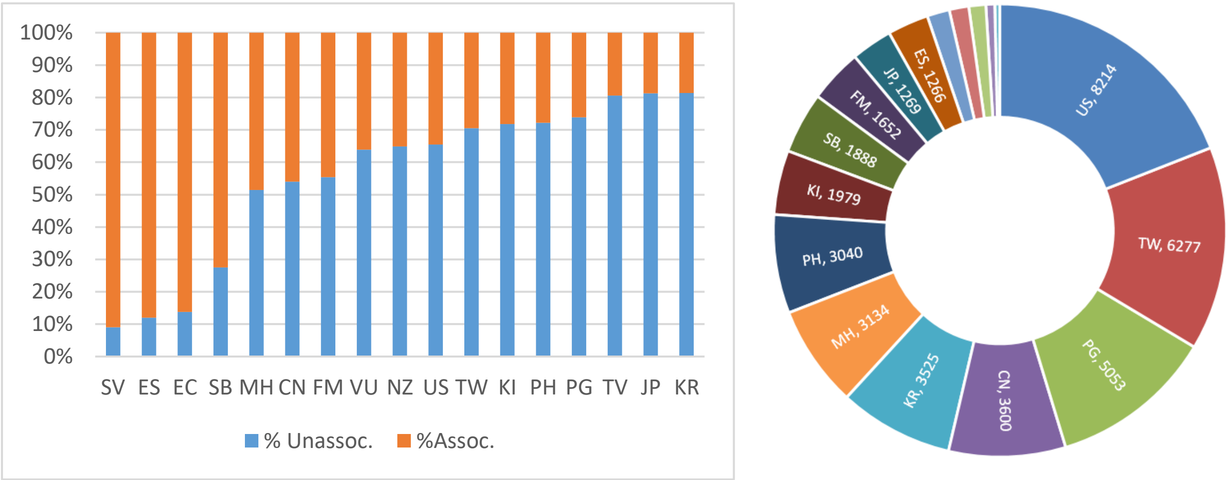

Figure 4: Relative level of associated set dependence (left panel) and total number of associated sets (right panel) by flag state in WCPO between 2013 and 2015. (data source: PNAO)

2.1.3 Catch

The proportion of the total WCPO purse seine catch taken in dFAD sets has grown rapidly since the mid-1990s, rising from around 1% of the total catch in 1995 to 37% in 2017 (Figure 5). The proportion of dFAD catches peaked at 42% in 2011, coinciding with a drop in free school catch. By contrast, over the same period the proportion of free school catch has risen more modestly, from an average of 41% in the seven years pre-2010 to an average of 55% in the 7 years from 2010-2016 (roughly reflecting the period pre- and post- the FAD closure).

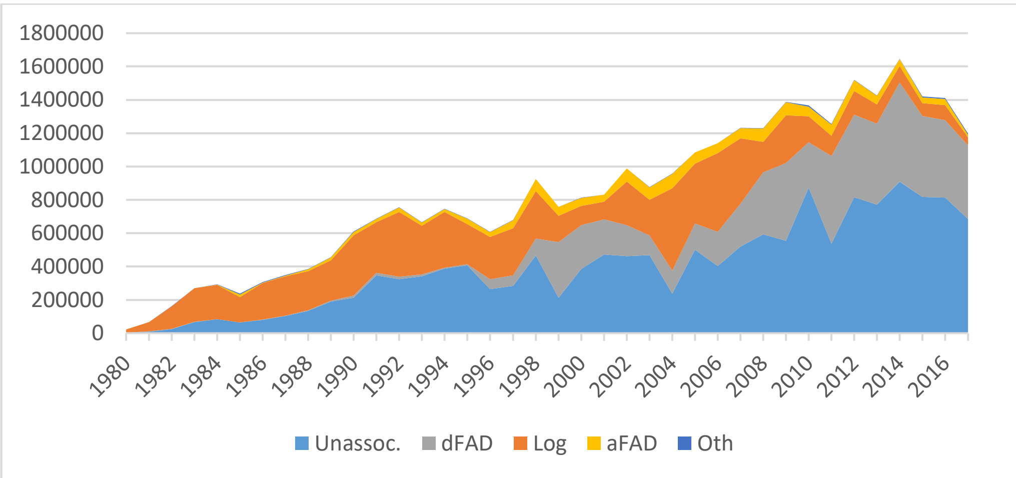

Figure 5: Total reported purse seine catch (t) in the core area of the WCPO fishery, 1980 – 2017.

Total dFAD catch in 2017 was 441,491t, comprising 76.6% skipjack, 17.3% yellowfin, 6.1% bigeye and 0.1% other species. By contrast, the 2017 free school catch was 684,530t, comprising 67.6% skipjack, 31.2% yellowfin, 1.2% bigeye and 0.02% other species.

The rise in dFAD usage has impacted the main target species within the WCPO PS fishery differently (Figure 6). For SKJ - the main species targeted on dFADs - total catches and the proportion of dFAD catch to total catch has broadly mirrored overall catch trends. Total catches on dFADs rose from negligible levels pre-1995 to around 40% of the total SKJ catch in 2017. The proportion of the total SKJ catch taken in free schools remained roughly static over the same period, with dFAD catch mainly replacing log catch.

For YFT, dFAD catches rose sharply after 1995, peaking at over 107,000t in 1999, before fluctuating between 40,000 – 80,000t. The dFAD catch has remained between 13 – 34% of the total WCPO PS YFT catch since 2000.

Arguably the largest impact of the rise of dFAD usage has been on BET. Catches associated with dFADs rose from around 2% of the total WCPO PS catch in 1995 to 71% in 2017, averaging 61% for the period from 2008-2016. Although the catch taken in log sets has declined since a peak of around 43,000t in 1997, the rise in dFAD catches has more than offset it, such that overall PS BET catches grew substantially from the mid-1990s onwards. Driven largely by catches associated with dFADs, the associated-set component of the PS fishery is now the largest single contributor to the reduction in spawning potential due to fishing for the WCPO BET stock (McKechnie et al, 2017).

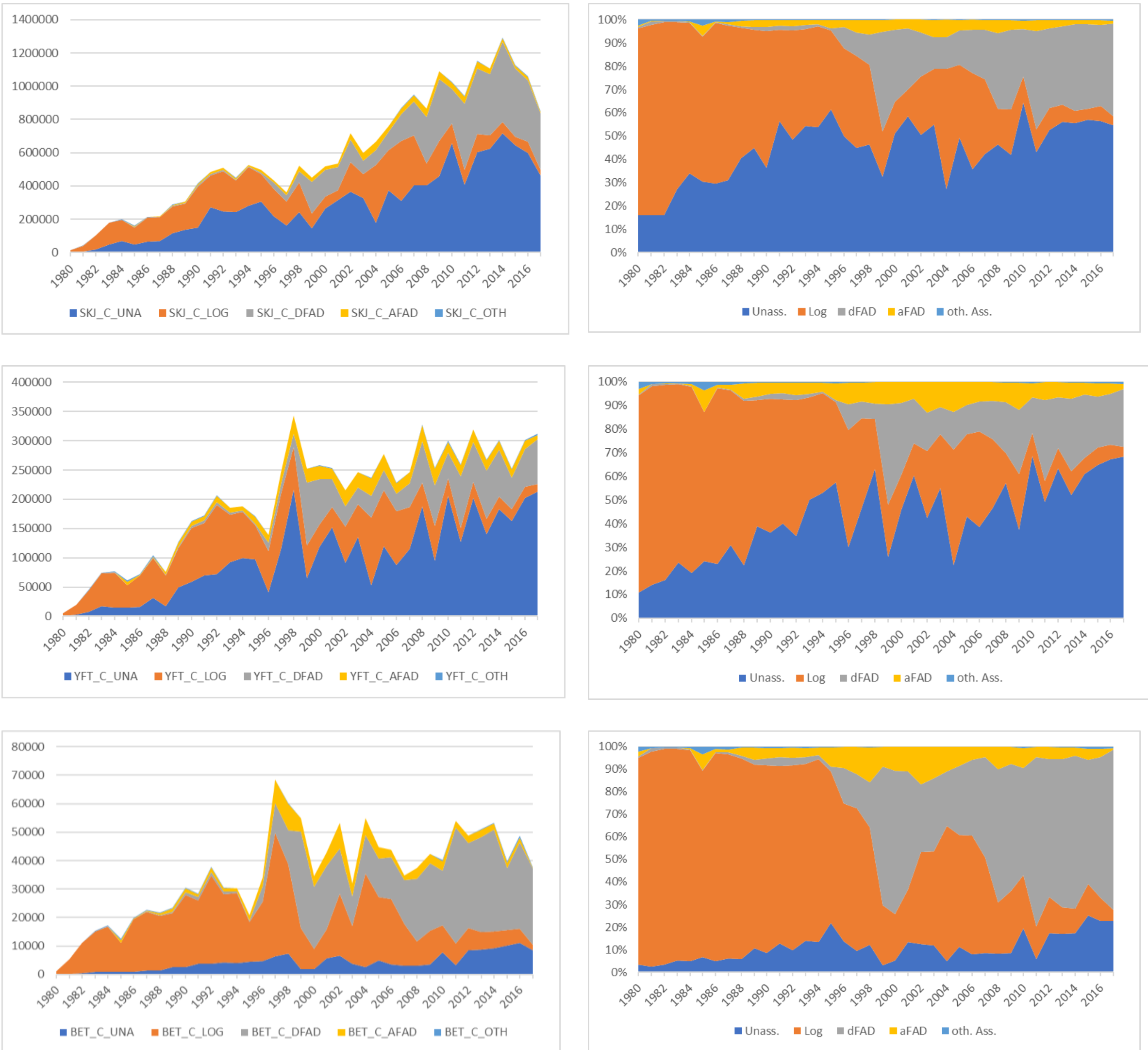

Figure 6: Total catch by set type (left panels) and proportion of total catch by set type (right panels) for skipjack (top), yellowfin (middle) and bigeye tuna (bottom), 1980 – 2017.

2.1.4 Catch rates

Catch rates in dFAD sets are substantially higher than those in free schools, reflecting both the lower proportion of unsuccessful sets and the aggregative capacity of FADs (Figure 7). Catch rates in dFAD sets generally rose during the period 2000 to 2016, although there was a pronounced drop in 2017. By contrast, free school catch rates fell marginally. In recent years, dFAD catch rates have been close to double those of free school sets.

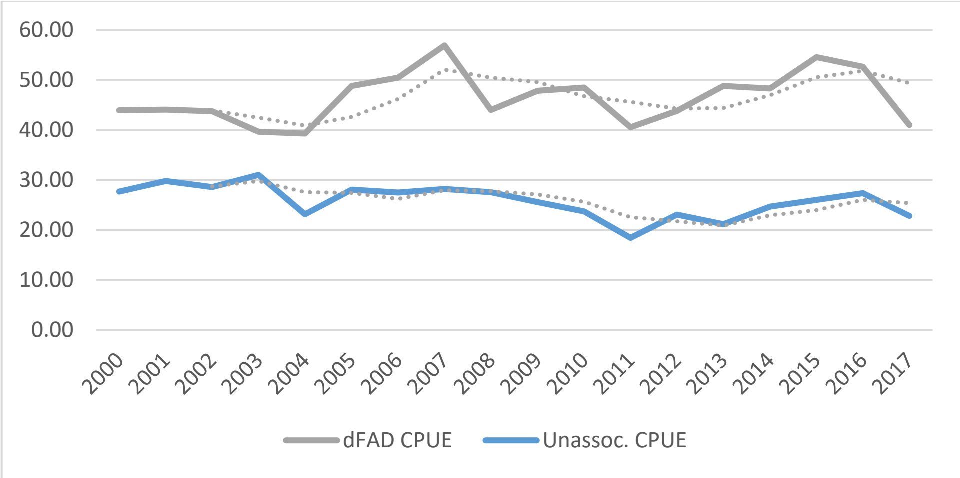

Figure 7: Trends in catch rates (total tonnes/set) between dFAD and free school sets, 2000-2017. Dotted lines are three year moving averages.

Across the main target species, catch rate differentials between dFAD sets and free schools for SKJ broadly mirror the total catch trends (Figure 8). While free school catches averaged around 72% of dFAD catch rates during the period 2000 – 2005, they fell to less than half (48%) of the dFAD catch rates in the period 2013 – 2017. For YFT, catch rates in dFAD sets are generally higher than free school sets although the differential is far less substantial than SKJ (and in 2017, there was very little difference). Catch rates of both dFAD and free school sets declined over the period 2000-2017, although free school catch rates have risen since 2013. Catch rate differentials are highest for BET. Although dFAD catch rates generally declined over the period 2000 to 2017, catch rates in dFAD sets have typically been between 9 and 25 times the catch rate in free school sets.

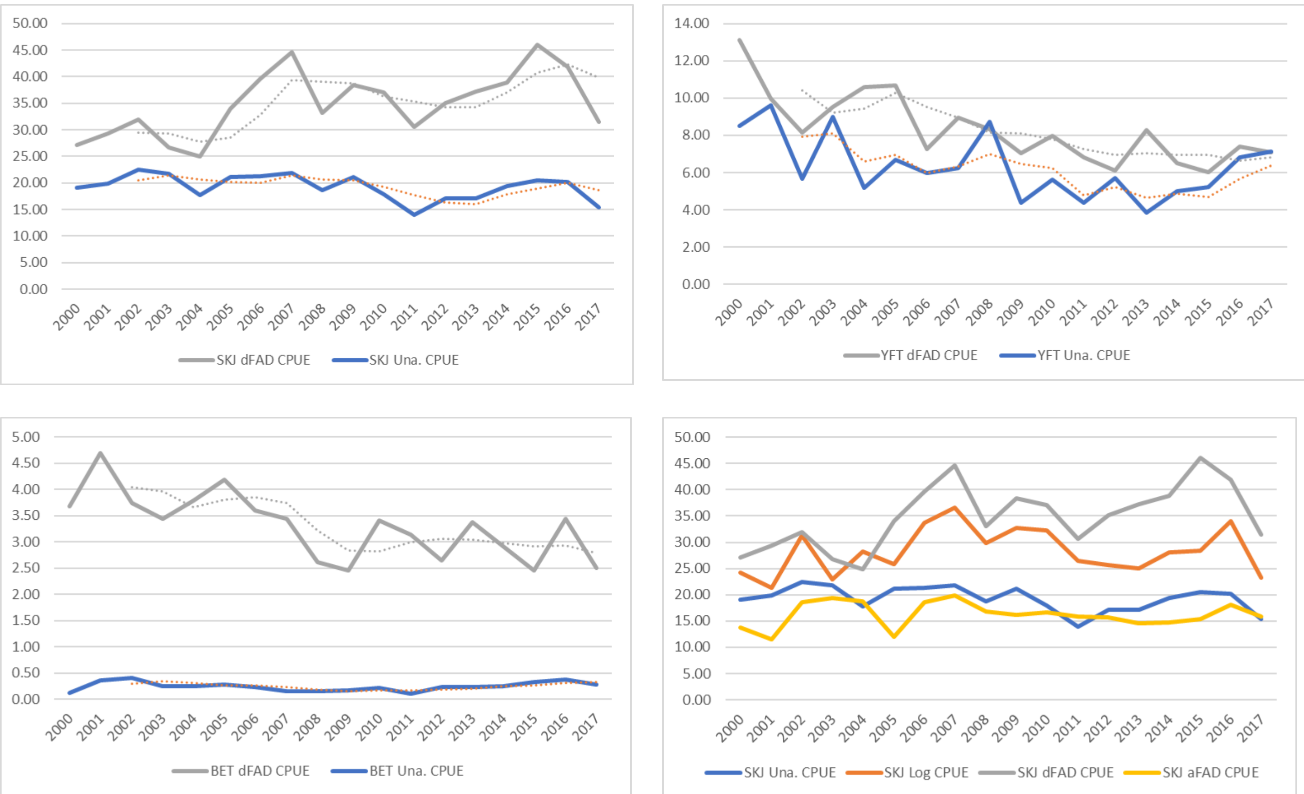

Figure 8: Trends in catch rates (tonnes/set) between dFAD and free school sets for SKJ (upper left), YFT (upper right) and BET (lower left), 2000-2017. Dotted lines are three year moving averages. Trends in SKJ catch rates across all major set types, 2000-2017 (lower right).

Amongst the main set types, dFAD sets have had the highest catch rates for SKJ in recent years (Figure 8). Although catch rates were broadly similar to log-set catch rates in the early 2000s, dFAD catch rates have outstripped log catch rates in recent years. By contrast, free school and aFAD catch rates have remained relatively stable over the same period.

Interestingly, while Maufroy et al (2017) report a similar increase in CPUE over time for dFAD sets in the Indian Ocean, they report that 'catch per travelled distance' (essentially the catch for each nautical mile of distance travelled) declined. They suggested this indicated that purse seiners were traveling longer distances from FAD to FAD to catch similar amounts of fish. We are not aware of any similar analysis of catch and steaming distance in the CPUE, although its worth noting at least one company we interviewed indicated their fuel costs had likely increased with the advent of echosounder buoys (even if profitability also rose) because vessels are prepared to travel further to FADs with higher biomass.

2.2 Density and distribution of FADs

Research in other ocean basins has shown that the direction and speed of movement of a dFAD on the ocean surface is driven primarily by surface currents, but also by wind and wave action (Davies et al, 2017). The density of dFADs in an ocean region is therefore not uniform, and dFADs tend to accumulate along current fronts and in circulation systems (Dagorn et al., 2013; Maufroy et al., 2015).

In the WCPO, detailed information on the density and distribution of FADs is relatively limited. The best and most direct information comes from a trial of FAD tracking commenced by the PNA in 2016. Under the trial, fishing companies with vessels on the PNA VDS Register are required to register all satellite buoys intended for use on FADs, with simultaneous reports provided to the PNA FIMS system for each report provided to the fishing company. Reports include the 'owner' of the buoy, location, drifting speed and course, and water temperature. While the system has shown itself to be technically capable of tracking FAD positions, the extent to which this information provides a comprehensive picture of dFAD distribution and density is uncertain given an apparent lack of compliance by some fleets (one fleet currently has over 7,000 FADs registered in the PNA system, but zero FADs reporting at the time of writing) and 'geofencing' by others (geofencing authorises reporting by FADs in some zones but not others, and has the effect of FADs 'going dark' in some zones – e.g. the high seas). Escalle et al (2018a) estimate that around 60-70% of buoy transmissions received by fishing companies are not forwarded to PNA.

Nevertheless, the available information allows for some broad observations to be made. Escalle et al (2018a) analysed the data available from 1st January 2016 to 18th March 2018 (covering >14 million transmissions across 26,595 buoys). They noted that the spatial locations of transmissions were dispersed over most areas of the tropical WCPO (Figure 9), with higher FAD density in Kiribati South of the Gilbert Islands and around the Phoenix Islands; Tuvalu (particularly in 2017); Papua New Guinea; and the Solomon Islands (Figure 10). The maximum number of buoys transmitting at least once per day in each 1^{o} grid was 3,000 in 2016 and 5,000 in 2017 (i.e. in the course of 2017, 5,000 unique buoys transmitted a position in the most densely populated 1^{o} grid). Despite that, it was clear that geofencing influenced the overall picture of density and distribution with southeast or northeast high seas areas and the high seas between Tuvalu and Phoenix Islands receiving large numbers of FAD sets, but few reporting FADs. Escalle et al (2018a) note that FAD density maps will likely present more extended areas or higher FAD densities, once complete and unmodified FAD tracking data are obtained.

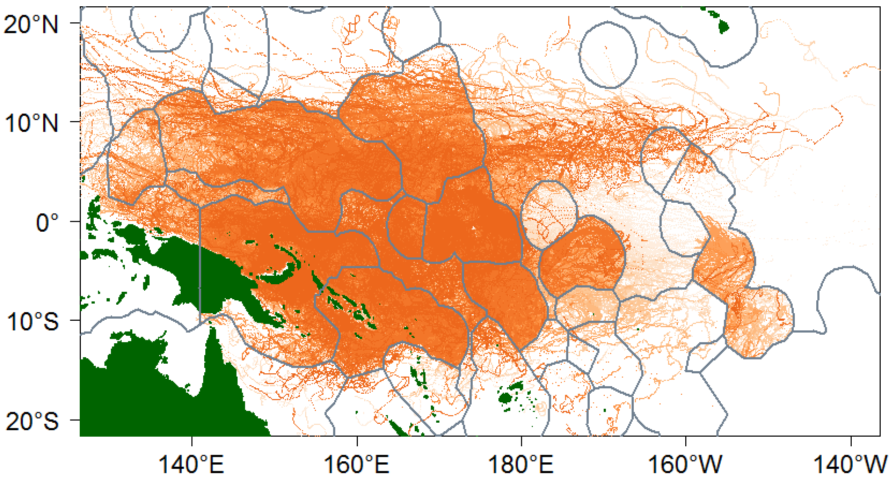

Figure 9: Position of unique FADs transmitting as part of the PNA FAD tracking trial (from Escalle et al, 2017). The colour of the track corresponds to the month of the report (light orange in January to the darkest shade in December). Note clear 'geofencing' of position reporting as FADs enter and exit some zones. Note also that this dataset includes active buoys which may be on board vessels in transit.

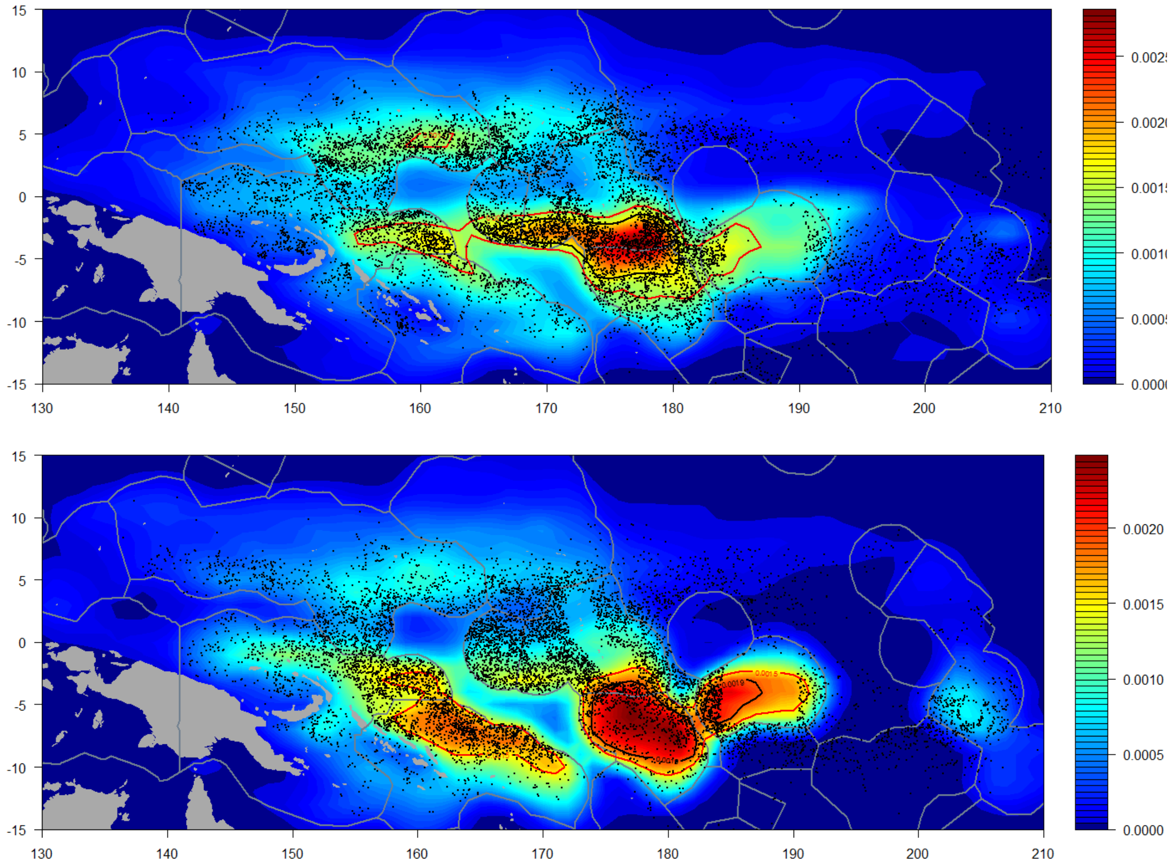

Figure 10: 'Heatmap' showing density of FADs transmitting at least once per 1° grid cell during 2016 (top) and 2017 (bottom) (from Escalle et al 2018a). Positions of associated sets as recorded in observer data are indicated as black dots. Colour scale corresponds to the proportion of transmitting per 1° cell.

The extent to which the pattern of distribution and density observed in 2016/17 reflects longer term distributions, and the extent of interannual and seasonal variability, will only be known with time. In the meantime, the results should be interpreted with caution given the reporting FADs are likely to represent only a relatively small fraction of buoys/FADs currently active in the WCPO area.

The practical effects of FAD density in the WCPO are not well studied. Higher densities of FADs can alter the habitat structure of the open ocean environment which could plausibly have impacts on target species behaviour and stock dynamics, as well as broader ecological implications. For example, in the Indian and Atlantic Oceans, Italian and Spanish skippers report that increasing FAD density on fishing grounds has led to a reduction in the school size of fish associated with FADs, as well as a decrease in the abundance of free schools (Maufroy et al, 2017). This relationship between increased FAD density and decreasing school size and availability of free schools is described in Figure 11.

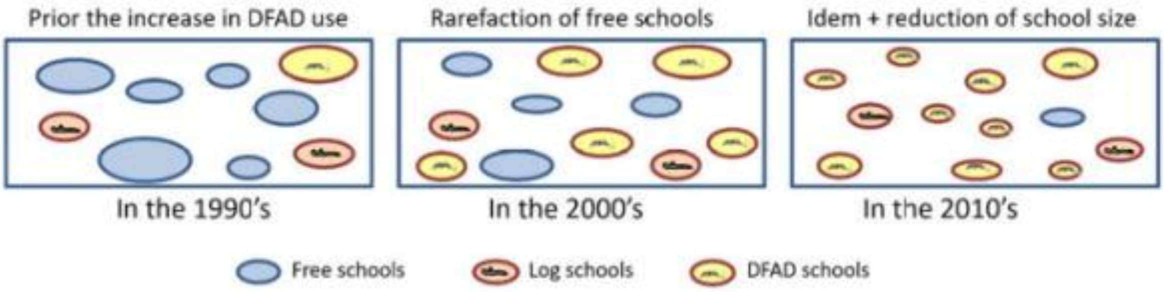

Figure 11: Impact of increased FAD density on school size and association with time (from Maufroy et al, 2017)

It has only recently become possible to examine the extent to which a similar relationship exists in the WCPO through the PNA FAD tracking trial data. Escalle et al (2018b) investigated the influence of FAD density on the number of associated and unassociated sets, as well as catch and CPUE per species. The number of associated sets and catch increased with FAD density. However, skipjack, bigeye, yellowfin and total CPUE from associated sets showed a slight decrease with increasing FAD density, with the analysis suggesting that CPUE decreases with FAD densities above 250 per 1° cell per month. No clear trend could be detected for unassociated sets.

Maufroy et al (2017) also report that “increasing the number of DFADs may alter the natural behaviour of tropical tunas, for instance by trapping tunas in suboptimal areas (ecological trap; Hallier and Gaertner, 2008; Marsac et al., 2000; Ménard et al., 2000), modifying school composition (Fonteneau et al., 2000; Hall comm. pers.), fragmenting tuna schools (Sempo et al., 2013; Fonteneau, 2014) or reducing residence times of schools under individual FOBs (instability of schools, Maufroy et al., 2016).”

2.3 Numbers deployed

The total number of FADs deployed in the WCPO is not well known. A number of groups have made tentative estimates, largely based on extrapolation from ‘known’ fleets and authorised vessel lists, although each of these are subject to inherent uncertainties and the absence of independent validation.

Gershman et al (2015) used two methodologies to estimate FAD deployments across the world’s oceans. The first approach analyzed publicly available scientific studies and RFMO reports in an effort to estimate deployments in the major tuna fisheries. The second approach estimated annual FAD use by combining the reported number of tropical tuna purse seine vessels with information on drifting FADs from industry experts and informal discussions with stakeholders in the tuna purse seine industry. Using the first methodology, they estimated a total of 29,700 FADs deployed in the WCPO in 2013 (essentially 297 vessels * 100 FADs each), although they acknowledged the estimate was probably conservative for a number of reasons. Using the second methodology, they estimated 49,710 FAD deployments in the WCPO in 2013.

Scott and Lopez (2014) undertook a similar estimation exercise based on available literature, expert knowledge of the active vessels in certain fleets, and in some cases, extrapolations considering the number of purse seiners authorized to operate in an area. Overall, they estimated around 91,000 drifting FADs were deployed annually across the world's oceans, with approximately 60% (54,600) deployed in the WCPO. Nevertheless, they noted that annual deployment estimates do not imply that the number of dFADs in the ocean increases by this value every year or that there are that number of dFADs in the ocean at any one time given FADs may be retrieved, lost, abandoned, re-deployed and/or recycled by fishers during their fishing trips. Broadly, they reported that the number of FADs deployed by a vessel during a trip will be influenced by a range of considerations including the number of other vessels' dFADs encountered, the potential poaching rate of an area, the likely quantity of free schools available in the fishing zone, the particular economic situation of the fleet owner and/or the number of dFADs deployed by vessels of the same company, which are sometimes shared.

In the WCPO, the most direct recent information on FAD deployments comes from observer reporting (via GEN-5 forms) and through the PNA's FAD tracking trial, although both sets of data are subject to important limitations. Based on this data, Escalle et al (2018b) used two different approaches to estimate the number of deployments and the active number of FADs per vessel over the past 7 years (2011-2017). The first approach used the number of deployments recorded in the observer data, the observer coverage by vessel, and a clustering of vessels based on their FAD fishing strategy to estimate the total number of buoy (and FAD) deployments per vessel and total in the WCPO. The number of deployments varied from 0 to 500 per vessel but few vessels (depending on the estimation method and year) deployed/redeployed more than 350 buoys per year. This corresponds to a total estimated number of deployments between 21,000 and 51,000 per year in the WCPO for the 2011–2014 (using the 'vessel estimates' and 'quartile 95%' estimation methods), but the numbers drop thereafter, likely due to delays in receiving observer data for recent years (Figure 12). It is also worth noting the substantial variation between the 5% and 95% quartile estimates.

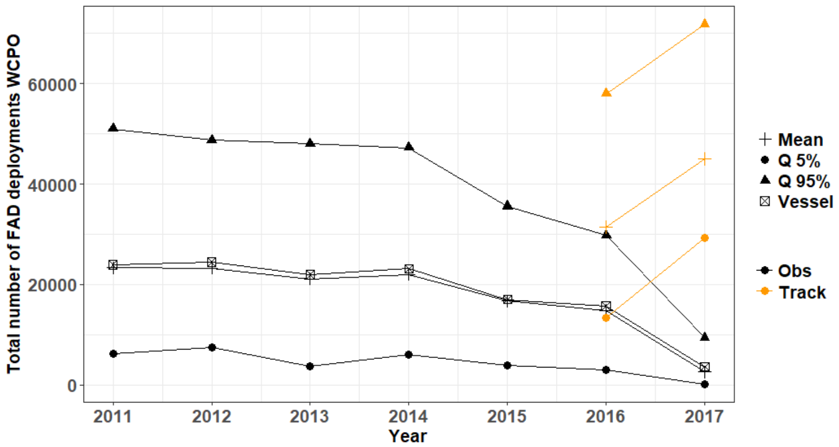

Figure 12: Estimates of the total number of FAD deployments in the WCPO using different estimation methods based on observer data only (black lines) and using a combination of PNA FAD tracking data and observer data (orange lines) (from Escalle et al, 2018b). Note that declining estimates in recent years are likely driven by delays in receiving observer data, rather than actual declines.

The second approach combined fishery data and the PNA FAD tracking data and therefore only covered 2016 and 2017 with precise estimates only possible for some vessels. The estimated number of deployments per vessel varied between 1 and 550 (mean = 129) in 2016 and 1 and 999 (mean = 226) in 2017. The estimated number of active FADs per vessel varied between 1 and 454 (mean = 102) in 2016 and 1 and 955 (mean = 163) in 2017. At the scale of the WCPO, this corresponds to 30,700–56,900 deployments in 2016 and 44,700–64,900 in 2017; and 26,200–37,300 active FADs in 2016 and 38,000–48,200 in 2017. These estimates use the mean and quartile 95% estimation methodologies as a range. The ratio between number of deployments/redeployments per year and number of active FADs per vessel and per year average at 1.48. The difference between the 2016 and 2017 estimates is likely due to the increased reporting of FAD tracking data by fishing companies in 2017.

Escalle et al (2018a and b) noted that the number of FADs deployed and proportion of FAD sets varied substantially amongst the fleet (Figure 13), with seven 'clusters' of vessels identified based on fishing strategy. Some (generally larger) vessels have fishing strategies oriented around FADs, with >75% of their sets being associated, while other (generally smaller) vessels deployed few of their own FADs and tended to focus largely on free school fishing (>80% free schools sets).

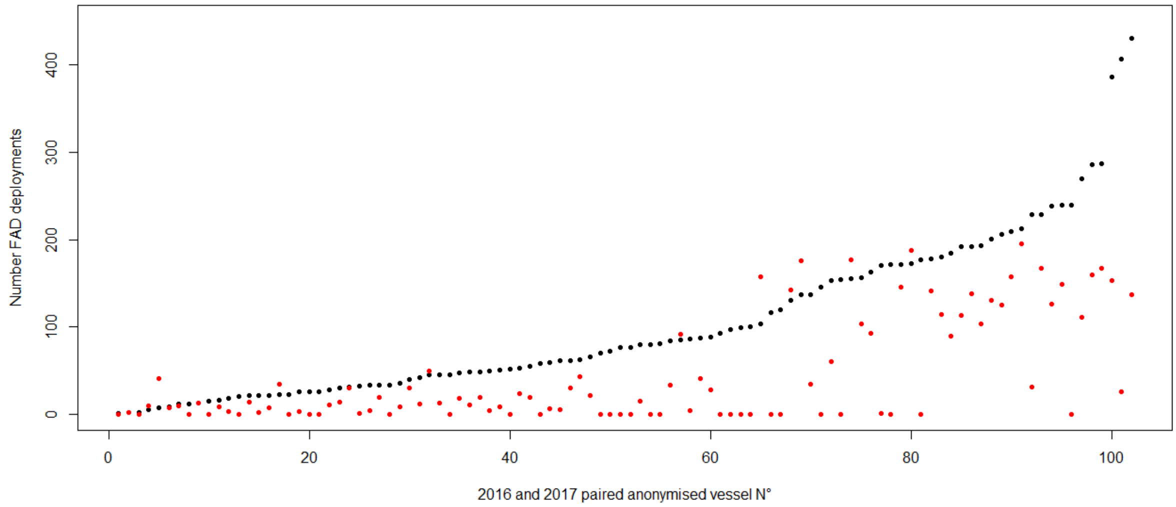

Figure 13: Estimated numbers of FAD deployments in the PNA FAD tracking trial data for known vessels, 2016 (red) and 2017 (black). (From Escalle et al, 2018a)

The mean estimate of 229 FAD deployed per vessel in 2017 is at the lower end of the range provided by companies participating in the project. The general range reported by companies was between 200 and 350 FADs per boat, with some reporting an average of around 300 FADs per boat. In all cases this was an increase on estimates of FADs used five and 10 years ago, which range from 100-200 FADs five years ago to 30-150 10 years ago. Interestingly, the estimates of FAD numbers provided by fishing companies were substantially higher than estimates provided by buoy manufacturers, who estimated around 60-100 buoys/vessel for Chinese and Taiwanese vessels and 200 buoys/vessels for all other fleets. Buoy manufacturers estimated number of buoys had increased by around 1/3 over the past 5 years.

A number of interviewees made the point that the recent limit of 350 FADs/boat adopted by WCPFC was agreed without too much drama, suggesting either that the 350 figure is not actually likely to be limiting or there are ways of managing total FAD numbers within fleets to be compliant. This is consistent with Escalle et al's (2018b) preliminary analysis indicating only 16 of 206 vessels had >350 active FADs in 2017. It is also worth noting the experience in other ocean basins suggest that any 'slack' in the limit will soon be taken up. For example, despite initially limiting themselves to 200 FADs per boat, the establishment of a much higher limit by IOTC (550, then 425) led the French purse seine fleet in the Indian Ocean to increase FAD usage, driven by competition with other fleets (Maufroy et al, 2017). SPC advised that there was no clear scientific basis for the 350 cap.

One of the potential concerns associated with the deployment of very large numbers of FADs equipped with sophisticated echosounder buoys is an increase in 'cherry picking' of FADs with the highest biomass. This could lead to substantial increases in fishing efficiency (a component of 'effort creep'), which would require active management under an effort-based management system such as the VDS. In EPO, which is arguably more FAD-dependent overall than the WCPO, Lennert-Cody et al (2018) found preliminary evidence of cherry-picking with larger numbers of deployments leading to improved fishing success in vessels deploying FADs themselves (even if this did not lead to increased numbers FAD sets). In the WCPO, Escalle et al (2018b) found that the number of deployments per vessel was positively correlated with both the number of associated sets performed and the catch per set. They noted this was to be expected where vessels with large arrays of FADs could select FADs with higher biomass before setting. Notwithstanding this, other indicators of effort creep in the PNA PS fishery appear to have remained steady or declined in recent years (Muller et al, 2018).

2.4 FAD design and manufacture

Unlike information on FAD numbers and density, relatively good information is available on FAD design and construction through observers. While there is some variation amongst companies and national fleets, many of the FADs currently in use in the WCPO share a number of common features. Perhaps the most common design features some form of float – often 6-10 purse seine floats – wrapped with used purse seine netting, with a length of purse seine netting hanging underneath. The length of net typically varies between 20m and 80m and is weighed down at the bottom with purse seine cable or rings. Many designs have lengths of bamboo inserted horizontally in the hanging netting to ensure it remains spread. Onto the net a range of attachments may be added including coconut fronds, sacking/bagging and coloured ribbons. Escalle et al (2018c) note that the depth and extent of appendages are used to control the drifting speed of the dFAD, to provide bio-fouling opportunities, and shelter and shade for associated non-tuna finfish, all of which are felt to enhance tuna aggregation.

The satellite buoy is attached to the surface raft structure with a rope of some other form of tether. The surface raft is typically designed to be low profile and with muted colouring to minimise the chances of detection by competing vessels. Observer sketches of a number of commonly used FAD designs are shown in Figure 14.

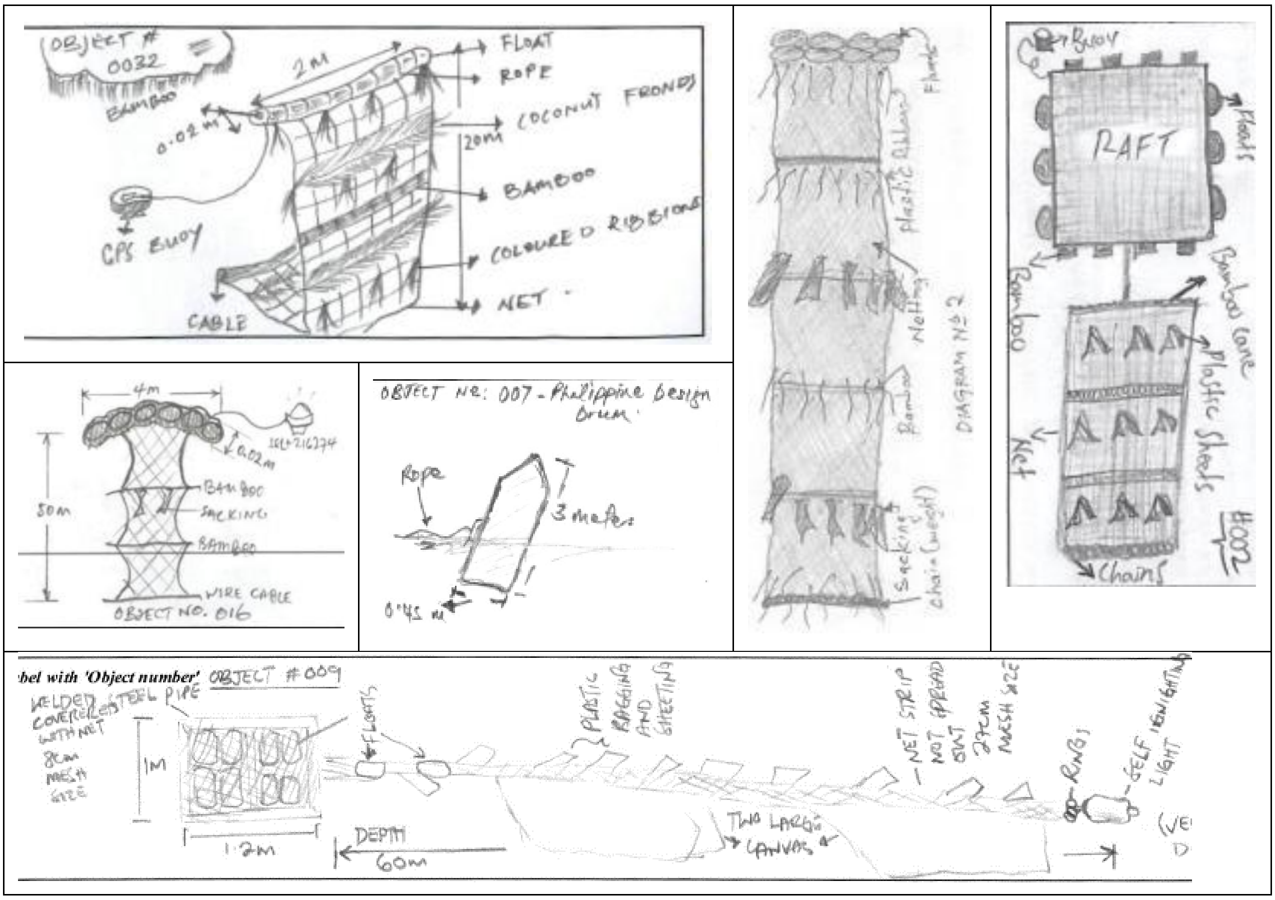

Figure 14: Observer drawings of commonly used FAD designs in the WCPO.

Variations on the above basic design include the use of bamboo, steel or PVC to form a square raft structure. Another type of FAD commonly encountered, particularly in the western areas, is the Philippines style drum, which consists of a 3-4m metal drum, conically shaped at one end (see middle drawing in Figure 14).

In recent trips (with Japanese fishing masters) observers have also reported a very deep type of FAD with up to 300m of netting underneath the buoy and a green light fitted to the bottom (see bottom drawing in Figure 14), presumably to act as an attractant, although observers indicated this design was not common.

Some of the companies interviewed for this study advised that FADs were constructed on board the vessel, while others had FADs made at land-based facilities. Skippers involved in ISSF workshops have previously advised that manufacturing FADs on land is desirable because it improves quality control, results in more uniformity in designs, and can save time (ISSF, 2015a). Observers interviewed for the project indicated that it was very common for FADs to be made by the crew while vessels were steaming. Most of the materials to manufacture FADs (old purse seine netting, cables, etc) are carried on board, with other materials (e.g. coconut palm fronds) loaded while in port.

Of the FAD designs reviewed for this study, the main components are typically made from petroleum products such as nylon netting, plastic and PVC which degrade slowly and, if not retrieved, will accumulate in the environment as marine debris. The use of biodegradable materials (apart from natural attachments such as coconut fronds) appears to be very limited. This is consistent with Escalle et al's (2018c) wider review which found the overwhelming majority of dFADs across all fleets were constructed of either entirely artificial materials, or a mixed natural/artificial raft with an artificial appendage (Figure 15). Less than 2% of dFADs were constructed entirely of natural materials.

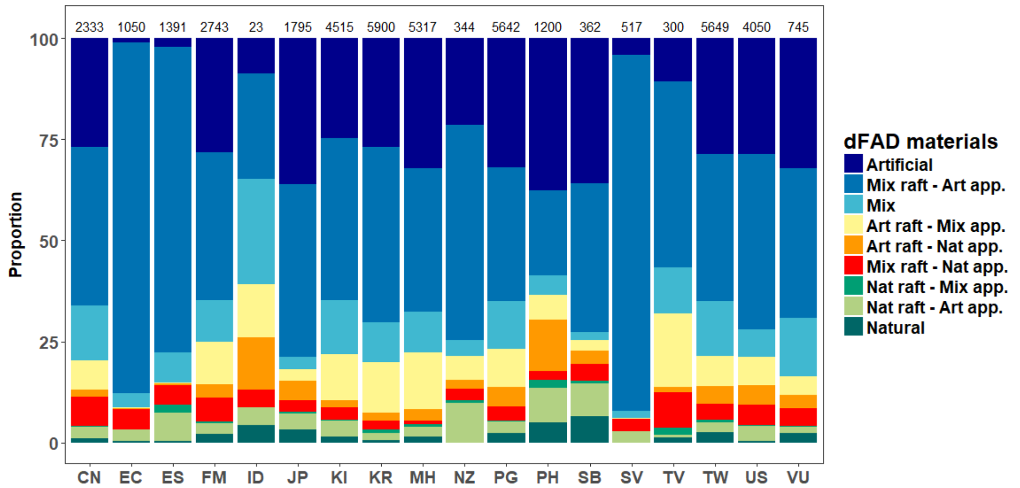

Figure 15: Proportion of dFADs constructed of natural (Nat) or artificial (Art) materials, as recorded by observers, 2011-2018 (from Escalle et al, 2018c).

The adoption of non-entangling FAD designs also appears to be limited. Although one of the companies interviewed for the study reported using 'sausage' type non-entangling FADs (where the mesh netting underneath the FAD is wrapped into sausage shapes), information available from observer reports suggests most FADs used in the WCPO continue to be relatively 'high entanglement risk' (HER) FADs incorporating exposed net with mesh sizes >7cm. Based on a review of observer reports from 2011-2018, Escalle et al (2018c) report that <12% of FADs used in the WCPO had no netting material, with between 60-90% of FAD appendages incorporating some form of netting material. They also report a slight increase in the use of netting material over time.

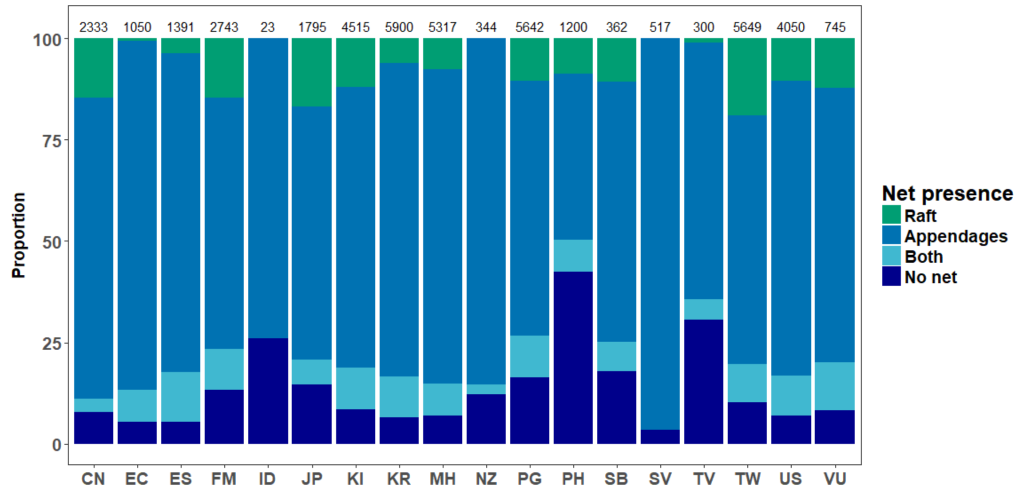

Figure 16: Use of net material in dFAD rafts and appendages, as recorded by observers, 2011-2018. (from Escalle et al, 2018c)

Research on rates and impacts of entanglement in the WCPO has been limited, although these types of HER FADs have been implicated in high rates of shark entanglement, and to a lesser extent turtle entanglement. Perhaps the most frequently quoted study estimated between 480 000 and 960 000 silky sharks were entangled and killed in FADs in the Indian Ocean, around 5–10 times that of the known bycatch (Filmalter et al, 2013). On the back of this study, purse seine fleets in the Indian Ocean moved from HER type FADs to lower risk designs comprising either smaller mesh and/or netting tied in sausages, or non-entangling FADs in which no netting material is used (Figure 17).

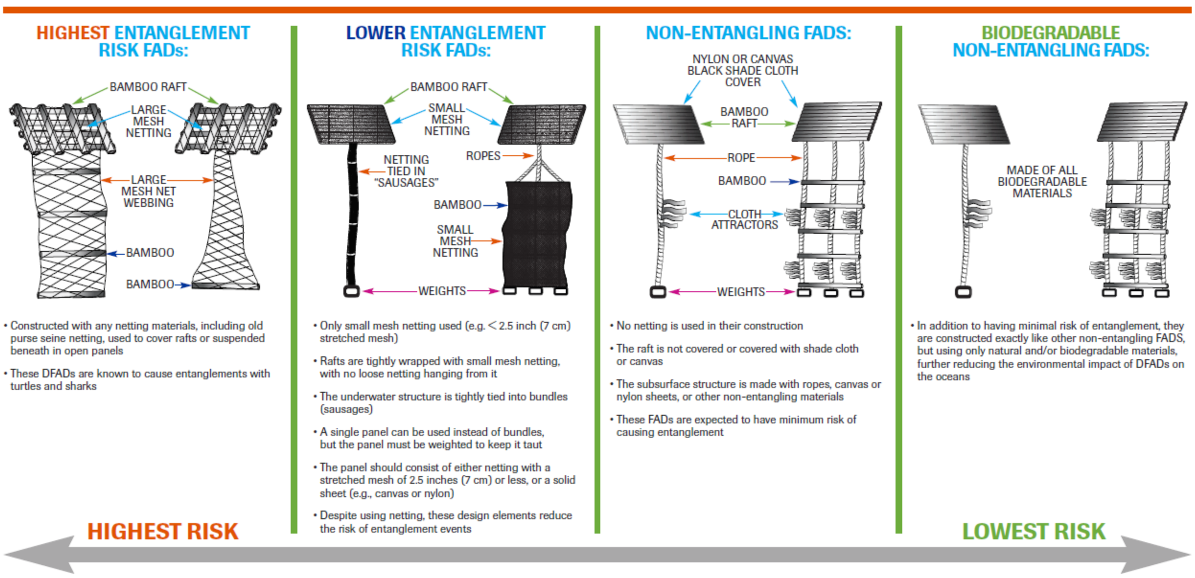

Figure 17: ISSF ranking of FAD designs from highest to lowest risk of entanglement (from ISSF, 2015b)

Measures for a transition to the use of non-entangling and biodegradable dFADs have now been adopted by each of the tRFMOs covering tropical waters:

- ICCAT has adopted measures that require the use of non-entangling FADs (NEFADs) since January 2017 (ICCAT: Recommendation 16-01, and historically Recommendation 14-01, para 31 and Annex 6);
- IOTC regulations have provided for a gradual adoption of NEFADs from 2014 onwards (most recently IOTC: resolution 17/08);
- IATTC encourages the utilization of NEFADs (IATTC: resolution C16-01);

- WCPFC CMM 2017-01 encourages the use of non-entangling and biodegradable FADs, albeit without details or a timeline. The CMM requires the 2018 annual session to consider the adoption of measures on the implementation of non-entangling and/or biodegradable material on FADs based on specific guidelines defined by the FAD Management Options Intersessional Working Group and advice from SC14 and TCC14.

Murua et al (2017) note that implementation of Lower Entanglement Risk (LER) FADs (i.e. FADs made with small mesh netting or netting tightly tied into bundles) and NEFADs (i.e. no netting used in their construction) is "practically complete" in the Indian and Atlantic Ocean, and is being increasingly adopted by fleets in the Eastern Pacific Ocean (see also Gilman et al, 2018). Although some companies interviewed for our study noted they hadn't been able to get non-entangling FADs to 'work' quite as well as current designs, Murua et al (2017) report that FADs with modifications to reduce entanglement have continued to work and catch tuna well in three oceans already, so there is no apparent reason why drifting LER and NEFADs would not work in the WCPO (they cite anchored FADs used by Philippines and Indonesian fleets in the WCPO as prime examples of NEFADS given they are constructed without the use of netting).

Skippers involved in ISSF workshops indicated that material costs of NEFADs were likely to be comparable to HER FADs. They also noted that in some ports where there is intensive construction of FADs on land due to high demand there are times when net material shortages, especially of small mesh, occur. Alternative designs with ropes, a much more common material, could prevent this problem (ISSF, 2015a).

2.5 FAD tracking systems

2.5.1 Satellite Buoy Manufacturers

2.5.1.1 *Satlink*

Satlink is a privately-held company headquartered in Madrid, Spain. They develop and sell satellite communications systems through partnerships with Inmarsat, Thuraya, and Iridium for land, aviation, and maritime markets. Satlink's marine fisheries products include buoys, electronic monitoring equipment, satellite communications equipment, and vessel monitoring systems.

2.5.1.2 *Marine Instruments*

Marine Instruments is a privately-held company headquartered in Nigrán, Spain, and a member company of Grupo Arbulo. For the longline and tuna purse seine markets, Marine Instruments manufactures radio buoys, satellite buoys, and electronic monitoring equipment, and are also completing development of an aerial drone. Marine Instruments also develops custom marine electronic systems for other markets.

2.5.1.3 *Zunibal*

Zunibal is a privately-held company headquartered in Derio, Spain. Their product lines include satellite buoys, vessel tracking systems, marine communications systems, and scientific equipment.

2.5.1.4 Kato

Located in Kaohsiung City, Taiwan, Kato is a privately-held company that manufactures and markets a broad range of equipment for the commercial fishing market. Their products include satellite and radio buoys, radio direction finders, communications systems, para anchors, strobe lights, and fishing hooks.

2.5.1.5 DigitalGlobe

DigitalGlobe is a publicly-traded company with headquarters in Westminster, Colorado, USA - a member company of MAXAR Technologies. DigitalGlobe primarily sells satellite imagery and satellite imagery services. The Marine Services division sells a GIS service providing daily maps of satellite-derived maps like water temperature, plankton, currents, weather, etc. They also sell vessel tracking hardware. They no longer sell buoys, but are included here because a number of their buoys remain active. These buoys were manufactured by Honeywell on contract to DigitalGlobe.

2.5.2 Satellite Buoy Models

Table 2 lists the specifications of most of the buoy models currently deployed by the international tuna fleet.

Table 2: Technical specifications of the main satellite buoys currently in use by the international tuna fleet.

Company	Satlink				Marine Instruments			Zunibal		Kato		Digital Globe
Buoy Model	ECO	ELB3010 ISD+ / SELECTIVE	ELB3010 ISL	ELB3010 DSL	M4I	M3I+	M3I	Tuna8 Explorer	Tuna8 Xtreme	KT-690S	KT-690SF	OBY-200
Management Software	ELB3010 Manager				MSB+			ZuniSea Controller		KT Control Software		Insight Explorer
# Transducers	2	2	1	1	3	2	1	2?	1	0	1	0
Transducer Freq (KHz)	200 ; 38	200; 38	190.5	190.5	50; 120; 200	200; 50	50	?	?	n/a	75	n/a
Weight (kg)	8	13.7	8.4	11	?	6.9	6.9	?	6.2	11.5	11.5	4.8
Communications	Inmarast				Iridium					Inmarsat		
Price										~$600	~$700	n/a

2.5.2.1 *Sounder vs. non-sounder buoys*

Sales today are almost exclusively composed of buoys that include sounders. The additional cost of a sounder buoy is negligible compared with the confidence of knowing whether fish are present. Discussions with a long-time Kato employee indicate that current sales are about 15% non-sounder buoys. Most other companies suggested near-100% sounder buoy sales. They note that over a period 3-5 years ago, the fleet converted predominantly to sounder buoys. The proportion of sounder buoys hasn't changed much during the past three years. The latest advancement in the sounder buoy market is buoys that have dual sounders at different frequencies, with the goal of discriminating between species, between smaller and larger fish, and eliminating the scatter caused by plankton. These dual-sounder buoys do not occupy a substantial share of the market yet, but as the algorithms are fine-tuned and the products accepted, their share of the market is expected to grow. Moreno et al (2017) note that research to better discriminate skipjack (which has no swim bladder) and yellowfin and bigeye (which have swim bladders) through acoustic target strength relationships is ongoing, but has not yet been incorporated into existing buoy technology.

2.5.2.2 *Price*

With the exception of Kato, the buoy manufacturers are reluctant to reveal their current pricing. The competition is steep within the buoy market. The companies struggle to maintain a sufficient profit margin so they are reticent to discuss pricing in any detail. That said, pricing is made up of two components, an initial buoy hardware price plus a recurring monthly satellite airtime charge while the buoy is active on a satellite network.

In general, non-sounder buoys from the leading manufacturers are typically USD $600-900, single-sounder buoys are ~USD $900-1,100, and dual-sounder buoys are USD $1,100+. Satellite airtime ranges from ~USD $10-30/month.

All of these prices are highly variable, however. Even the same buoy model may be priced differently between different customers. The manufacturers give discounts for myriad reasons, some of which include favoring important customers, rewarding high-volume purchases, providing attractive introductory offers, displacing competitors, or supporting customers who have worked with them to conduct sea trials. Like with the hardware, the manufacturers can also play some games with airtime pricing. Maybe they charge more for hardware and less for airtime, for example. Or they might subsidize buoy airtime if the customer uses them as their complete satellite airtime supplier.

2.5.2.3 *Competitive advantages by buoy model*

Each buoy company exploits certain advantages to capture their share of the market.

Satlink

Satlink gained enormous respect from customers with the incorporation into their sounder buoys of a transducer manufactured by long-time sonar leader, Simrad. Satlink believes their cutting-edge technology and their emphasis on environmental sustainability separate their buoys from the others. They were the first to replace lead-acid solar rechargeable batteries in their buoys with a supercapacitor. They also seek to minimize their use of non-biodegradable materials and maximize the use of recyclables in their production. Their latest "ECO" buoy utilizes two transducers at different frequencies. They claim this technology has the capability to discriminate between fish species. They say they have done sea trials with existing customers with positive results, although there has not yet been a third-party study to determine the efficacy of their dual-beam system for species discrimination. They note that algorithm development over time will improve the accuracy of this feature.

Marine Instruments

Marine Instruments believes their unique value is derived from the team of electronics and programming professionals they employ. They pride themselves on their product design and component testing. The latest Marine Instruments "M3I+" buoy model uses two transducers at different frequencies for discriminating between fish species. Like Satlink, they acknowledge that this is not a perfect science. There are limitations to the technology, but the dual-beam capability adds real benefits to customers by eliminating interference from plankton. They believe additional algorithm development should continue to improve the species discrimination capability. Marine Instruments also touts their "MSB" buoy management software, with unique tools like an "optimal route" algorithm. Using this tool, a captain can select a group of drifting buoys/FADs. Based upon the vessel location, plus drift speeds and directions, the algorithm calculates the optimal order of FADs to fish for the best time and fuel savings.

Kato

Kato buoy sales are sold almost exclusively to fishing companies in China and Taiwan. They find their main advantages to be their Chinese language sales and support, plus the lower price of their buoys. Additionally, they promote a theft-alert feature that notifies the owner of a buoy if the buoy is removed from the sea.

Zunibal

Zunibal notes the high frequency of soundings collected by their buoys every day (4,320). Zunibal also has a buoy feature that ensures the buoy will only take soundings when it is in a vertical position. Zunibal notes the "eco-design" of their buoys, being free of alkaline and lead batteries.

DigitalGlobe

DigitalGlobe's OBY-200 buoy is no longer in production, so they do not promote its advantages. While it was being sold, the low price, smaller size, and more reliable alkaline battery (compared with solar-powered rechargeables) were noted as its advantages.

2.5.3 Technical Operation

2.5.3.1 *Buoy activation*

Each of the buoy models are activated manually via a magnetic switch. Once activated, the buoy can power on, begin its initialization or automated processes, and become awake for commands.

Each buoy also must be activated on their respective satellite network (Iridium or Inmarsat). The process for registering and activating the buoy on the satellite network is handled by the manufacturer. When the customer has received the buoy and is prepared to deploy it for the first time, they contact the manufacturer with the buoy serial number to activate the buoy on the satellite network. Once active on the satellite network, airtime billing for the buoy is typically initiated by the manufacturer until the customer requests that the buoy be de-activated. Activation on the satellite network alone is not enough to begin receiving position reports or any other data from the buoy. The buoy must subsequently be activated manually by activating the magnetic switch and have a clear view of the sky so the buoy can communicate with the satellite.

When a buoy is lost or damaged, it is incumbent upon the buoy owner to notify the buoy manufacturer to de-activate the buoy from the satellite network and end the airtime billing. This doesn't need to be a permanent de-activation. Often, during a FAD fishing closure, for example, buoys are temporarily de-activated for several months before being re-activated on the satellite network when fishing resumes.

2.5.3.2 *Buoy management by fishing vessels*

Table 1 indicates the software required to command and manage the various buoys. Each manufacturer has its own control system. In some cases, they have also allowed third-party software systems (MaxSea Time Zero, CatSat, InsightExplorer, etc.) to display buoy positions, or in rare cases to send commands to the buoys.

Several companies require installation of hardware in addition to their management software. The system includes a computer, their management software, sometimes email capability, and often an integrated satellite phone. Requiring a complete, dedicated control system minimizes variables like different operating systems, different satellite communications systems, conflicting software, computer viruses, etc. It's an expensive challenge to address these kinds of problems in the remote regions where these vessels operate. The manufacturers also benefit financially by ensuring the satellite airtime required by their customers is delivered through a system supplied by the manufacturer.

The buoy management systems have the same core functions. They include an electronic navigational chart on which buoy and vessel positions are displayed. The software includes basic chart plotting tools. It also includes the tools to command the buoys and to display the sonar pictures for each buoy. There are filters that allow the operator to quickly identify the buoys or regions on the chart that are most productive based on a rough measurement of productivity calculated by the software for each sonar buoy.

With the exception of the Kato system which is quite basic, each manufacturer includes some features that are unique. Zunibal provides some low-resolution satellite oceanographic data like sea surface temperature, plankton, and sea surface height anomaly. Marine Instruments has features like the "route optimization" tool noted previously. Satlink is proud of the ease of use of its software and how intuitively they display the buoy data. Each manufacturer displays their sounder data differently, with varying levels of resolution, reporting frequency, and intuitiveness.

2.5.3.3 *Buoy management by manufacturers*

The buoy manufacturers manage the airtime and provide technical support for all the buoys they sell. Manufacturers maintain the hub of communications between the buoys and the end-users, with complete access to the data of all the buoys and the ability to send commands to the buoys. If, for example, a vessel's computer fails and the customer requires position reports for his buoys, they can request the positions from the customer support desk at the respective manufacturer.

The manufacturer also may receive additional metadata from the buoys that the customer may not see (e.g. a measurement of signal strength). This kind of information offers very little real value, but it can be used as a clue to the disposition of a buoy if there is a problem with it.

It cannot be overstated how careful the manufacturers are about safeguarding their customer's information. The buoy manufacturers recognize the buoy position and sounder data to be proprietary to their customer. The manufacturers insist that they may not share the data or use the data for other purposes without the specific consent of their customer.

2.5.3.4 *Malfunctions*

Buoy malfunctions are quite rare within the first 3 to 6 months. In the early days of the buoys some manufacturers had weaker quality control, but today there are few complaints about buoy reliability. The satellite modems and antennas are extremely reliable, and the manufacturers have perfected the materials, waterproofing, and technical aspects of the buoys after thousands of buoy deployments and multiple improvements in buoy models.

Identifying a malfunction of a buoy is not a perfect science. If a buoy sinks or is destroyed, it simply stops reporting. Neither the owner nor the manufacturer receives an indication of the loss. They simply don't receive any future reports. Likewise, if a buoy is manually turned off, there is no notification provided to the buoy owner or the manufacturer.

There are certain clues that a buoy may have malfunctioned prior to failure. For example, the buoy temperature may soar. This is sometimes associated with sea water entering the buoy through a leak and shorting the battery. Satellite signal strength can drop, causing reports from the buoy to go missing, or this may be evident in metadata from the buoy and satellite network received by the buoy manufacturers. Poor signal strength is sometimes associated with a buoy that is slowly sinking under the weight of heavy, fouled lines or a sinking FAD. In both cases, however, the buoy may simply stop reporting without a symptom.

2.5.4 Satellite Buoy Usage

2.5.4.1 *Manufacturer comments*

As one would expect, the buoy manufacturers are reluctant to disclose their buoy sales figures on a global, regional or company-specific basis. Their estimates for the typical number of buoys operated in the Western Pacific ranged from 60-100 buoys per vessel among the Taiwanese and Chinese fleets to about 200 buoys per vessel among the other fleets. One of the manufacturers estimated that these number have increased by about one third over the past five years. Another noted that the fishing companies normally comply strictly to the requirements of the local management agency regarding the number of buoys/FADs they can operate.

Sharing of buoys between vessels or companies is possible by all the buoy manufacturers and is quite frequent. The buoy owner simply contacts the manufacturer with the buoy serial number to authorize sharing of the buoy with another vessel or company. Any number of vessels can share the data from a single buoy, assuming the authorization of the buoy owner. Transfer of buoy ownership between companies is also fairly common, but none of the manufacturer will transfer ownership of a buoy to another client without first obtaining authorization from the prior owner. If a buoy is found by a third party, it is not possible for them to hack it or otherwise activate it without the assistance of the manufacturer, all of which agree they are bound to seek approval from the prior owner.

The buoy manufacturers are reluctant to discuss the deployment strategies of their customers, or they simply don't know too much about the strategies. There were no reports by the manufacturers of third parties being hired to deploy, recover, or manage buoys on behalf of the end-user. They indicated that deployment of FADs by a company-owned support vessels is done occasionally, but more so in the Indian Ocean as opposed to the Western Pacific, and typically among the largest, most capital-intensive fleets, never among the companies with a single fishing vessel or small fleet.

2.5.4.2 *Preliminary data from PNA FAD tracking trial*

To get some sense of relative usage of different buoy types amongst fleets fishing in PNA waters, FIMS data from the PNA FAD tracking trial was analysed. Under the trial, fishing companies with vessels on the VDS register are required to upload the details of all FADs in use, including serial numbers. Notwithstanding some clear problems with non-compliance (e.g. Escalle et al, 2018a), the tracking trial data provide the most accurate available snapshot of buoy usage.

To provide a 'typical' snapshot of current buoy usage, the PNAO provided a list of buoys registered on FIMS as at early June 2018 but 'unassigned' to specific fishing vessels (i.e. buoys were registered to fishing companies but not specific vessels). The unassigned buoys were chosen for administrative convenience (these were a relatively large grouping and easy to extract from FIMS), so it is possible the snapshot is not necessarily representative of all FADs registered. Nevertheless, for our purposes it provides the best available window into the buoys currently in use.

The snapshot of unassigned buoys contained 4702 buoys, of which 4188 had a registered start date of 1st January 2018 or later. Amongst these 2018 registered buoys, over half (57%) had a serial number commencing with ISL+, corresponding to Satlink (ELB3010) buoys (Figure 18). The next most frequently occurring buoy type was P, produced by Kato, which accounted for around 18% of buoys. Marine Instruments buoys (M3I, 'MSI', M3+) and Zunibal buoys (T8, T7+) accounted for around 11% and 10% of buoys respectively.

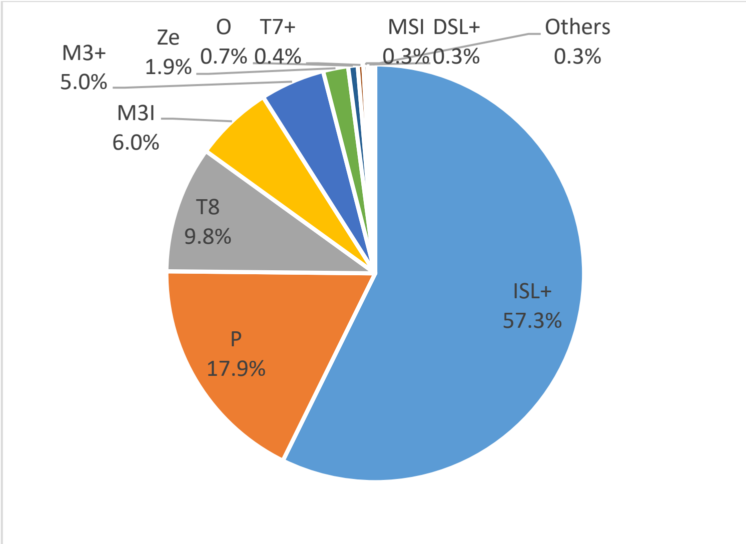

Figure 18: Buoy serial number prefix amongst 'unassigned' buoys registered in FIMS with a commencement date in 2018 (n=4188).

Amongst users of ISL+ (Satlink) buoys, the highest proportion of buoys were registered to Korean flagged vessels (38%), followed by Kiribati (25%) and FSM (14%) vessels (Figure 19) (although it is worth noting these proportions may reflect the fleets most compliant with buoy registration, rather than overall buoy usage across the fleet). Other flagged vessels to use ISL+ buoys included the US, Philippines, Tuvalu, PNG and Japan. The main users of P (Kato) buoys were vessels flagged to US, Taiwanese and Chinese fleets (Figure 19). Interestingly, around 37% of Kato buoys were of serial numbers corresponding to non-echosounder buoy models. This is consistent with experience indicating that Chinese and Taiwanese vessel operators were amongst the most sensitive to price, and therefore may be relatively later adopters of echosounder technology.

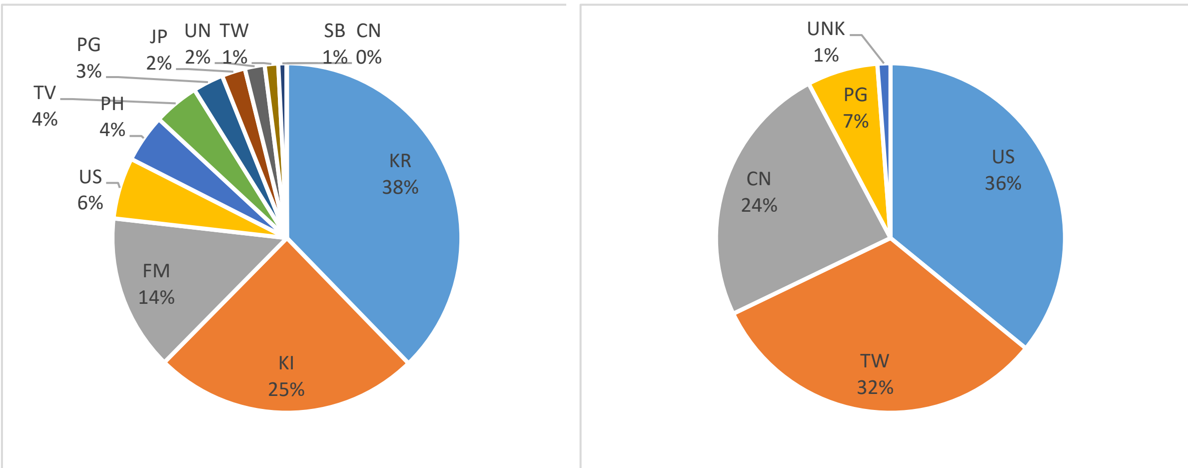

Figure 19: Proportion of 'ISL+' buoys (left panel) and 'P' buoys (right panel) registered to vessels of each flag State.

2.5.5 Buoy management comments

The buoy manufacturers made several interesting comments and suggestions during our discussions related to management within the PNA region:

- **Utilize the technical expertise of the manufacturers** - as management measures are considered, reach out to the buoy manufacturers for their thoughts on ways that technology can be developed or employed to address their concerns.

- **Integrate buoys with electronic monitoring systems** - One of the requirements of the human observers on the purse seiners is to confirm the unique FAD number of a purse seine set. It would be a simple solution if the unique registration number for a FAD was the same as the unique serial number of its associated satellite buoy. Unfortunately, it is difficult for the observer to obtain the buoy from the FAD during a fishing set and to read the serial number of the buoy. One thought is to include RFID technology within the buoy so the serial number can be automatically received by a human or electronic observer when the buoy is within range of the fishing set. This RFID technology could also track buoys that are stored on the ship for logistics purposes or perhaps to help the vessel demonstrate compliance with fisheries regulations. Preliminary discussions with RFID suppliers indicate that the retail price of an active RFID tag with appropriate specifications is around $2-4, while a reader is in the order of $2,000.
- **Geofencing capability** - Pilot programs are underway by some manufacturers to provide geofencing capability for environmental protection purposes. The thought is that geofences could be set at a fixed distance around islands or sensitive shallow waters. If the buoy crossed the geofenced boundary, an alert could be sent to the vessel and/or to management authorities. The manufacturers didn't expressly propose specific management actions like fines, requirements for FAD recovery, or remediation requirements, but the technology is being developed to support those measures if they are implemented.
- **Navigable buoy** - Marine Instruments indicates that they are developing a navigable buoy that can move on a pre-programmed or remotely-managed course. The buoy doesn't have the capacity to tow a FAD with its associated netting, but there might come a time when FADs don't require all the netting. Preliminary research suggests that in the Eastern Pacific there is no significant difference in catches between deep-net and shallow-net FADs (Schaefer et al, 2018). If this research is broadened to discover that little or no netting is required for Western Pacific FADs, the navigable buoy might have sufficient power to tow the net-less FADs to avoid reefs and islands, or perhaps return the FAD at some point to a vessel or holding area.
- **Remotely deactivating sounders** - If fishing vessels are required to guarantee the recovery of all their deployed buoys, they will need the-buoy manufacturers to modify their systems so sounders can be selectively deactivated. This would save money on satellite airtime until the buoy can be recovered, while allowing routine position reporting of the buoy to continue. Most of the sounder buoys report their positions and sounder reports together. Buoy position reports require very little data communications. Sounder reports require considerably more. When a vessel is unable to recover a buoy due to distance or other conflicts, they typically write it off as a loss and de-activate the buoy on the satellite network, essentially disposing of the FAD at sea. If they have a vested interest in recovering the buoy via a management system of incentives or penalties, they would have a financial interest in turning off the sounder while continuing to report the buoy positions, saving a considerable amount of money in satellite communications airtime.

2.6 Logistics of deployment

The logistics of FAD deployment are less widely studied in the WCPO than other ocean basins (e.g. Ramos et al, 2010; Maufroy et al, 2017). Companies interviewed for the project advised that FADs are deployed directly by the purse seiners, with FADs either loaded at the port of departure or made on board the vessel. Unlike other ocean basins, companies advised that they did not use support vessels to deploy FADs. Nevertheless, our sample is not representative of the entire fleet and at least one group of 24 buoys in the FIMS 'unassigned' dataset above was assigned to Philippines flagged vessels registered as 'support' vessels on the WCPFC RFV.

Circumstantial evidence of FADs being transported on, and potentially deployed by, longline and unidentified vessels is reported to exist, although empirical evidence is limited. It is possible that comparative analysis of VMS position for all fishing and support vessels reporting to the FFA VMS against the location of deployment recorded in the PNA's FAD tracking dataset may reveal some interesting patterns. It is also worth noting that some interviewees for the project reported 'knowing' that FADs were being deployed by third party vessels for some fleets, albeit no hard evidence was presented. One observer interviewed for the project reported at least one instance in which FADs were manufactured by crew on purse seine vessels then loaded onto carrier vessels when the vessel arrived in port.

In other ocean basins, support vessels are used across all tasks related to dFAD fishing, including deployment, monitoring of aggregations and retrieving FADs when they drift off too far from the area of interest (Scott and Lopez, 2014). Support vessels also look for and evaluate other vessels' FADs and safeguard aggregations of tuna on their own dFADs from theft by other vessels (Arrizabalaga et al., 2001). Maufroy et al (2017) report that use of support vessels had a significant effect on the efficiency of individual tropical tuna purse seiners of the Indian Ocean during the period from 2003-2014. Purse seiners assisted by their own support vessel recorded 12.3% more catch per day, 15.3% more catch per set and 12.3% more 'catch per distance' compared to purse seiners without support vessels.

All companies interviewed indicated that the position of the vessel and the direction of currents were the primary influences on deployment location. This is consistent with evidence from other ocean basins – for example, Maufroy et al (2017) found that seasonality and the use of oceanic currents were key factors for deployments in the French purse seine fleet in the Indian and Atlantic Oceans. These fishers (and associated support vessels) either avoided or targeted certain currents (e.g. in the Indian Ocean, GPS buoys were deployed off Tanzania and Kenya with the objective of a northward drift, so that FOBs could reach the cold rich waters of the upwelling off Somalia). Scott and Lopez (2014) reported that skippers interviewed for their study considered area of deployment and drift more important to FAD biomass aggregation than structural design (albeit they considered the hanging structure under the FAD was important in regulating drift to productive areas[2]).

Escalle et al (2018a) examined the position of deployments in the PNA's FAD tracking dataset during 2016 and 2017. They found that the highest rates of deployment occurred in Kiribati south of the Gilbert Islands, Nauru and east of the PNG EEZ in 2016 and 2017, as well as east of the Phoenix Islands in 2017 (Figure 20). Across both years, they identified three deployment hotspots:

1. East of the PNG EEZ and extending to the High Sea pocket 2;
2. a large hotspot in the centre of the WCPO mostly covering Kiribati, Nauru, North of Tuvalu and high Seas; and
3. West of Kiribati Phoenix Island EEZ.

[2] Albeit, note that Shaefer et al (2018) found no significant difference between drift speeds of 'normal' and shallow FAD designs in the EPO.

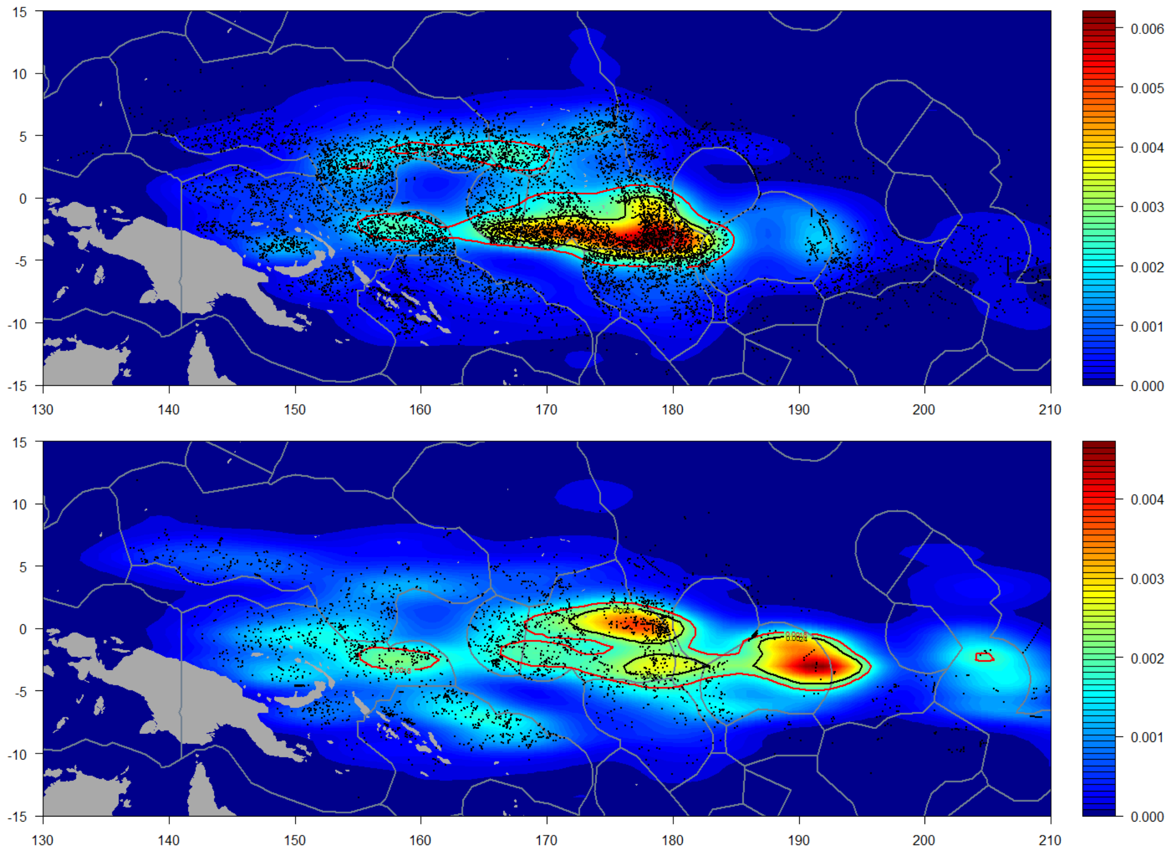

Figure 20: 'Heatmap' of buoy deployments per 1° grid cell in 2016 (top) and 2017 (bottom). Position of FAD/buoy deployment as recorded by observers is indicated as black dots (2017 data incomplete). The maximum number of deployments per cell in 2016 was 140 and 300 in 2017. (from Escalle et al, 2018a)

These results seem intuitive given the generally westward movement of the South Equatorial Current through the main fishing grounds (at latitudes below the Equatorial Counter Current) (Figure 21). Nevertheless, it is likely that geofencing and variations in reporting between different fleets mean that other important trends in the actual spatial pattern of deployments are masked. In particular, Escalle et al (2018a) point to a 'non-negligible' number of deployments outside PNA waters, specifically in the eastern High Seas, as recorded by observers, which do not appear in the FAD tracking data due to the geo-fencing.

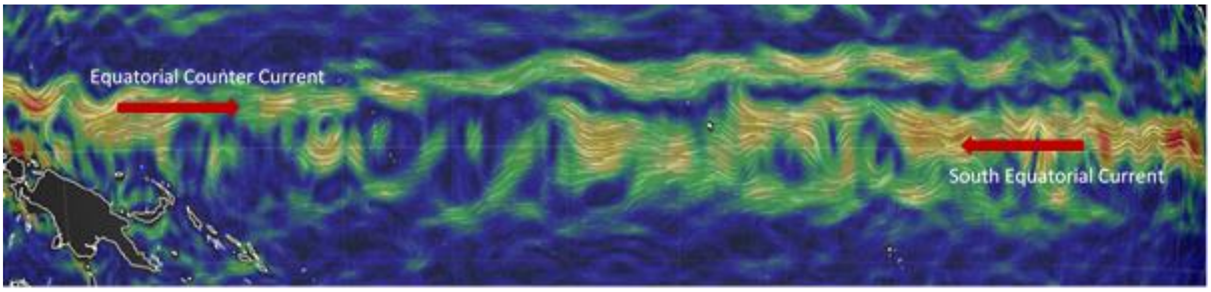

Figure 21: Current direction and strength in the equatorial WCPO, as at 1st August 2018 (Source: www.earth.nullschool.net). The South Equatorial Current between around 5°N and 10°S flows in a generally westward direction, although complex gyres may form. The easterly flowing Equatorial Counter Current exists around 5°N to 8°N.

Companies interviewed differed on the amount of time FADs were deployed in the water. Some advised the average was around 2 months (with a minimum and maximum time of deployment of 1-3 months), while others averaged between six months to a year (with some advising they'd seen deployments up to 3-4 years). Escalle et al's (2018a) analysis of the PNA FAD tracking dataset indicated that FADs drifted on average for 92 days (with around 2-3% remaining at sea for >1 year) and travelled a mean distance of 1092 km (with around 1% travelling over 5,000 km).

Most companies advised that FADs were retrieved by purse seine vessels after use, although a number indicated that where FADs drifted into closed waters, beached or drifted far from the main fishing grounds these were not retrieved. Escalle et al's (2018a) analysis showed that slightly more than half of the FADs in the PNA's trial were still drifting within the PNA region at their last recorded position, with around 25% considered to be 'lost' (i.e. drifted outside of the main fishing grounds – roughly 10°N to 10°S). Only around 10% of FADs were identified as being recovered (although this may be an overestimate if only the buoy was retrieved or appropriated and the FAD left in the water). The percentage of FAD recovery varied by company with more than 20 companies recovering fewer than 10% of FADs, while a small number of companies retrieved 40-50% (SPC, 2018). FADs identified as being recovered were almost exclusively within the 10°N to 10°S band, with very few recovered once they drifted outside this area.

Escalle et al (2018a) also undertook an analysis of likely FAD beaching events (defined as three consecutive stationary transmissions within 10km of land) within the PNA's FAD tracking dataset. They identified 1,350 likely beaching events from January 2016 to March 2018, with highest rates of beaching in PNG (483) and the Solomon Islands (379) (Figure 22). Assuming around 30% of FADs are transmitting to the PNA trial, the total number of beaching events during the same period may be in the order of ~4,100. The ecological impacts of FAD beaching in the WCPO are not well known but may include damage to sensitive coral reefs, marine pollution as well as ghost fishing. The issue of FADs beaching on sensitive habitats appears to be gaining increasing attention in at least some parts of the region's media and public consciousness[3]. Other than generic conditions under MARPOL Annex V, which makes discharge of fishing gear into the water where there is no intention to retrieve it an offence, we are aware of no specific requirements obliging vessel operators to retrieve all FADs or pay costs associated with environmental remediation. In practice this means little 'discipline' is imposed on vessel operators with respect to the number of FADs deployed, with the benefits of FAD use being privatised and the environmental costs socialised.

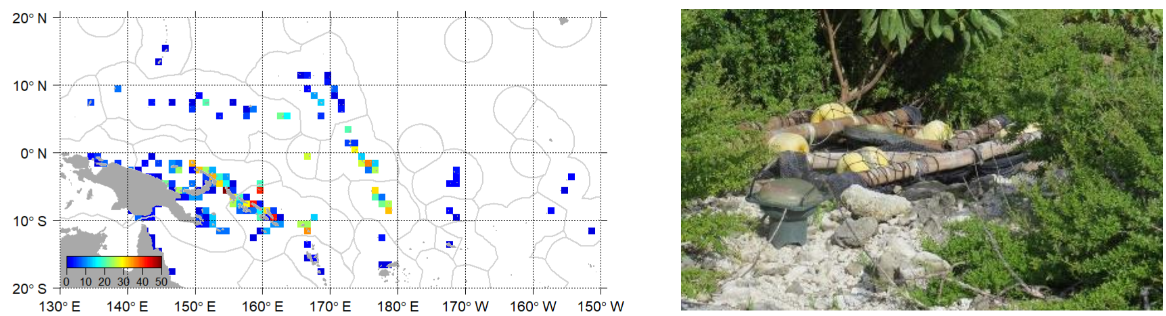

Figure 22: Density of FAD beaching events by 1° grid cell between January 2016 and March 2018 (left panel; from Escalle et al, 2018). FAD beached on the Cook Is Suwarrow Atoll (right panel; www.radionz.co.nz).

[3] http://www.cookislandsnews.com/item/69916-mmr-aware-of-fad-debris-problem/69916-mmr-aware-of-fad-debris-problem; https://www.radionz.co.nz/international/programmes/datelinepacific/audio/2018651596/fishing-rubbish-polluting-cooks-pristine-suwarrow-atoll;

2.7 Ownership, leasing and trading arrangements

There is no current requirement to register or nominate ownership of FADs deployed in the WCPO, other than through the PNA FAD tracking trial. The completeness of these registrations is uncertain, although Escalle et al (2018b) estimated around 30% of buoys are registered and actively polling. On the PNA's FAD database, some FADs are allocated to individual vessels, while others are allocated to companies.

Companies interviewed for the project indicated that FADs are largely owned by individual vessels. This seems intuitive if FADs are manufactured and deployed on board the purse seiner. In one case, the company had FADs manufactured on land and charged the vessels within its fleet at cost. Notwithstanding that, there is considerable evidence of FADs increasingly being shared by fleets. One company interviewed indicated that information from all FADs within the fleet was available to head office staff, who combined this with broader oceanographic information (currents, sea surface temperature, phytoplankton etc) to provide assistance to skippers with fishing strategies. Observers also report considerable sharing of both information (on both free schools and FADs) and FADs amongst vessels with common ownership.

While there is no requirement to register ownership of FADs, companies will often apply some form of marking to the satellite buoy itself to identify which vessel or company owns the buoy (Figure 23). Markings may allow communication between vessels (e.g. to seek permission to set on a sister vessel's FAD) or facilitate the return of the buoy to its owner where buoys swapped from FADs are taken back to port. By contrast, observer anecdotal information indicates that no markings of 'ownership' or identification are applied to the FAD structure (raft or appendages) by most companies. This is likely driven by the high level of buoy exchange between FADs and makes tracking the full 'life history' of the FAD difficult. The one exception seems to be some parts of the Japanese fleet who will often attach a unique ID to the FAD itself (usually a blue piece of hard plastic with the ID engraved, attached to the float).

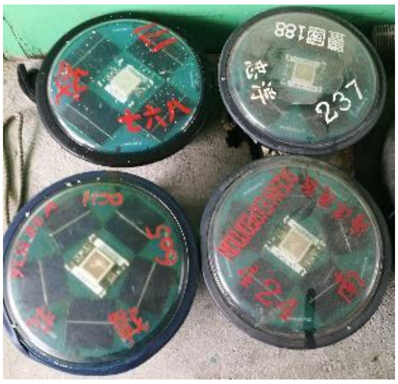

Figure 23: Satellite buoys marked with vessel identifications markings.

From a practical point of view the concept of dFAD 'ownership' is a complex one. Because buoys are frequently exchanged at sea, the original deployer of the FAD often has no knowledge of the position and fate of the FAD for much of its life. Moreover, FAD rafts and appendages are often modified by other vessels after detection (e.g. tied together, new appendages added), which may happen multiple times within a FAD's life, such that the current FAD structure may bear little resemblance to the structure originally deployed. Nevertheless, establishing ownership from a legal point of view is important in assigning responsibility for retrieval, as well as any costs associated with environmental damage (e.g. costs associated with habitat rehabilitation following FAD beaching). Assigning ownership to individual vessels is also essential in monitoring compliance with any vessel-based FAD limits (e.g. the 350 FAD/vessel limit under WCPFC CMM 2017-01). Given the frequent exchange of buoys, the most practical approach is likely to be to assign ownership – and therefore legal responsibility - to the company who owns the satellite buoy that is currently attached to the

FAD (see for example discussion on FAD ownership in Gilman et al, 2018). In practical terms then, swapping buoys on a FAD at sea is a conscious decision by the vessel captain to assume ownership and responsibility. If no buoy is currently attached to the FAD, the company who owned the buoy most recently attached to the FAD should be assumed to be the owner, if this can be established.

We have been able to find no clear evidence that third party businesses either leasing or selling pre-deployed FADs are operating in the WCPO, although that doesn't necessarily mean it's not happening and at least some interviewees claimed to have knowledge of third party vessels deploying FADs. Intuitively, in the current operating environment where (a) there are few limits on FAD deployment and no responsibility attributed to FAD owners for environmental costs, and (b) there are considerable profits to be made from FADs with high biomass associated with them, mass deploying FADs and selling or leasing ownership of productive FADs appears to be a potentially viable business proposition. This might be particularly the case for businesses with existing vessels capable of mass deployment and access to cheap materials (e.g. used purse seine netting). As discussed above, it is possible that correlation of VMS information with FAD deployment location from PNA's FAD tracking data may provide further insights into parties currently deploying FADs, however current geofencing of data may limit the usefulness of the analysis.

By contrast, there is clear evidence of trading of FADs amongst vessels within the fleet, or between ocean basins. Perhaps the clearest evidence comes from trades between EPO and WCPO vessels for FADs originally deployed in the EPO, but have drifted westwards into the WCPO. One company we spoke with reported it was common for trades to occur between captains of the same flag State who knew each other. In most cases the price is reportedly not very high, with codes for satellite buoys being 'sold' for a few hundred dollars or a proportion of the initial catch from the FAD. Escalle et al (2018b) also identifies a group of vessels which report few deployments but the highest catch per set in the WCPO who's results may be explained by FADs being set in the EPO and either leased or traded to large WCPO vessels.

Although there is less evidence of trading between regions in the WCPO, it seems perfectly plausible that vessels who typically operate, for example, in the eastern areas would seek to recover some costs for FADs which drift too far westwards.

3 Options for FAD Management

The final component of objective 1 of the TORs requires the identification of options for future FAD management. Our general conclusion from the background research in Phase 1 was that, although there were areas in which demonstrably effective action on FAD management had been taken (e.g. there is clear evidence the FAD ban established by PNA, and later mirrored by WCPFC, has reduced bigeye mortality, consistent with scientific advice), overall the PNA (and the broader WCPO) is generally 'behind the 8 ball' on FAD management across a range of areas.

In particular, despite the acknowledged potential for increased FAD usage (and in particular widespread uptake of latest generation echosounder buoys) to substantially alter the efficiency, operational character and economics of the purse seine sector, relatively basic information and systems to support effective management and track impacts over time are lacking. This includes, for example:

- a lack of good information on number of FADs deployed and actively monitored;
- a lack of information on FAD distribution and density, as well the absence of a fishery-wide system to register and track the real-time location of FADs (although FIMS has proven itself technically capable of tracking FADs, non-compliance and geofencing have weakened the utility of the data); and
- an absence of good information on FAD deployment and retrieval.

Importantly, there is currently no obligation on industry to report information on FAD use to management authorities, other than to provide an indication of set type in logsheets. Given the rapid evolution of FAD usage and technology in the past decade, this has ultimately meant that industry's understanding of FAD usage and its impact on economics is likely to be well ahead of PNA Parties at present (which is not a healthy situation for any fisheries manager/resource owner).

In addition to a lack of information, there is little recognition in the current management system of the environmental costs associated with using FADs. These are broadly of three main types: (a) impacts on bycatch and non-target species from dFAD sets, (b) incidental mortality ('ghost fishing') of non-target species from entanglement in dFADs and (c) costs associated with habitat damage and marine debris from dFAD beaching events. There is no clear responsibility on owners to retrieve FADs at the end of their productive life or take responsibility for the environmental costs of remediation in the event of beaching. Moreover, until the recent WCPFC 350 FAD limit (which itself is probably a Clayton's cap for most vessels) deployment was essentially uncapped.

Against that background, our overall view is that the general 'architecture' of FAD management in the WCPO is in need of significant strengthening across a range of areas (e.g. strengthening information, better registration, marking and monitoring, environmental measures, etc). If necessary, new management measures should be introduced sequentially, focusing initially on measures to strengthen the information base and better registering, marking and monitoring FADs and subsequently on extracting optimal economic rents associated with FAD use. Our view is that it's in PNA's interests to lead that process – e.g. through a new or revised Implementing Arrangement (IA) focused on FAD management – rather than relying on the WCPFC process to produce necessary reforms. We note this is consistent with PNA Leaders' Delap Commitment to better manage FADs signed in March 2018.

With that in mind, the project team worked with PNAO to produce the paper reproduced at Annex 1 setting out possible management reforms across four main areas:

1. **Improved provision of FAD data** – this would place obligations on vessels operators to provide information on FAD inventories, design and all activities (e.g. deployment, setting, retrieval, etc);
2. **Registration, marking and monitoring and control measures** – these measures would require all buoys used within PNA waters to be registered, uniquely identified and allow for continuous tracking until retrieval. The measures would also allow for 'ownership' of FADs to be determined;
3. **Environmental measures** – these measures would seek to recognise the environmental costs associated with FAD use by making owners responsible for retrieval of all deployed FADs and any costs associated with beaching. Measures would also aim to reduce incidental mortality and habitat damage through use of low entanglement and biodegradable materials;
4. **'Economic' measures** – these measures set out a range of economic instruments that could be applied to achieve management/economic objectives. A key issue will be to ensure that any new measures do not result in the creation of an instrument for rent extraction separate from (and potentially competing with) the VDS.

The paper was considered by a workshop of PNA Parties held in Brisbane on 18-21 June, 2018.

From a project perspective, the key outcomes were that:

- Participants supported the need for an IA, particularly to ensure that PNA maintains control of FAD management
- Participants broadly supported the proposed information provision, registration, marking and monitoring and environmental measures – PNAO would take the lead on progressing these issues;

- The project team would examine the 'economic' options as part of Phase 2 of the current project – Parties agreed that all options in the paper should be considered in the SWOT analysis except for prohibiting FAD usage, which they considered impractical.

In the context of the 'economic' measures, participants noted that:

- removal of the 4th month had removed the biggest problem with the FAD closure;
- The main advantage of the FAD closure was that it was easy to apply and it avoided difficult allocations, and applying additional limits on top of the VDS which would be difficult;
- Raising revenue was not a purpose of any additional FAD measures and that the VDS would remain as the instrument for raising revenue – options involving fees should be designed to create incentives to modify industry behaviour to fish sustainably rather than raise revenue. Some of the measures might result in additional revenue, but that was not the purpose of the exercise;
- PNA needed to continue to consider alternatives to the FAD closure because of the risk that the changing technology would increase FAD fishing outside the closure period;
- The Consultants need to consider the impact of any alternative FAD measures on domestic fleets as well as the overall fleet profitability;
- Any limits relating to FADs need to be allocated to Parties, not vessels and be tradable.

To that end, examination of these 'economic' options (including the original FAD leasing concept) through a SWOT analysis will form the basis of Phase 2 of the project. The intent will be to relatively efficiently identify the most attractive and practical options for more detailed examination in the Phase 3 'business case'.

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Annex 1: Management Options paper

PARTIES TO THE NAURU AGREEMENT

Workshop

18-21 June 2018

Brisbane

WP4. FAD MANAGEMENT ISSUES

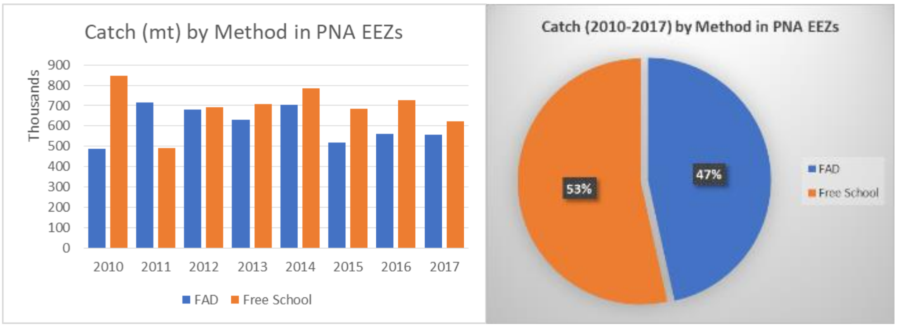
Background

1. PNA Leaders recognised the continuing priority attached to improved FAD management when they decided at their recent Summit *"To task Ministers to develop measures to reduce bycatch including the improvement of the management of FAD fishing."*

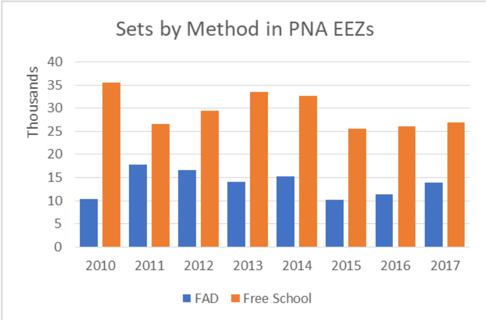
2. Parties had already agreed at PNA37 to:
   a) Approve, in principle, preparation of a 3IA requiring FAD Buoys to be registered and report to FIMS.
   b) Run a workshop to upgrade the attached programme to be a policy document to be endorsed in late 2018.
   c) Note the opportunities to combine further work on the FAD charging Trial with ongoing work on FADs, including FAD tracking.

3. Some relevant features of the FAD fishery include:
   a) Around **90% of the industrial purse seine fishery FAD sets are made in PNA waters**[4]. This has been the basis for PNA taking control of the regulation of FADs in PNA's interests, and having the Commission follow. **A feature of the current setting is the intense effort of industry and fishing states to have the Commission take greater control of the regulation of FADs to meet their interests, and reduce PNA control**.
   b) Almost **half of the purse seine catch in PNA waters and the WCPO is taken in FAD sets** as shown in the table below – although this still means that most of the catch is taken in sets on free schools

[4] References to PNA include Tokelau



But the use of FADs seems to be increasing as shown below



c) Those catches in FAD sets make a **very large contribution to the economic returns to PNA** from the purse seine fishery because of the higher catch rates in the purse seine fishery

d) In terms of our understanding of the impacts on regional stocks:
- Fishing on FADs rather than free schools generally makes **little difference to the state or productivity of the skipjack and yellowfin** stocks;
- Fishing on FADs rather than free schools has a **substantial impact on the state and productivity of the bigeye stock** and on the stocks of some other species taken as bycatch in the purse seine fishery, **particularly silky sharks**

e) Compared to **other oceans**, there is a **much lower share of the catch in the WCPO purse seine fishery taken by fishing on FADs**, largely because of the FAD closure, as shown in the table below; and it is likely that this contributes to the more positive status overall of the major WCPO tropical tuna stocks.

Shares of Purse Seine Catch Taken in Free Schools (2010-12)			
Atlantic	E Pacific	Indian	W. Pacific
33.2%	21.1%	23.2%	50.6%

f) **FAD technology and use continues to develop rapidly**. Recent developments include:
- **Mass deployment**, as the cost of buoys decreases and the power of buoys increases, with vessels reported as deploying hundreds/thousands of buoys per boat
- The increasing use of **sonar capable/echo-sounding** buoys, replacing VHF and satellite-linked GPS buoys, that provide increasingly accurate information on biomass indicating the presence and size of schools with the FAD

- **The use of vessels other than the purse seine vessel** to deploy and recover FADs

A key outcome of the technology gains is the ability of fleets to **cherry pick FADs** to set on through centralized monitoring and directed targeting of the purse seine vessel without having to physically visit the FADs, **reducing searching time and focusing effort on the most productive FADs**. These ongoing developments appear to have the potential to substantially restructure the fishery encouraging **greater use of FADs, higher catches per set and possibly changes in the geographical pattern of fishing across the WCPO. Larger catches of target species per set may also reduce bycatch mortality.**

g) **Trends in catch rates and fishing power are unclear**: as shown below, neither CPUE in the FAD fishery in terms of catch per set or the overall show yet the clear increases in catch rates that would be expected from the reported advances in FAD technology – depending on how the high CPUE in 2015 and 2016 is viewed. Recent skipjack and yellowfin stock assessments also do not point to increases in fishing power, raising the possibility of FAD saturation, in the same way as reportedly observed in the Indian Ocean

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Catch/day (mts)	28.1	27.8	27.5	29.4	28.2	23.4	29.8	28.4	32.4	35.6	35.6	30.8
Catch/FAD set (mts)	42.0	42.3	37.9	41.3	41.5	36.7	37.9	41.5	43.4	47.6	46.9	39.4

h) Estimates of FADs **annually deployed in PNA waters** are **about 50,000 – 80,000 units**. Most are not set on;

i) The **FAD Closure**, introduced by PNA in association with the VDS, **has been surprisingly effective** in reducing bigeye catches, as shown in the SPC table below

Annual Purse Seine Bigeye Catches								
	2009	2010	2011	2012	2013	2014	2015	2016
Actual	53,798	52,075	70,562	61,806	69,991	64,598	47,274	57,282
W/out FAD Closure	61,410	65,082	86,615	76,804	94,657	80,846	62,153	81,679
% Reduction	12.4%	20.0%	18.5%	19.5%	26.1%	20.1%	23.9%	29.9%

j) **The costs of the FAD closure have also been greater than expected**. The FFA has previously estimated the costs of the FAD closure in terms of reduced catch as around $15m per month of closure per year. However, this does not include the reduction in revenue from the reduction in days sold and the overall reduction in competition for days reducing overall VDS prices.

FAD-Related Initiatives

PNA FAD Tracking Trial

4. The trial has shown that:

a) FAD registration and tracking is feasible

b) FIMS is capable of tracking FADs as long as the service provider copies the reporting to FIMS in agreed NAF format

c) the architecture developed under FIMS can provide a fully integrated reporting mechanism for FADs that also incorporates the VDS, eObserver Reports, and eLog Reports as well as Catch Summary.

5. However, the trial has failed to secure comprehensive industry compliance with the requirements for provision of FAD tracking data because of the weakness of the legal basis for the requirement for provision of FAD tracking data and enforcement. Among other things, many vessel operators have failed to report near real time to FIMS, many have not registered FADs at all, or have switched them on to register then stopped the FIMS reports, or geo fenced the reports switching them on when they enter the EEZ, and switching them off as they leave.
6. The Trial has also shown that FADs are being deployed commercially by longliners, LL carriers, Tankers, and dedicated support craft as well as purse seiners, typically in high seas areas.

WCPFC FAD Management Options Intersessional Working Group (FAD IWG)

7. The IWG will have its 3rd meeting in Majuro on 3rd October.
8. The agenda has not yet been provided, but at WCPFC14, the agreed PNA statement, which was not delivered because of time included the following:
   - *PNA appreciated and supported the work of the FAD WG*
   - *We thought good progress was made in some areas including provision of additional FAD data, FAD marking and FAD research priorities.*
   - *We consider that there is scope for additional useful work through the FAD WG to build these outcomes and on ecological FAD design*
   - *we see little value in the WG reworking issues on FAD management which have already been given substantial attention without progress in the past.*
   - *The bulk of the FAD sets in this region are made in the waters of coastal states, and most of them are in the waters of PNA and other FFA Members.*
   - *PNA has well developed strategies for managing FADs in PNA waters and, while we are open to new ideas, there will be little value in a FAD Working Group with a focus on how fishing on FADs should be managed in PNA waters.*
   - *In addition, in our view, the standards for managing FADs in this region are higher than under other tuna RFMOs.*
   - *That is one of the main reasons why this is the only oceanic region in the world where most of the Purse Seine catch is taken on free schools.*
   - *In other regions, the bulk of the Purse Seine catch is taken in sets on FADs or dolphins. We are open to an exchange of ideas on managing FAD fishing in the WG, but we cannot agree to lower relevant standards, such as the definition of a FAD set, to the levels applied in other regions such as the eastern Pacific.*
   - *That would not be a good use of the time of the Working Group*
9. It follows from this that PNA would want the Agenda to focus on the areas of *additional FAD data, FAD marking and FAD research priorities* that were the areas of progress in the previous work of the IWG, as well as Non-Entangling and Bio-Degradable FADs. In addition, it was agreed in CMM 2017-01 that the IWG will review whether the limit on the number of FADs deployed for each vessel is appropriate. Since the meeting is only one day, there is little scope for covering additional items.

10. However, it was clear from the remarks of NGOs at WCPFC14 that they expect to open up the whole area of FAD management options, and fishing states will surely support that move.

11. The broad position of PNA at WCPFC14 was that if the FAD IWG went down that road, this would be the last meeting of the IWG – PNA would not agree to it continuing. An alternative approach is to limit discussion on FAD management options to high seas only. At the same time, Parties might want to use the IWG to provide information on what is being planned for PNA waters.

PNA FAD Management Scheme Study

12. This study was initially a response to the decision of the Parties at SPNA47, where it was agreed that PNA should undertake a study of PNA involvement in owning and leasing of FADs. The scope of the study was subsequently broadened to cover other FAD Management Options. Following the decision of the Parties at PNA37 to approve, in principle, preparation of a 3IA requiring FAD Buoys to be registered and report to FIMS, the Study personnel have provided, in collaboration with PNAO, the analysis below of options for possible elements of Implementing Arrangement provisions relating to FAD management as a basis for discussion in that direction.

13. The study is being undertaken in 3 phases:
    a) The first phase was a review and compilation of existing information on FAD usage, finishing with the identification of possible management options (including the original commercial leasing scheme proposed);
    b) The second phase is a SWOT analysis of the possible management options; and
    c) Phase 3 is a 'business case' for the implementation of the most attractive option/combination of options.

14. The team is largely finished the Phase 1 review, but has jumped ahead a bit to provide the attached list management options for this meeting. The next phase will do a SWOT analysis of the options in the paper that Parties wish to see considered further with the intention to have the Phase 1 and 2 reports finished to allow consideration at the pre-Ministerial in Nauru. If its practical, we would seek some guidance from Parties at that meeting about which options/combination of options they'd like us to do some more detailed work on in the Phase 3 'business case'.

Possible Objectives:

15. As with any management/economic reform, there is a need for PNA Parties to agree and define the objectives to be achieved.
16. In the case of a strengthened package of FAD management measures, possible objectives may be to better understand and manage FAD usage in PNA waters:
    a) for the purposes of stock and ecosystem management;
    b) for the purpose of optimising sustainable returns to PNA Parties in the longer term;
    c) To strengthen PNA control and improve compliance with FAD-related national laws in PNA waters; and
    d) To minimise impacts of FAD usage on the environment.

17. Objectives should be realistic and achievable and, if necessary, proceed in a step-wise manner. For example, it may be the case that our current knowledge of the fleet/vessel level economics is insufficient to determine a 'best' approach to optimise rents associated with the use of FADs. A

shorter term objective then might be to improve our understanding of fleet/vessel economics (by introducing measures, such as FAD tracking to collect better information) to allow us to make an informed decision in the medium term.

18. Defining the objectives to be achieved is a necessary step in evaluating the effectiveness of alternative management measures and optimising the design of any future package.

Conclusion

19. Parties are invited to:
    a) Discuss and consider the proposals in the Attachment for inclusion in a PNA Implementing Arrangement covering:
        i) Improved Provision of FAD Data
        ii) Registration, marking and monitoring and control measures
        iii) Environmental measures

    b) Review the proposals for "Economic Measures" with a view to identifying any proposals that should be put aside without further consideration by the Study Team

Attachment - Possible measures to be addressed in a PNA Implementing Arrangement:

Possible management measure	Issues/questions
Improved Provision of FAD Data	
Vessel operators to provide data on: a) FAD design and construction of FAD to be deployed or encountered (materials, electronics, size etc) b) FAD activity (deploying, retrieving, setting, visiting, loss etc)	• Vessel operators will be required to provide (by e-reporting): - an inventory of electronic buoys including ID no. at the start and end of each trip - data on each FAD interaction - data on FAD design (materials, size etc, • This has already been agreed by WCPFC12 • Is there any other FAD data PNA want vessel operators to provide?
Registration, marking and monitoring and control measures	
No vessel may set on a floating object (unless it is on the PNA FAD Register/unless there is an electric buoy attached that is in good standing on the PNA FAD Register)	• There is a fundamental question of whether PNA should register the FAD (i.e. including the attachment) or just the electronic buoy • The current PNA FAD definition will be retained • There will be a reporting requirement – minimum twice daily and any polling? • Should anchored FADs be covered? Yes definitely to avoid loop holes and so their numbers and locations are known • The PNA FAD registration process will need to be sufficiently robust to attach legal responsibility to the designated FAD operator – this may require a FAD registration by the FAD operator and then FAD/buoy activation can be automated • Ownership of FAD buoy should be able to be transferred with agreement of both parties • There will need to be a type approval relating to the capacity of the buoy (echosounding required – no) • Good standing will cover reporting • Extra-territoriality is an issue – can PNA require info on HS deployments like the port to port requirement for VMS • Confidentiality is an issue. There will need to be a confidentiality arrangement parallel to that for VMS • A key question here is around compliance – to what extent will the observer be involved in monitoring compliance, and what access will they have to the register of FADs? Presumably, the observer will need access, as now to data on bridge identifying the FAD – beyond that, to what

	extent should the observer be able to access the PNA FAD registry for data on that FAD or other FADs (say in the vicinity) or on the vessel at the start of the trip
It is an offence for a FAD/electronic buoy to be in the waters of a PNA Member unless: a) (the FAD is on the PNA FAD Register/ there is an electric buoy attached that is in good standing on the PNA FAD Register) b) the FAD operator is authorised to operate FADs in the waters of the PNA Member	• this is the key requirement for FAD tracking • a key element of the registry is to attach responsibility for a FAD/buoy to a FAD operator this is a major issue • all domestic operators (FSMA) would be authorised to operate FAD in all Party waters • others would have to secure authority through buying licenses for fishing or some equivalent instrument
All (FADs/buoys) must be 'marked' with a permanent, unique identifier	• Although monitoring the buoy allows monitoring of the number, distribution and density of FADs in the WCPO, given the frequency of buoy swapping and appropriation the only effective way to track the 'life history' of a FAD is to apply a permanent, unique ID on the FAD itself. Understanding the life history allows us to examine key management questions (e.g. aggregative capacity of different designs/materials, influence of soak time on aggregation, influence of deployment location on aggregation, etc) • Marking both the FAD and buoy is consistent with proposed FAO guidelines of marking of fishing gear. • Anecdotal information indicates the FAD is already marked by some fleets (e.g. Japanese) • The key question for PNA is whether to make marking of the buoys and attachments a PNA requirement or leave it for the WCPFC
Every FAD operator shall ensure that all buoys within the tropical WCPO (to be defined) shall report from deployment to retrieval	• This provision should be structured to avoid geofencing of information – a question is how best to structure this requirement to ensure information continues to be transmitted on the high seas and elsewhere outside PNA waters in the same way that VMS data is required to be transmitted from port to port • A key issue for industry if the data is provided in near-real time will be confidentiality, which might be based on the confidentiality arrangements for VMS.
It is an offence to switch off satellite buoy communications until the FAD is retrieved	• This stops companies switching off buoys when FADs are outside the main fishing grounds, and allows tracking of position to facilitate retrieval • Switching of satellite buoys when outside fishing grounds arguably demonstrates no intent to retrieve the FAD which is an offence under MARPOL Annex V

	• Similar issues here around extra-territoriality of powers – need to ensure arrangements can be structured such that Parties can make it a requirement to continuously report outside of PNA waters (i.e. if the transmission is switched off outside PNA waters, it is still an offence)
It is an offence to set on, or interfere with, a FAD not associated with the vessel	• This is a fundamental issue – does PNA want to protect the property rights of vessel/FAD operators in the FADs they deploy • FADs can either be 'associated' with a vessel, or a fleet/company. Considerable setting on other companies' FADs occurs at present, with buoys often cut off and discarded. • Making it an offence to set on another vessel/companies' FADs or detach the buoy and attach another arguably provides greater protection and 'asset value' of each FAD for fishing companies – it is possible (albeit unclear) that this would reduce the incentive to deploy 'extra' FADs because some will be set on by other vessels (the corollary being that all vessels appear to set on other vessels' FADs, so it may not make much difference) • Banning setting on, or interfering with, the FADs of others, greatly simplifies and strengthens keeping track of FAD attachments
Treat FADs as fishing gear for the purpose of national laws	• This measure would make all national laws applying to fishing gear also applicable to FADs, such as requirement for licensing, requirement to keep FADs out of territorial seas and closed areas etc • This is probably the case already but this would confirm it. • FAD registration and tracking greatly enhances the practicability of this approach • Issues include: - Whether this would undermine FAD fishing unduly - Whether this should be left as a national/Party option • If Parties agree, national laws would also cover non-interference with FADs
Control on Support Vessels	• There is substantial uncertainty about the extent of support vessel use but the FAD Tracking Trial shows vessels other than purse seiners engaged in deploying and retrieving FADs • It is probably time to start controlling support vessels more effectively including requiring them to report on FAD related activities and carry ROP observers if they are deploying or retrieving FADs
Environmental measures	
All buoys and man-made attachment (deployed in PNA waters/WCPO) must be retrieved.	• FADs deployed but not retrieved contribute to marine debris, and may beach in sensitive habitats such as coral reefs

<table>
<tr>
<td>The company/vessel registered as the operator of the FAD buoy is responsible for retrieval. Responsibility continues irrespective of whether the FAD is inside or outside PNA waters.

Where FADs beach, the FAD operator is responsible for any environmental remediation costs.</td>
<td>• Under MARPOL Annex V, it is an offence to deploy fishing gear unless there is a legitimate intention to retrieve it
• Making companies responsible for retrieving FADs and paying the costs of environmental remediation is likely to create considerable disincentives to ‘profligate’ FAD deployment
• There are a range of practical questions here around how to make this requirement work effectively – e.g.
- should a geofenced boundary be established around all land and reef areas (e.g. territorial seas); perhaps with alerts at 50nm and 12nm to boat and coastal state
- should vessels be required to pay a bond for retrieval/rehabilitation?;
- At what point does the FAD need to be retrieved – for example, if the FAD clearly drifts out of the main fishing areas, should there be a requirement to retrieve it – or some penalty?</td>
</tr>
<tr>
<td>All man-made FADs must be constructed from non-entangling materials by XXX</td>
<td>• FADs made from entangling material (e.g. purse seine netting) have been implicated in the incidental capture of large numbers of sharks (mainly silky sharks), and to a lesser extent sea turtles in other ocean basins (e.g. Indian Ocean - albeit the extent of studies have been relatively limited)
• The extent of entanglement in the WCPO is not well known. On the one hand, one study estimated that half a million silky sharks were entangled annually in the Indian Ocean. On the other hand, SPC has reported that in 2015, when 40,000 silky sharks were estimated to be caught in the purse seine fishery, WCPO observers noted less than 10 dead silky sharks entangled in netting under dFADs, although these were observed only in the infrequent event that dFADs were lifted from the water. Overall, silky shark mortality rates are low, varying from by set type.
• Vessels/companies in other ocean basins have reportedly successfully transitioned to non-entangling FADs, with limited impacts on catch rates of target species, but there are some contrary reports in this region
• The use of non-entangling FADs in the WCPO appears limited, although given the experience with similar fisheries in other oceans, there is probably a reasonable expectation that a transition to non-entangling materials could be made without fundamentally altering fleet economics
• ISSF committed to all authorised vessels to use non entangling FADs in the WCPO, but little evidence of their use is reported.
• If the concept of moving to non-entangling FADs is accepted, there is a discussion with industry around how quickly a transition could be achieved</td>
</tr>
</table>

	• The fundamental issue for PNA on FAD design is whether to take this on as a PNA measure or leave it to the WCPFC, at least for now • An alternative would be to establish a scientific program to gather evidence on rates on entanglement in PNA waters or the WCPO, and base future decisions on the outcomes. Relevant scientists would need to be consulted on the likely costs and timeframe involved. A consideration is whether Parties see value in attempting to have the FAD component of the PNA PS fishery MSC certified. In the absence of good information on entanglement rates, there may be pressure to act precautionarily.
All FADs/FAD attachments must be constructed from biodegradable materials by XXX	• There is likely to be a discussion here with industry around the balance between biodegradable Vs responsibility to retrieve – e.g. industry may be willing to transition faster to demonstrably biodegradable materials as a trade off to a requirement to retrieve given costs involved • The impact of a transition to biodegradable materials on catch rates/economics is not known • There is some definitional work to be done • PNA Members need to be clear about the impacts on their domestic fleets • The overall fundamental issue again is whether PNA want to take this on, or leave it for the WCPFC for now
'Economic' measures	
Note: the measures below will be explored in the SWOT analysis in Phase 2 – they represent options only and are designed to cover a broad suite of possible approaches. The outcomes of Phase 2 will be presented to PNA Parties – the 'business case' and implementation arrangements behind the most attractive option (or combination thereof) will be explored in more detail in Phase 3. We have NOT set out respective pros and cons below. A key issue generally will be the extent to which alternative FAD management schemes establish a right separate to the VDS, and whether this serves to strengthen or weaken existing arrangements.	
Ban FADs	• There is considerable demand for 'FAD-free' tuna in the global marketplace, with price premiums of various quantities paid by different schemes. • The key question here is whether price premiums associated with free school fishing (and any broader environmental benefit – e.g. no FADs beaching on reefs) could outweigh the operational advantages of FAD usage. The impact on VDS price would be a key consideration, but perhaps difficult to predict.
Charge for FAD days	• A charge for FAD days could be applied in two forms: a) A price premium for VDS days in which FAD sets are made (this could be either <u>prospective</u> - i.e. within the overall TAE, decide a maximum number of 'FAD days' and charge a price premium for these – or <u>retrospective</u> – i.e. charge a fee for each VDS day in which a FAD set

	is actually made, based on logbook/observer data). The prospective option above is similar to the FAD day model already agreed by Parties, but which appears to have little traction to date. b) A charge for each day that a FAD is within a Party's EEZ (irrespective of whether its set upon) – e.g. if we assume 60,000 FADs in the WCPO, operating 365 days/yr – a charge of $1/day would generate $21.9m. Parties would receive revenue proportional to the number of FAD days in their zones. Revenue from FADs polling on the high seas could put to other uses (e.g. funding the PNA Office) or distributed amongst the Parties.
Charge for FAD sets	• Similar to the charge for FAD days, a charge could be applied for each set made on a FAD (equivalent perhaps to the difference in assumed profitability between FS and FAD sets, or slightly more to act as an incentive for FS sets) • In the same way as FAD days above, a charge for FAD sets could be applied prospectively or retrospectively
Limit the no. of FADs	• The overall number of FADs operated in PNA waters (at any one time/over a year) by vessels on the VDS Register could be limited. This option may be attractive if the number of FADs in the water is important for management purposes (e.g. if FAD density impacts stock dynamics, if it affects the availability of free schools, if entanglement/beaching is a problem, etc. There are 2 main forms of limits to FAD nos. a) Allocating the FAD limit to Parties, to in turn allocate amongst fleets (e.g. by auction) would automatically create a right separate to the VDS. The impacts of two separate rights would need to be thought through carefully. b) Allocating to vessels, which is effectively what is done in CMM 2017-01 with the 350 FAD buoy limit per vessel – this effectively creates a vessel/flag-based limit – which PNA could modify for PNA waters e.g. reduce foreign vessels to 250 FADs/buoys each
Limit the no. of FAD sets	• A total no. of FAD sets would be allocated among Parties • It was considered by PNA as the alternative to the FAD closure and FAD charging • It is regarded as global best practice • It requires a difficult allocation and is complex to apply alongside the VDS
Charge for each FAD deployed	• A charge could be levied for each FAD deployed – this might be attractive if Parties consider there is no need to limit the overall number of FADs deployed (within the 350 cap). The charge could be adjusted in future to act as an economic limit on FADs (i.e. put as many FADs in the water as you want up to 350, but they're going to be expensive; FADs over a certain number could be charged at a higher rate

Rebate for free school days	• Under this option the benchmark price for VDS days could be raised by an agreed amount (broadly consistent with the expected profitability increases arising from FAD usage), with a rebate paid to vessels if they could demonstrate they fished on free schools only. The benchmark price and rebate level could be adjusted in future as knowledge of the economics of FAD fishing improves, with a clear incentive for FS fishing.
PNA Leasing scheme	• This option would be consistent with the TORs for the project – i.e. PNA prohibits companies from setting on FADs except for those operated by PNA, and establishes its own operation (either solely or in partnership with a commercial entity) to deploy and lease FADs • An alternative may be to establish a smaller commercial trial to test the market for FAD leasing and get a better understanding of FAD logistics and costs.
Status quo (with marking/monitoring/env)	• This option would adopt the agreed FAD registration, marking, monitoring and environmental measures only, and instead attempt to optimise revenue collection through the VDS (i.e. by allowing industry to optimise their own profitability/capacity to pay through optimal FAD usage).

PNA FAD Management Scheme

Phase 2 Report

October 2018

About MRAG Asia Pacific

MRAG Asia Pacific is an independent fisheries and aquatic resource consulting company dedicated to the sustainable use of natural resources through sound, integrated management practices and policies. We are part of the global MRAG group with sister companies in Europe, North America and the Asia Pacific.

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Contents

1 INTRODUCTION ... 2

2 CURRENT FAD RIGHTS AND ECONOMICS ... 3

2.1 FAD Rights: The Status Quo ... 3
2.2 The Right to Set on a FAD ... 4
2.2.1 The Benefits of Setting on a FAD ... 5
2.2.2 The Benefits of Setting on FADs: Price Discovery Challenges ... 5
2.2.3 The Environmental Costs of Deploying and Setting on FADs ... 6
2.3 The Right to Deploy a FAD ... 7
2.4 Determining the 'Right' Number of FAD Setting Rights for the VDS ... 9
2.4.1 Illustrative Example ... 9

3 SWOT ANALYSIS OF FUTURE FAD MANAGEMENT OPTIONS ... 10

3.1 Charge for FAD days – 'FAD Day' option ... 10
3.1.1 Overview of option ... 10
3.1.2 SWOT analysis ... 11
3.1.3 Summary analysis ... 11
3.2 Charge for FAD days – 'Buoy day' option ... 12
3.2.1 Overview of option ... 12
3.2.2 SWOT analysis ... 12
3.2.3 Summary analysis ... 13
3.3 Limit number of FAD sets ... 13
3.3.1 SWOT analysis ... 14
3.3.2 Summary analysis ... 14
3.4 Charge for FAD sets ... 14
3.4.1 Overview of option ... 14
3.4.2 SWOT analysis ... 15
3.4.3 Summary analysis ... 16
3.5 Limit number of FADs ... 16
3.5.1 Overview of option ... 16
3.5.2 SWOT analysis ... 17
3.5.3 Summary analysis ... 17
3.6 Charge for each FAD deployed ... 18
3.6.1 Overview of option ... 18
3.6.2 SWOT analysis ... 18
3.6.3 Summary analysis ... 19
3.7 Rebate for free school days ... 19
3.7.1 Overview of option ... 19
3.7.2 SWOT analysis ... 19
3.7.3 Summary analysis ... 20
3.8 PNA FAD leasing scheme ... 20
3.8.1 Overview of option ... 20
3.8.2 SWOT analysis ... 23
3.8.3 Summary analysis ... 24
3.9 Status quo ... 24
3.9.1 SWOT analysis ... 24
3.9.2 Summary analysis ... 25

4 GENERAL OBSERVATIONS AND CONCLUSIONS ... 25

5 PROPOSED FOCUS OF PHASE 3 ... 27

6 REFERENCES ... 29

1 Introduction

This report is the second in a three-part series of reports to the Parties to the Nauru Agreement (PNA) focusing on FAD management. The reports are the main outputs of a World Bank Ocean Partnerships Project-funded project aimed at underpinning the development of a PNA FAD Management Scheme.

The project is broadly structured in three sequential phases:

1. The **first phase** focused on reviewing and consolidating existing information on FAD usage in the WCPO, and the preliminary identification of possible future management options;
2. The **second phase** is intended to assess the strengths, weaknesses, opportunities and threats associated with the future management options, including a commercial leasing scheme, to determine the economic and environmental merit of the concepts and the legal implications;
3. The objective of the **third phase** is to develop a business case for the most attractive future management option (or combination of options).

This report sets out the results of the Phase 2 SWOT analysis (see Box 1). The analysis focused on the 'economic measures' outlined in the future management options paper developed by the project team and the PNA Office at the conclusion of Phase 1. Consistent with the discussions with PNAO during the early stages of the project, the scope of economic options to be considered was broadened from the original focus solely on a PNA commercial FAD leasing scheme. The intent of the Phase 2 SWOT analysis is to allow for a rapid screen of the available options with a view to identifying the most attractive candidates for more detailed 'business case' analysis during Phase 3.

Box 1: What is SWOT analysis?

SWOT analysis is an analytical framework for examining the key factors influencing the achievement of a specified objective. SWOT analysis groups key pieces of information into two main categories:

- Internal factors — the *strengths* and *weaknesses* internal to the organisation; and
- External factors — the *opportunities* and *threats* presented by the environment external to the organisation.

Strengths and weaknesses are internal attributes that are either helpful or harmful to achieving the objective. These can be changed over time with some effort.

Opportunities and threats are external factors that either enhance or reduce our chances of achieving the objective. These are happening whether we like it or not.

In most cases, SWOT analysis should be short and simple, and should avoid complexity and over-analysis because much of the information is subjective.

A key consideration in undertaking the SWOT analysis was the extent to which each option contributed towards achieving the objectives of the PNA FAD Management Scheme. Parties have not had a chance to formally define these, but on the basis of the outcomes of Phase 1, were assumed to be broadly:

1. Strengthening PNA's understanding of, and capacity to analyse, FAD usage and its impacts in WCPO purse seine fisheries (including biological, ecological, economic and social impacts);

2. Strengthening PNA's capacity to control, manage and monitor ongoing FAD usage in WCPO purse seine fisheries for the purposes of achieving Parties' individual and collective fisheries objectives; and
3. Minimising to the extent practical the environmental costs associated with FAD use, and to ensure any costs unable to be reduced to zero are borne by FAD users.

The project team also took into account the main outcomes of the PNA Parties' Workshop on FAD management issues, held in Brisbane on 18-21 June 2018, as well as subsequent discussions with PNAO staff in Auckland on 29th June. In particular, the Brisbane workshop noted that:

- removal of the 4th month had removed the biggest problem with the FAD closure;
- The main advantage of the FAD closure was that it was easy to apply and it avoided difficult allocations, and applying additional limits on top of the VDS which would be difficult;
- Raising revenue was not a purpose of any additional FAD measures and that the VDS would remain as the instrument for raising revenue – options involving fees should be designed to create incentives to modify industry behaviour to fish sustainably rather than raise revenue. Some of the measures might result in additional revenue, but that was not the purpose of the exercise;
- PNA needed to continue to consider alternatives to the FAD closure because of the risk that the changing technology would increase FAD fishing outside the closure period;
- The Consultants need to consider the impact of any alternative FAD measures on domestic fleets as well as the overall fleet profitability;
- Any limits relating to FADs need to be allocated to Parties, not vessels and be tradable.

The Auckland meeting further noted that:

- It is possible that two instruments may be required: (1) to mitigate against mortality associated with setting on FADs and (2) another to mitigate against mortality associated with all deployed FADs; and
- International experience clearly showed that two management systems (e.g. quota and pot limits) running side by side was overly complex and contradictory - having two systems of limits or allocations or charges would likely undermine VDS revenues.

For each of the economic measures examined, a brief overview of the option is provided together with a SWOT analysis. Based on these, a discussion of the key issues arising is presented along with recommendations for the Phase 3 business case analysis.

2 Current FAD Rights and Economics

2.1 FAD Rights: The Status Quo

Before reviewing the options for FAD management, it is important to describe the status quo as accurately as possible from a property rights and economics perspective. There are two distinct existing rights relating to FADs:

i. The right to deploy a FAD
ii. The right to set on a FAD

The future relationship between these two rights is critical to the design of an effective FAD management regime and its associated incentives. The economics of this relationship are actually very complicated for four reasons:

i. The costs and benefits of both FAD deployment and FAD setting are highly variable (dependent on time, place and a range of environmental factors).

ii. Harvesters in the WCPO and Parties to the VDS independently face very different sets of costs and benefits with respect to FAD deployment and use.
iii. The deployment of, and setting on, FADs are separate but inter-related phenomenon but the management of these two activities is currently a contestable space. Any lack of integration in their respective management can have unpredictable consequences.
iv. The deployment of, and setting on, FADs have large environmental and economic spill-over costs or externalities that are not effectively included in the calculus of those who either deploy or set on FADs.

These externalities are explored in more detail below but the fundamental challenge in the design of a FAD management regime is to ensure that all costs and benefits are counted in decision making about FAD deployment and setting. It is only when this condition is met that it is possible to determine whether FAD use increases or decreases the value of Days individually and collectively in the VDS. This is not simply an exercise in gathering better information about those costs and benefits (which are poorly understood today) but ensuring, as far as possible, that costs and benefits are aligned.

FAD management is not a 'clean slate' exercise. As outlined above, Parties have expressed some clear preferences about design of future arrangements already. In addition, the absence of an effective regulatory regime for FADs today does not mean that there are not property rights with significant present value, notwithstanding their informal nature. It is essential to compare any future option with this existing rights framework. This description is dealt with in two parts (setting and deployment).

2.2 The Right to Set on a FAD

- Outside of the three-month closure period, VDS Day holders are entitled to fish on FADs.
- Within the geographic ambit of the VDS, the right to set on a FAD is therefore an attribute of the current Day right and the benefits available to harvesters from this attribute are therefore embodied in the price that buyers are prepared to pay for a Day.
- Outside of the FAD closure period, every Day sold/purchased carries an attached sub-right to set on a FAD up to twice in that Day (for practical purposes).
- Currently, FAD setting rights are therefore initially owned by Parties to the Palau Arrangement in proportion to their relative PAE for a given year. They are transferred to Day owners when those Days are transferred by the Parties (by whatever transfer methods are employed by those Parties).
- Under the status quo, therefore, any increase in the net benefits of FAD fishing to harvesters can be expected to drive up Day prices (to the extent that competition for Days encourages buyers to bid away all but normal returns on fishing when pricing Days).
- Conversely, any decrease in the net benefits of FAD fishing to harvesters, say through the imposition of additional FAD compliance costs, will depress Day prices (all other things being equal).
- The benefits of setting on a FAD are currently shared between Parties and harvesters. The exact split of benefits will be sensitive to the process by which Days are sold.
- Under current arrangements, all revenue obtained by Parties in the form of FAD charges represents an equivalent reduction in total Day revenues available from the VDS. This conclusion is also true for all future FAD charging regimes.
- Individual Parties have the existing right to regulate setting on FADs in their Exclusive Economic Zone (including banning setting on FADs) by changing the attributes of single-zone Day rights sold to restrict or ban setting on FADs. The costs of such restriction or ban would be borne wholly by the Party in the form of reduced Day revenue. Any environmental benefit of such restriction or ban would be shared with other Parties.

2.2.1 The Benefits of Setting on a FAD

The targeted general benefits of setting on a FAD are to improve the overall efficiency (profitability) of purse seine fishing under the VDS and the pressure to use FADs originates from the harvesting sector. To the extent that these improved returns are above the normal rate of return on capital outlaid by purse seine fishers to obtain them, some of those benefits are potentially available to Day sellers in the form of increased Day prices, providing the structure of the Day selling process is sufficiently competitive to require buyers to give up those 'surplus' benefits out of fear of losing access to Days through under-bidding for them. There are therefore currently two separate cost/benefit analyses that determine whether FAD setting is economically beneficial:

i. <u>Harvesters</u> presently weigh the cost savings of operational efficiencies from FAD setting against the costs of FAD deployment plus any associated regulatory costs, compliance costs and FAD fees. This harvester-centric analysis captures all of the economic benefits but only a portion of the economic costs of FAD use.
ii. <u>Parties</u> need to weigh the portion of the harvesting efficiency gains (above) they are able to capture in the form of increased Day prices against the environmental costs of FAD use that are not considered at all in the cost/benefit analysis of harvesters (but lack the information to carry out this comparison). In other words, Party-centric cost/benefit analysis needs to compare the <u>environmental costs</u> of FAD use not counted by harvesters against the share of <u>harvesting benefits</u> of FAD use offered by harvesters as a real FAD Day premium.

We can summarise the situation as follows: FAD use is good for harvesters (given the limited set of costs they actually face) but we do not know if FAD use is good for Parties (all costs considered). The problem is that Parties currently do not know what FAD premium is built into current Day prices (their share of the net harvester benefit of FAD use) and have no agreed process to try and quantify the potential environmental and associated economic costs of existing or future FAD use that ultimately rest on their shoulders alone. Obtaining estimates for these Party-specific benefits and costs is respectively difficult and very difficult. Without these two vital pieces of information (at least to the quality of credible estimates) Parties have no proper way of estimating the net benefits to them of either existing FAD management arrangements or the respective merits of any alternatives to the FAD management status quo.

It follows from this observation, that a key desirable attribute of any future FAD management option will be its capacity to generate, and then apply, that information for the ultimate benefit of Parties.

2.2.2 The Benefits of Setting on FADs: Price Discovery Challenges

As mentioned, Tokelau has already applied a FAD charge and other Parties are following this development with interest. The difficulty is that a FAD charge, particularly if introduced by a single Party, provides less information about the value of setting on a FAD than is often assumed. First, it is hard to say how much of the FAD charge is being financed by the harvester through discounting the associated Day price. Second, the FAD charge probably does not reveal the full extent of the willingness of the buyer to pay a FAD premium because of the high level of competition between the nine sellers of single zone Days and the associated shallowness of the 'market demand' for Days in any one zone. Competition between sellers not only reduces the pressure on buyers to reveal their true willingness and ability to pay for Days, it also reduces the pressure to reveal their true willingness and ability to pay for supplementary FAD rights joined to Day rights. At the extreme, if a Party 'over-reaches' in the relative size of its FAD charge, some buyers may well abandon the market in Days from that Party, further weakening the Party's position as a seller.

These general issues of buyer collusion and seller competition on the performance of the Day market have been examined in detail within the 'Capitalisation' project which proposes a partial solution in the form of the creation of a standardised multi-zone day sold through a single auction process. FAD management considerations can be potentially integrated within such a market and are discussed in more detail below.

Notwithstanding the problems of interpreting the results of existing FAD charging initiatives, the anecdotal reports that a charge of around $3,500 would be needed to change behaviour away from FAD use are intuitive. The reason is that if the costs to the harvester of using FADs are greater than the benefits, then they will not be used. If we assume that 60,000 FADs are currently deployed for 15,000 sets, then the average benefit of a FAD set must be above the costs of deploying and operating four FADs. Taking the life of a FAD as 10 months, and FAD costs of $1,100 each plus telecom charges of $20/month ($200)[1], then the harvester cost per FAD set = 4 x ($1,300) or $5,200. Obviously, this cost is reduced if the FAD set:FAD deployment ratio is better than 1:4 and this is presently a sketchy assumption.

Another way of presenting this simple logical analysis (based on the assumptions above) is to say that if the average benefit to a harvester per FAD set is not $5,200 then FAD fishing is corrosive of Day revenues. At $5,200/set the marginal benefit of a FAD set to a harvester is nil and the capacity of the harvester to support a FAD charge over and above the Day price they would have paid in a fishery closed to FAD fishery is also nil. It is only when the benefits of FAD fishing rise above these minimal direct costs to harvesters of $5,200 per FAD set that Parties even have the prospect of receiving any revenue that can offset the environmental costs and risks from FAD use ignored by harvesters in their cost/benefit analysis and economic decision making.

2.2.3 The Environmental Costs of Deploying and Setting on FADs

The evidence is that FAD fishing within the VDS (at least at certain times and places) generates positive net benefits to harvesters. Those benefits include reduced fish search costs, steaming times and increased tonnages of fish caught per set or per Day. Strictly speaking this 'evidence' is a (reasonable) presumption that harvesters know their costs and pursue strategies that enhance their bottom lines. However, a positive net benefit to harvesters is not necessarily a positive net benefit to the fishery or to its effective owners; the Parties. This is because of the external costs or spill-over costs of FAD fishing including:

Setting

i. Setting on FADs changes the composition of purse seine catch, increasing the proportion of juvenile yellowfin and bigeye tuna. FAD fishing increases the harvesting pressure on the most vulnerable species in the purse seine fishery compared to an equivalent amount of free-school harvesting.
ii. Setting on FADs increases the catch of some associated non-target species such as silky sharks.
iii. Setting on FADs reduces the average size of target species harvested i.e. for the same tonnage of catch, FAD fishing causes more fish mortality per tonne of product.
iv. There is a negative market perception of FAD fishing that depresses the potential value of fish from fisheries that allow this practice. Individual companies who wish to sell FAD-free labelled product can do so, but with significant verification cost and lower benefit because of practices in the balance of the fishery.

Deployment

[1] See page 21 of Phase 1 Report

v. Certain FAD designs cause mortality of marine life through 'ghost fishing' for as long as they are not recovered, while entangling materials in beached FADs may also cause mortalities of seabirds and other animals.
vi. Non-biodegradable FADs that are not recovered can comprise a durable and unsightly litter problem where they eventually run ashore. FADs may also result in physical damage to sensitive reefs even where they are biodegradable (e.g. bamboo).

The existence of spill-over effects is widespread in most economic activity and can be an acceptable cost of obtaining an associated economic benefit. Spill-over effects are often able to be ameliorated. Effects v. and vi. (which strictly speaking are spill-over effects of FAD deployment rather than setting on FADs) can be substantially reduced by FAD design and construction controls and/or requirements for FAD retrieval. These effects form a distinct category that is best addressed by an appropriate regulatory approach rather than through a price mechanism.

Setting

Some FAD setting effects can also be ameliorated by the tools already available within the VDS. For instance, the fact that FAD fishing may increase tonnes of fish taken per Day is not, in itself, a problem under the VDS. If catch per Day increases by 10% then the TAE needs to be reduced by 10% to maintain the target catch level and stock size in the purse seine fishery. Similarly, the impact of reduced average fish size can be managed through a further reduction of the TAE to account for the higher mortality numbers/tonne of catch that FAD fishing produces once that change in mortality rate is known.

The potentially serious (and difficult to ameliorate) FAD setting externalities arise from the change to catch composition of species that would occur through the widespread use of FADs in the WCPO purse seine fishery (i and ii). Relative to free school fishing, FAD fishing increases mortality of yellowfin tuna, bigeye tuna and certain 'vulnerable' non-target species such as silky sharks. The immediate concern is the effect of more extensive FAD fishing on the bigeye tuna stock, already under pressure from the ineffectively controlled longline fishery. While the bigeye tuna stock remains above its limit reference point and there is no target reference point for this stock, the spill-over effect of this increased mortality is minimal. However, if the increased mortality should reduce the bigeye tuna stock to below any adopted target reference point, then the spill-over effect will be the need to introduce stricter conservation measures. The available conservation measures will affect the performance of the whole purse seine fishery and would therefore be very costly. If the increased mortality should reduce the bigeye tuna stock to below the limit reference point (LRP) then the conservation response required within the options available under the VDS is potentially enormously expensive.

Bigeye spill-over effects are not linear and given the current state of scientific certainty about the state of bigeye tuna relative to its reference points and the blunt nature of the main conservation measure available in the VDS (a TAE cut or a longer FAD closure) then the sensible economic strategy for Parties is to take minimal risks with breaching the bigeye LRP. The VDS works well as an economic instrument when the TAE is being driven by the state of the largest stock (skipjack tuna). The VDS becomes a highly inefficient economic instrument if the TAE is being driven by the state of the smallest stock (bigeye tuna). The consequences of the switch from one dynamic to the other comprise the potential spill-over effects of a FAD management regime that ultimately triggers that change. Those unintended consequences, should they eventuate, would far outweigh any benefits from FAD fishing in the meantime.

2.3 The Right to Deploy a FAD

- In the WCPO, FAD deployment is currently restricted only by WCPFC CMM 2017-01, which requires that vessels "have deployed at sea, at any one time, no more than 350 drifting FADs with activated instrumented buoys". SPC analysis indicates that this is unlikely to serve as a practical limitation on deployment for most vessels. Effectively, anyone can deploy any number of FADs (up to the 350/vessel limit) of any design[2]. FAD deployment is perhaps best described as a freedom rather than a right and it is a freedom that is likely to be exercised only by those who have a right to set on a FAD or who are employed by, or contracted to, entities with FAD setting rights (or who are at least confident of obtaining such rights). Within the VDS a FAD setting right would require the possession of a Day right. There is a hierarchy of rights that must be preserved. Deploying a FAD (sensibly) requires a right to subsequently set on it and setting on a FAD in the VDS (necessarily) requires a Day right.

- Individual Parties to the VDS are entitled to regulate FAD deployment in their zone (including banning such deployment). Parties cannot effectively prevent the deployment of FADs that drift into their EEZ (albeit there is some argument FADs are 'fishing gear' and could require a license).
- Logically, the right to deploy a FAD would carry the responsibility to collect the FAD at the end of its deployment. Currently there is no such responsibility. There are some practical difficulties with imposing this responsibility that arise if FAD deployment is regulated or authorised at the level of a Party. In many cases the FAD will drift out of the jurisdiction of the Party that authorised its deployment.

The analysis above suggests that the right to deploy a FAD generates modest externalities that can be fairly well ameliorated by regulating FAD design (non-entangling and biodegradable FADs). Parties have a clear interest in ensuring that any FADs used in the WCPO are so designed and constructed. The next question is whether Parties should be concerned about the number of FADs deployed. The preliminary answer to this seems to be no, provided Parties can limit the number of FAD sets in their fishery and the impact of FAD density is not sufficient to result in substantial changes to stock dynamics.

The reasoning for this conclusion is that only harvesters with the right to set on a FAD have an incentive to incur the costs of deploying FADs and the number of FADs it will be economic for them to deploy will be a function of the number of FAD set rights they hold. As indicated above, the ratio between FAD deployments/FAD sets is a critical determinant of the economics of FAD use by harvesters. It follows from this that the priority for Parties is to focus on the development of an effective regime for managing setting on FADs. FAD deployments would be an economically rational ratio of the allowable number of FAD sets. Limiting FAD sets will therefore limit FAD deployments although the actual ratio will be an outcome of decentralised economic calculation rather than regulation. If this is achieved, Parties can support a liberal FAD deployment regime, providing those FADs are of an environmentally friendly design. It is slightly counter-intuitive that something prior can be effectively controlled by controlling something that must follow chronologically.

Parties should strongly resist any attempt by other agencies (such as the WCPFC) to regulate FAD setting in the WCPO. In particular, the introduction of any FAD charging regime (whether for deployment or setting) should be resisted as it is virtually certain that such a charging regime will cannibalize Day revenues otherwise available to the Parties. A lesser (but still troublesome) economic threat would be posed by the implementation of a restrictive FAD deployment regime by someone other than PNA. To the extent that this restriction reduced FAD setting deemed economically positive by Parties collectively (considering all spill-over effects) then limiting FAD deployment will reduce available Day revenues for no net environmental gain.

[2] albeit CMM 2017-01 'encourages' the use of non-entangling FADs.

2.4 Determining the 'Right' Number of FAD Setting Rights for the VDS

More than half of purse seine catch in the WCPO is taken by free school fishing (compared with approximately 20% in other ocean regions). Given, the environmental spill-over costs of FAD fishing, Parties should be wary of accommodating a harvester driven expansion of FAD fishing that increases harvester returns but ultimately reduces the value of aggregate Vessel Days. In other words, FAD fishers need to pay a premium for Days that more than compensates Parties for any present or future environmental costs of FAD fishing.

The most obvious way of determining the premium that harvesters are prepared to pay for FAD Days is to sell Days through an auction process that would allow bidders to nominate whether they wish to purchase FAD setting rights with any Day they buy. Parties could examine the prices bid and set what they consider to be a minimum FAD Day premium that adequately compensates for the risks they carry (in their capacity as fishery 'owners') from FAD fishing. Buyers who offered a competitive Day price plus a FAD premium above the minimum price set by the Parties would be sold a bundled Day plus a FAD right. The 'right' number of FAD Days would therefore be determined by the interaction of the market for both types of Days with the FAD premium floor price set by Parties.

The first question that arises is the ratio of FAD Set Rights to FAD Days. If we take the number of Days as 38,000 for example, theoretically those Days could accommodate 76,000 sets. However, as the average set rate for vessels is actually less than 2/Day and as more than half the catch is free school, then an initial ratio of 1:1 is probably more than adequate to accommodate present demand. In this example, each Day sold in the VDS would carry the right to set once on a FAD (provided the premium paid was agreeable to Parties).

The aim should be to have free-school and FAD fishers competing for Days in the same market. The presence of free school bidders in the market reduces the ability of occasional FAD fishers to subsidize the cost of FAD Days by under-bidding for FAD-free Days. Furthermore, this joint market should be as deep as possible. Single zone Day markets are unlikely to elicit the full willingness to pay of prospective buyers for either FAD Days or non-FAD Days. Market depth is achieved by the auction for multi-zone Days through a single auction where the marginal clearing price bid sets the price paid by all bidders. (i.e. everyone pays the lowest successful bid price).

2.4.1 Illustrative Example

> 10,000 multizone Days are available for auction. Bidders are allowed to place multiple bids but must designate whether any bid is for a FAD Day or a non-FAD Day. Parties agree and determine that the premium they require for a FAD Day will be set in that auction at $2,000. $2,000 is thereby deducted from every FAD Day bid that has been received to produce an adjusted FAD Day bid for the purpose of ranking. All non-FAD Day and adjusted FAD Day bids are then ordered from high to low until the clearing price for the 10,000th Day is found. All bids below this level (say $12,000 per Day) are unsuccessful. All successful non-FAD Day bidders then pay $12,000 per Day. All successful FAD Day bidders pay $14,000 (clearing price for a Day plus the FAD Day premium determined by the Parties for the auction). Note that with the exception of the marginal bidder, all bidders (whether for FAD or non-FAD Days would pay less than they actually bid).

Parties should not under-cut the agreed $2,000/Day premium when selling single zone Days with FAD rights in that year. In a single-zone market it will be harder to know whether the $2,000 premium is being financed from the Day price unless there is a deep competitive market for non-FAD Days in that particular zone.

The reason this example is illustrative is that it presupposes the existence of a standardised multizone Day sold through a centralised electronic auction process. This is a proposal that has strong interest but no agreed implementation timetable. The 'Capitalization' project of PNA reinforces the point that the VDS is still in its infancy and significant evolutionary development is required and can be anticipated. This development will potentially create considerably better opportunities for price discovery around FAD setting value than exists today. By the same token, care must be taken that FAD management initiatives do not have the unintended effect of compromising this wider VDS development.

3 SWOT Analysis of Future FAD Management Options

This section sets out a SWOT analysis of the future FAD management options outlined in the joint PNAO/MRAG AP paper presented to the PNA FAD Workshop held in Brisbane on 18-21 June 2018. For each option, an overview of the basic concept is provided together with a description of any main design considerations. A SWOT analysis of each is then presented taking into account the broad objectives to be achieved set out in section 1 and the preceding analysis of the FAD property rights in the fishery in section 2. The overall findings of this report are that none of the previously identified management options provide a complete formula for effective FAD management and that a mix of measures is likely to be necessary. Furthermore, the options below are confined to actions that are available now. These options are likely to significantly enhanced by the emergence of a more sophisticated Day market – should that eventuate.

Finally, these options are not all mutually exclusive and the most effective FAD management regime may well require the co-ordinated use of different options to manage deployment and setting and their respective spill-over effects.

3.1 Charge for FAD days – 'FAD Day' option

3.1.1 Overview of option

Under this option a price premium could be applied for all VDS days in which FAD sets were made. There are two basic options for implementing a FAD day arrangement:

- The first option would be to agree a number of 'FAD days' for the upcoming year in advance, based on stock management or other objectives. FAD days would then be allocated amongst Parties based on an agreed formula. Fees could either be applied consistently across all Parties (i.e. a standard fee), or Parties could be allowed to distribute FAD days amongst licensed vessels as they saw fit (e.g. by auction, preferential allocation to domestic vessels, etc). To fish on a FAD during any day, a vessel would need both a VDS day and a FAD day allocation (to fish free schools, they would need a VDS day only). Under this option, fees would be charged prospectively at the time of sale;
- The second option would be to leave the number of FAD days uncapped, with the number of days controlled by the price attached to the FAD day. Where the number of FAD days needed to be reduced, fees could be raised, and vice versa. Under this option, fees could be applied either prospectively (i.e. vessels purchase the right to fish on a FAD for any of their VDS days from an uncapped pool) or retrospectively (i.e. FAD day fees are charged only for those VDS days in which a FAD set was actually made, based on logbook/observer data).

Under either of these options, the existing FAD closure would be removed. It is possible to have an arrangement where the number of FAD days are agreed in advance, with fees charged retrospectively (i.e. only after vessels have used them), but in practice this is likely to create a 'race to fish' the FAD days and ultimately destroy VDS value.

The second (uncapped) option is similar in concept to the 'free school incentive' arrangement already agreed by PNA Ministers at their 10th Annual Meeting. Under this agreement, a charge of $1,000/day would be applied to any VDS day in which a set on a FAD is made by a foreign vessel (domestic vessels were exempt) in 2017 and 2018. The key outstanding issue was whether the fee would be charged prospectively or retrospectively. When it was last considered, Parties noted that monitoring FAD use for the purposes of charging would require additional development in FIMS. Parties agreed at PNA36 that a Working Group would meet to design the necessary improvements, although the meeting has been held over due to other commitments.

Preliminary analysis of FAD usage in PNA zones shows that around 1/3 of fishing days involve sets on FADs (~15,000p.a.). Around 1/3 of those days are fished by exempt domestic vessels, so the ‘chargeable’ FAD days would be in the order of 10,000. In that context, PNAO (2018) concluded that a charge of $1,000/day would have limited impact and a larger charge would be needed. At this stage, PNAO report that only Tokelau has applied the FAD charge. Anecdotal reports suggest that a charge of around $3,500 would be needed to change behaviour away from FAD use, and that risked disrupting the VDS.

Based on data from 2010-2016, the foreign fleets most impacted by any FAD day charge are likely to be the European vessels, China and the US.

3.1.2 SWOT analysis

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal	• Potentially a means of removing the FAD ban if FAD day charges set at levels which effectively limit BET mortality • Likely to be effective at changing behaviour if fee set at sufficiently high levels	• Anecdotal evidence suggests that a FAD charge would need to be in order of $3500/day to be effective, which may disrupt VDS • FAD days provide for only partial control over the number of FAD sets (and therefore fishing mortality) – it may be possible for vessels to undertake more than one FAD set in a day (and FAD days may provide incentives for this) • The economics of FAD fishing is likely to be different in each zone – a flat fee may disincentivise FAD use in some zones but not others.
	Opportunities	**Threats**
External	• Patterns in willingness to pay across different fleets/zones are likely to provide some information on the economics of FAD use over time	• FAD use of the high seas undermines objectives of FAD day arrangement

3.1.3 Summary analysis

The main merit of this approach is that placing a charge on FAD Days focuses squarely on the key management issue which is setting on FADs. Both options suffer the same serious deficiency in that the FAD fee is just a ‘stab in the dark’ in the absence of an effective ‘price discovery’ process. Whether the FAD charge applies retrospectively or prospectively or whether the FAD Day numbers are capped or uncapped, the FAD charge might be financed from a reduction in Day revenue. FAD charging is already a non-explicit component of Day revenues. FAD charging is definitely a promising approach but considerable definitional and design work is required before a practical regime that can overcome these problems can be implemented. For instance, the ratio between FAD Days and FAD sets would have to be agreed by the Parties, assuming a cap on set numbers was desirable.

3.2 Charge for FAD days – 'Buoy day' option

3.2.1 Overview of option

The alternative to applying a 'FAD day' charge via a premium on the VDS day would be to apply a charge for each day that a FAD buoy was in a zone (irrespective of whether it was set upon). Under this option, the number of days each buoy transmitted in each zone could be recorded and a standard fee applied - e.g. if we assume 60,000 FADs in the WCPO, operating 365 days/yr – a charge of $1/day would generate $21.9m. Parties would receive a share of the total revenue proportional to the number of FAD days in their zones. Revenue from FADs polling on the high seas could put to other uses (e.g. funding the PNA Office) or distributed amongst the Parties.

Fees could also be applied differentially, based on whether a vessel had a license to operate in the zone (e.g. $1/day for each licensed vessel; $5/day for each unlicensed vessel). In effect, the charge for unlicensed vessels would act as an administrative penalty (similar to a fine) discouraging companies from allowing 'unlicensed buoys' from floating through zones and dealing to some extent with Parties concerns about unlicensed FADs 'dragging fish' out of their zones. Even if the broader buoy day proposal was not adopted, a charge for each buoy day for unlicensed FADs could be applied.

Assuming the objective of the exercise is not to generate additional revenue, the objectives of a 'buoy day' charge would need to be clearly agreed and fees set accordingly. For example, if the objective was to discourage FAD deployment consistent with achieving an agreed level of BET mortality, fees would need to be set at a level which achieved (indirectly) an optimal number of FAD sets/BET mortality. 'Buoy day' charges could be raised or lowered as required.

Assuming a standard charge is set for each 'buoy day', based on SPC's analysis of transmission locations from 2016 and 2017 (Escalle et al, 2018), the greatest share of revenue would go to Kiribati, Tuvalu and the Solomon Islands. Relatively less revenue would flow to FSM, RMI, PNG, Palau and Nauru. However, it should be noted that the current understanding relative FAD density across the WCPO is substantially influenced by non-compliance and geofencing by fishing companies. Looking at the picture of actual FAD sets, rather than buoy transmissions, may give a more accurate picture of likely FAD density. In 2016 and 2017, FAD sets were still high in Tuvalu, Kiribati and the Solomon Islands, but were also high in Nauru, PNG and the south west of FSM. Given the extent of geofencing, the revenue generated through buoy transmissions on the high seas is largely unknown.

In practice, applying a buoy day charge could act as a direct 'lever' to achieve some target stock policy objectives – e.g. higher charges are likely to reduce FAD numbers therefore limiting the impacts of FAD density on stock dynamics and the availability of free schools – but could only work indirectly to achieve other objectives – e.g. limiting the number of FADs through a charge does not directly control the number of FAD sets and BET mortality. To achieve this second objective, the relationship between buoy day charges, actual FAD sets and BET mortality would need to be well understood and relatively predictable. It is not yet clear that either of these conditions are currently met.

3.2.2 SWOT analysis

	Helpful	**Harmful**
	Strengths	**Weaknesses**

Internal	• Potentially a means of removing the FAD ban if charges effective in limiting BET mortality • 'tax' on buoys may assist to reduce numbers and deal with impacts of FAD density on stock dynamics, free school availability • Higher fees for 'unlicensed' buoys could assist in dealing with issue of unlicensed 'fishing' by drifting FADs	• If the objective is to control mortality of BET, 'tax' on buoys only does this indirectly – may be same number of sets on fewer buoys; much less direct measure than controlling FAD sets • Limited understanding of relationship between buoy charges, FAD numbers and BET mortality at present – setting an effective fee would be challenging • Fees for buoy days likely to cannibalise revenues from VDS days • Distribution of revenue is likely to be skewed towards the eastern PNA Parties • Implementation tells us relatively little about economics of FAD fishing
	Opportunities	**Threats**
External		• External drift of unregistered FADs from the EPO remains a problem • Geofencing of WCPO buoys would compromise system, albeit this should be resolved through stronger requirements for continuous transmissions

3.2.3 Summary analysis

This option is inferior to a charge on FAD setting. Buoy Day charges are effectively a deployment charge and the main issue that Parties need to manage is not deployment but setting on FADs. While it is possible that FAD deployment at very high densities may influence stock dynamics, it is likely that a charge on FAD setting will place indirect downward pressure on the numbers of FADs deployed.

3.3 Limit number of FAD sets

Under this option, the overall number of FAD sets in PNA waters (and WCPO) could be capped at a level consistent with environmental/economic objectives (say, starting at the current number of FAD sets, around 12,000 - 15,000). The number of FAD sets could then be allocated amongst the Parties for distribution to fleets (e.g. either by sale or auction), or trade to other Parties. In order to set on a FAD in PNA waters, a licensed vessel would need both a VDS day and an amount of allocated FAD sets – e.g. a vessel may have 200 VDS days and 100 'FAD sets'. The vessel's allocation would be decremented for each unit used (e.g. in the case above, if the vessel fished for one day and made one FAD set, they would have 199 VDS days and 99 FAD sets left). Vessels without FAD set rights would be required to fish on free schools. It is possible that FAD sets could be allocated directly to vessels from the FAD set 'pool', but this violates the agreement reached at the Brisbane workshop that any FAD related instruments need to be allocated to Parties.

Charging for FAD sets differs from a 'FAD day' in that each FAD set accrues a separate charge (or decrements a unit) – two FAD sets on the same day under a FAD day scheme would result in only one FAD day being decremented; two FAD sets under a 'charge per set' scheme would result in two separate fees being levied or FAD sets decremented.

The overall number of FAD sets in the fishery could be adjusted over time to achieve stock management and broader conservation objectives – e.g. the number of FAD sets could be tied to a formal harvest control rule for BET such that the number of FAD sets reduced as the limit reference point was approached.

Administration of the scheme would require the establishment of an accounting system to monitor each vessel's FAD sets usage against rights held.

3.3.1 SWOT analysis

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal	• If charges were effective, could serve as a replacement to the FAD closure • Directly addresses cause of BET mortality (relatively straightforward set of decision rules could be developed) •	• Would likely require a difficult allocation process amongst Parties • Complex to apply alongside the VDS and may affect base VDS prices
	Opportunities	**Threats**
External	• FAD set rights could be auctioned to both optimise revenue and improve Parties' understanding of the economics of FAD use (i.e. companies' willingness to pay)	• FAD setting rights that are not firmly attached to a Day can be financed from Day revenue without Parties being able to detect the extent of cross-subsidization • FAD sets on the HS undermine in zone limits

3.3.2 Summary analysis

The appeal of this option is that it allows a direct and immediate mechanism to manage the level of environmental impact associated with FAD sets. However, selling Day rights and FAD setting rights separately confounds the ability of Parties to use market mechanisms to discover the 'proper' price for either Day or FAD setting rights. It is therefore a blunt tool that is easier manipulated by harvesters than Parties.

3.4 Charge for FAD sets

3.4.1 Overview of option

The main difference between this option and the one above is that there would be no overall limit on the number of FAD sets – instead, numbers would be controlled by a charge applied to FAD sets. All other things being equal, higher charges should result in fewer FAD sets and vice versa. As with the option above, these could be charged prospectively, or retrospectively based on e-log reports with verification from observers. Where the overall number of FAD sets needed to be reduced for stock conservation reasons, the charge could be increased.

Charges would need to be determined with a FAD set target (or range) in mind, based on stock conservation objectives (perhaps linked to some form of HCR). Charges could be increased for higher numbers of FAD sets (e.g. the 100th FAD set might cost a vessel three times the 1st FAD set), similar in concept to the increasing 'deemed value' charge applied to quota overcatch in NZ fisheries. Any separation of FAD setting charges from the fee for an associated Day creates a lack of transparency about the economics of VDS fishing. Such lack of transparency constitutes an opportunity to harvesters and a threat to Parties.

Charges could be applied as a flat fee across all Parties, although this ignores the relative differences in economics of FAD use between different zones. A charge sufficient to change behaviour in one zone may not work in another. To that end, it is likely any system relying on FAD charges would need to be applied at a zone level (i.e. FAD set target ranges for each zone are established, with specific FAD set charges to achieve the objective in each zone).

The setting of charges would likely require relatively good information on the economics of FAD usage, although they could be adjusted over time based on experience.

3.4.2 SWOT analysis

	Helpful	**Harmful**
	Strengths	**Weaknesses**
Internal	• Market-based instrument designed to drive industry behaviour – adjustable over time to achieve stock management/ environmental objectives • Higher fees are paid by vessels causing higher BET/YFT mortality • Number of FAD sets not limited, therefore does not create a second formal 'right'/ instrument to compete with VDS (albeit may influence day prices – e.g. vessels may argue a VDS day without the automatic right to set on a FAD should be worth less) • Vessels pay costs consistent with their FAD use – vessels fishing predominantly on free schools pay less than FAD-dependent fleets. • Avoids need for formal allocation, although if FAD set targets/ranges applied to each zone would need to be set providing a 'de facto' allocation and influencing relative attractiveness • If charges were effective, could serve as a replacement to the FAD closure • Assuming number of FADs not limited, avoids need to undertake potentially difficult compliance around FAD limits.	• If FAD set charge is set by Parties, requires good information on FAD economics to ensure charges are set at levels that change behaviour – otherwise ineffective - but can be amended over time based on experience • Doesn't address environmental issues associated with number of FADs in water (beaching, incidental mortality, effects on target stock dynamics) directly, but these can be addressed through gear design etc • May drive higher levels of FAD deployment/cherry picking to ensure cost of FAD set recovered/each FAD set delivers maximum value (albeit only up to the point that revenue equals costs) • Likely harder to apply in practice than a strict limit on FAD sets
	Opportunities	**Threats**
External		• May drive additional FAD sets on the HS if no charge

3.4.3 Summary analysis

This is potentially an excellent approach to the refined balancing of Party-borne FAD setting environmental costs against enhanced revenues from the VDS. The main handicap to its deployment is the fact that existing single-zone Day 'markets' are not competitive enough to generate good price information. It requires an associated regulatory approach to deal with the environmental impacts of FAD deployment.

3.5 Limit number of FADs

3.5.1 Overview of option

Under this option the overall number of FADs able to be used by vessels registered on the VDS register would be capped. This option may be attractive if the number of FADs in the water is important for management purposes (e.g. if FAD density impacts stock dynamics, if it affects the availability of free schools, if entanglement/beaching is a problem, etc). The cap would be set at a level consistent with pre-agreed stock management and/or environmental objectives and adjusted periodically.

There are two possible ways to implement the cap:

1. **Party-based allocation** - capping the overall number of FADs and allocating available FADs amongst Parties. Parties would then be free to distribute the right to deploy a FAD in the manner most beneficial to them (e.g. by auction). The actual deployment of the FAD could be limited to the selling Party's waters (i.e. if you buy the right to deploy a FAD from Party X, you must deploy the FAD in Party X's waters), but in practice highest prices are likely to be received if the right to deploy is available anywhere in PNA waters (i.e. the right can be bought from Party X, but the FAD can be deployed in Party Y's waters – as long as no more than the allocated number of FADs are deployed).
2. **Vessel-based allocation** – capping the overall number of FADs and allocating those amongst the registered vessels (e.g. if the overall cap was 30,000 FADs, dividing amongst 300 registered vessels would mean 100 FADs each). This is consistent in principle with the 350 FAD/vessel applied in CMM 2017-01, which is applied as of right. The WCPFC 350/vessel cap effectively establishes a vessel/flag-based limit – which PNA could modify for PNA waters e.g. reduce foreign vessels to 250 FADs/buoys each. Having said that, we note this option is inconsistent with the agreement at the PNA's Brisbane workshop that any FAD limits should be allocated amongst Parties, not vessels, so we have not examined this option further. The discussion below assumes a Party-based allocation.

To make the scheme work in practice, clear definitions would need to be established around the right being purchased by industry, and when the right started and stopped. The main thing of interest to Parties under this approach would be the number of FADs/buoys actively deployed in the water. To that end, the 'right' would presumably be the right to deploy a FAD in the water; the right is exercised while the FAD is in the water and the right ceases at the end of the allocation period (whatever that happened to be).

Some clear thinking would also need to be done around the relationship between the FAD limit and the duration of the right to deploy a FAD allocated to industry. Importantly, the operation of a FAD limit scheme would differ from a standard fisheries quota/allocation scheme under which each company's usage of their allocation commences at zero at each new allocation period (typically annually, including the VDS). Under the FAD limit scheme, if the allocation period is annual, each company will commence the year with a number of FADs in the water (i.e. they will not start at zero). To that end, practical rules will need to be developed around the time period companies have to adjust to inter-annual changes – for example, if a company has purchased the right to deploy 300

FADs this year and had 300 FADs deployed, but is only able to purchase rights for 200 FADs next year, how long should they be given to ensure compliance (e.g. either by removing FADs from the water, or by transferring ownership of the FAD to another company with a 'spare' right to use a FAD)?

It would be up to Parties whether to limit the number of FADs able to be registered to each vessel. While CMM 2017-01 sets a 350/vessel limit, if the overall number of FADs registered/active was effectively limited through PNA, there is arguably little need for the WCPFC cap (which is likely to be ineffective at current levels in any event). Allowing FAD rights to be allocated to companies would be consistent with an increasing trend towards managing FADs within fleets, and would avoid potentially difficult compliance arrangements to verify individual vessel based limits.

As with all schemes, clear and effective compliance arrangements would need to be established to ensure integrity of any FAD limit. In this case, breaches could occur by purse seine vessels deploying more FADs than they had a right to deploy, or by third parties deploying FADs in areas outside PNA's direct control – e.g. on the high seas in the WCPO, or in the EPO. While observers should be able to detect most instances of non-compliance on licensed purse seine vessels (albeit perhaps not all if vessels hid buoys and deployed FADs at night), this may not be the case for third-party deployments. To that end, other arrangements would be needed to verify compliance – e.g. the right to audit records of 'type approved' buoy manufacturers to determine if non-registered buoys are operational in PNA waters, which could then be matched with VMS tracks to determine if vessels are interacting with buoys.

3.5.2 SWOT analysis

	Helpful	**Harmful**
	Strengths	**Weaknesses**
Internal	• May help to address broader environmental issues around incidental mortality, reduce scope for beaching, limit FAD density impacts on target stock dynamics (albeit entanglement/beaching could be addressed in other ways) • May help limit effort creep under VDS by reducing scope for cherry picking	• Would create a second competing right to VDS • Does not address core target species issue which is number of FAD sets (given that most FADs are not set on) – i.e. if fishing mortality only occurs if FADs are actually set upon, limiting the number of FADs to limit F is a blunt instrument • Would likely require difficult allocation amongst Parties • Would require potentially complex and costly compliance arrangements to ensure scheme integrity
	Opportunities	**Threats**
External		• External drift of FADs from the EPO would remain a compliance challenge • Potential for third parties to deploy FADs on the high seas • Pooling of FADs amongst fleets may undermine individual vessel based limits

3.5.3 Summary analysis

FAD deployment is not the key thing requiring management (assuming FAD density does not substantially influence stock dynamics across a large portion of the stock). In the absence of a charging regime, FAD deployment rights under this option are valuable rights conferred on harvesters (irrespective of whether they are first allocated to Parties or vessels). These rights are currently 'owned' by Parties. This transfer of status quo Party economic rights to harvesters makes this option fundamentally unattractive.

3.6 Charge for each FAD deployed

3.6.1 Overview of option

Under this option a charge would be levied for each FAD deployed in PNA waters (or which drifted through PNA waters). This option differs from the previous option in that no hard cap on the number of FADs would exist. Vessels deploying larger numbers of FADs would pay higher fees. If desirable, a higher fee could be applied to FADs over a threshold number (e.g. each FAD up to 200 costs X; each FAD over 200 costs X*2) to disincentivise profligate deployment.

In the absence of a cap on FAD numbers and allocation to Parties, charges would most likely need to be administered regionally (e.g. by PNAO), with revenue allocated to Parties based on some pre-agreed formula (e.g. number of FAD days in each zone). FAD charges could be adjusted over time consistent with stock management objectives (e.g. charges could be raised where BET mortality needed to be reduced and vice versa).

Charges could be applied either prospectively – e.g. in order to deploy a FAD, the buoy must be registered in advance, which attracts a fee upon registration – or retrospectively – e.g. a lump sum fee could be applied at year's end for the total number of FADs deployed by the vessel/company. Either way, a system to administer charging, accounting and distribution of revenue to Parties would need to be established, likely within PNAO.

3.6.2 SWOT analysis

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal	• A 'tax' on FADs set at effective levels may help address some target species stock management objectives (e.g. limiting impacts of FAD density on stock dynamics, availability of free schools) • Could contribute to minimising marine debris and entanglements (albeit these are primarily addressed through other means) • May help limit effort creep under VDS by reducing scope for cherry picking	• Would likely require a difficult discussion amongst Parties around distribution of revenue • The number of FADs in the water only indirectly influences BET and other species mortality resulting from sets – most FADs are never set upon. The relationship between FAD numbers and FAD sets is not yet well known. • The interaction with VDS is not clear – revenue generated from any FAD charge may compete with VDS revenues and/or disrupt efficient operation of the VDS market
	Opportunities	**Threats**
External		• Charging for FAD deployments may incentivise 3rd party deployment of FADs • External drift of FADs from the EPO would remain a compliance challenge (albeit vessels could be required to register, and pay for, EPO FADs prior to setting upon them)

3.6.3 Summary analysis

Once again, this is an option that does not address the key issue (FAD setting). Separate charging for FAD deployment is almost certain to be cannibalistic of Day revenues, but the separation of Days and FAD deployment rights makes the level of cross-subsidization very difficult to estimate. This provides an economic opportunity to harvesters and a significant economic risk to Parties.

3.7 Rebate for free school days

3.7.1 Overview of option

Under this option, the benchmark price for VDS days could be raised by an agreed amount – broadly consistent with the average expected profitability increase arising from FAD usage - with a rebate paid to vessels if they could demonstrate they fished on free schools only. The benchmark price and rebate level could be adjusted in future as (a) knowledge of the economics of FAD fishing improves and (b) the need to discourage FAD sets and incentivise free school sets changes (for example, deteriorating BET stock status may lead to higher benchmark price and/or higher free school rebate price, and vice versa).

Clear measures would be needed to validate the absence of FAD sets (which may draw from the Pacifical experience in verifying free school sets – e.g. observer verification, catch composition etc), as well as administer rebates.

Under this option, we assume that TAE and PAE arrangements would remain the same as they are now. One issue is whether the rebate level would be applied consistently across all Parties, applied in a differential manner agreed by all Parties (for example, avoiding FAD sets may have a disproportionate benefit in some zones, therefore rebate levels may be higher), or left to individual Parties to apply. At this stage, we have assumed a single rebate level would apply across all Parties.

Based on the analysis prepared for the PNA's proposed FAD Charging Trial, a differential of >$1000/day between free school days and FAD days would be required to incentivise changes in fleet behaviour.

3.7.2 SWOT analysis

	Helpful	**Harmful**
	Strengths	**Weaknesses**
Internal	• Provides a clear incentive for free school fishing, assuming rebates can be set at effective levels • Allows for ongoing adjustment of rebate level to strengthen or weaken incentives for free school fishing based on prevailing circumstances	• There are likely to be clear differences in the relative economics of FAD use between different vessels and between different zones – establishing a rebate level effective for all is likely to be challenging • Consistent rebate may result in changes in effort distribution – favouring zones for which FADs are less important • Requires good knowledge of the economics of FAD fishing (including changes over time) and agreement around a framework to adjust rebate levels over time • Doesn't, by itself, deal with issues around FAD numbers/density (although higher free school rebates would presumably encourage lower FAD use)

	Opportunities	Threats
External	• Experience with different rebate levels over time is likely to provide some information on the relative economics of FAD vs free school fishing in different fleets/zones	

3.7.3 Summary analysis

A rebate scheme for not setting on a FAD is really the same as a scheme for charging for FAD setting with three disadvantages. First, a rebate scheme is more expensive to administer. Second, a rebate scheme requires all harvesters to outlay the higher cost of buying FAD Days, even if they intend to fish free-school tuna. This adds a significant finance cost into the overall budget of free-school operators that will suppress the Day price they could otherwise afford. Third, the risk of using/not using a FAD right best sits with harvesters (not the Parties) just in the same way that the risk of using/not using a Day best sits with harvesters.

3.8 PNA FAD leasing scheme

3.8.1 Overview of option

This option is consistent with the original TORs for the project - i.e. PNA prohibits companies from deploying or setting on FADs except those operated by PNA, and establishes its own operation (either solely or in partnership with a commercial entity) to deploy and lease FADs.

This option offers the opportunity for PNA to control the FAD market, deploying the number and type of FADs at times and locations of its choosing. This would allow PNA members to have direct control over the number of FADs in Parties' waters (to a large extent) (allowing control over issues such as FAD density, and possible impacts on free school availability), as well as ensuring all FADs used were consistent with environmental objectives (e.g. non-entangling, biodegradable, etc). Given PNA would have access to all data from FADs (position, speed, biomass, density, etc) across the region, this option would also ensure all available FAD information was made available for scientific/economic analysis in support of PNA's objectives.

The costs of operation would need to be recovered through leasing access to FADs to industry. In practice, this could be structured in a number of ways:

- The simplest option would be for FADs to be leased on a long-term basis, from the point of deployment to the point of retrieval. Fees could either be structured as a flat fee, or auctioned prior to each deployment. The lease price or industry bids would reflect the fact that not all FADs would be set on;
- A more sophisticated option would be for PNA to auction access based on biomass information (i.e. "we have a buoy here with 150t of biomass underneath it, how much are you prepared to pay for access to the code?"), with industry leasing the buoy thereafter;
- Other options may involve companies leasing FADs for certain periods (e.g. monthly/quarterly leases), or in certain zones (e.g. a company could opt to transfer control of the FAD back to PNA after it drifts out of zones for which its vessels are licensed). In this way, a single FAD may be leased to a number of different companies throughout its life.

The type of approach chosen – as well as a range of other price setting and operational issues - would need to be guided by clear agreement amongst Parties around the objectives of the scheme. For example, in the case of the economic objectives, is the intent of the exercise to generate maximum revenues from FAD use for Parties, or is the exercise more about having control of FAD usage in the WCPO, and therefore costs should be set to cover costs only? (If, as was agreed at the Brisbane workshop, the VDS should remain the primary instrument through which rents are generated, presumably the intent would be the latter.) If a key objective is to better understand the economics of FAD use amongst industry, some types of pricing strategies may deliver richer information about willingness to pay etc than others. If the objective is to deliver certain level of fishing mortality on key target stocks, information would be needed on the relationship between FAD number and fishing mortality.

In practice, the operation of any FAD leasing scheme would require access to considerable capital infrastructure (i.e. vessels to support the deployment and retrieval of FADs), as well as practical 'know-how' on manufacturing, deployment strategies etc. Realistically, the PNA has neither of things at present. The most logical approach is likely to be to partner with an existing company (e.g. a large fishing/logistics company) with capacity to deploy and retrieve FADs across the region, and/or to contract the services of fishing vessels to deploy/retrieve FADs on PNA's behalf. A considerable 'back-end' support infrastructure would need to be established to administer and monitor the operation (e.g. monitoring FADs, accounting for leasing fees, planning deployments/retrievals, etc).

A small side benefit of the arrangement may be the establishment of small service businesses (e.g. FAD manufacturing companies) in key PNA port States (albeit this could occur under a number of future management scenarios).

Notwithstanding all that, the type of 'comprehensive' PNA FAD leasing scheme described above would be a very major disruption to the established operation of the WCPO purse seine fishery, the economic consequences of which for both vessels and Parties are uncertain. Although free school catch still accounts for over half of the total WCPO catch, the use of FADs is important to the overall economics of the fishery, with many vessels/fleets geared towards FAD use.

The risks and practical challenges associated with operating such a scheme would need to be weighed very carefully against the potential benefits described above. Some of the main risks and challenges include:

- **Risks to vessel efficiency, profitability and VDS revenues** – Under existing arrangements, vessels are able to deploy their own FADs, of their own design, and in locations and at times of their choice. Deployment strategies will undoubtedly be optimised for each individual vessel (or increasingly fleet) based on hard won experience, and are planned with a view to fishing conditions and locations several months in advance. Vessels are then able to monitor their array of FADs and plan the fishing strategy they believe will deliver optimal profit. Under any PNA FAD leasing scheme, many of these conditions may not be met – the FADs will be of PNA's design, deployed in PNA's chosen locations and at times of PNA's choosing. Depending on the operation of the scheme, companies/vessels may not have the same array of FADs to monitor and plan fishing tactics; many vessels may end up with fewer FADs and in non-preferred locations. While consultation with industry (and contracting in industry knowledge) could help optimise FAD design and deployment location/timing to some extent, the impact on vessel fishing efficiency and profitability is uncertain (although the risk is almost entirely downside – it's hard to see external production and control of FADs improving industry profitability). Any reduction in vessel profitability will have an inevitable impact on company's capacity to bid for VDS days, which in turn may impact Parties' revenue. In the same vein, fishing companies may argue that the VDS at the moment includes an implied right to be able to deploy FADs consistent with any license conditions.

Parties are likely to face arguments that removal of that right devalues each VDS day (because to do what they were previously doing, companies now need to buy both the VDS day *and* lease FADs). Parties should therefore expect arguments from fishing companies that the base price of a VDS day should be reduced consistent with the amount that they will need to pay to lease FADs.

- **Legal, economic and reputational risks associated with being FAD owners** - Assuming PNA was the legal 'owner' of FADs under this approach, Parties would assume responsibility for the fate of FADs as well as any associated marine debris and incidental mortalities. This means taking responsibility for the costs associated with retrieval of all FADs, as well as any environmental remediation costs associated with beaching. The costs of both of these are uncertain, but are likely to be potentially very large (the costs of retrieving several tens of thousands of FADs in very remote locations alone is likely to be very substantial). It is possible that PNA could transfer responsibility for retrieval and any remediation costs to industry as part of a lease agreement, but this is likely to substantially influence the price vessels are prepared to pay.

  In addition to any environmental and economic costs, any beaching of PNA deployed FADs within the WCPO region or elsewhere (e.g. the Australian Great Barrier Reef) has the potential to lead to reputational damage to PNA, potentially eroding the high moral environmental ground Parties have earned through their stewardship of the fishery and in particular MSC certification of the free school fishery (e.g. 'one the one hand PNA are saying they're good environmental citizens by certifying their free school fishery, but on the other hand they're deploying FADs which are washing up on sensitive reefs'). Any beaching is also likely to result in difficulties in relationship with PNA coastal communities.

- **Compliance challenges** – Considerable thought would need to be given to the compliance challenges associated with operating a PNA FAD leasing scheme. These are broadly of two types: (i) 'external' risks and (ii) 'internal' risks. In the former case, the integrity and economics of any PNA leasing scheme relies on its ability to guarantee scarcity (i.e. that the only FADs available in PNA waters are PNA deployed FADs). The main external compliance risks come from vessels deploying FADs in the adjacent high seas, or in the EPO where FADs naturally drift westwards into PNA waters. PNA has no immediate authority to restrict deployments in these waters. While PNA may either ban setting on non-PNA FADs, or require them to be registered with PNA and perhaps pay a fee prior to setting on them, this may place observers in a difficult position if responsible for verifying compliance (although perhaps not much more than reporting FAD sets during the FAD closure at present). The internal compliance risks are around ensuring that vessels set only on FADs for which they've paid leasing fees. At present, setting on other vessels' FADs is fairly commonplace within the industry (with crew members spotting other vessels' FADs reportedly paid a bonus in some cases). Under any scheme in which vessels have paid PNA to lease specific FADs, either (a) arrangements would be required to make it an offence to set on other vessels' FADs, with an appropriate supporting compliance regime or (b) if setting on other vessels' FADs was allowed, PNA likely would need to accept a lower lease fee (because access could not be guaranteed). Even where vessels intended to set on their own leased FADs, observers would need some mechanism to verify that the FAD belonged to the host vessel.

In addition to these, a considerable number of operational issues would need to be thought through – for example:

- if a vessel is leasing a FAD, what rights does that confer? Does it allow the vessel to transform the FAD (e.g. add different appendages according to its own preferences)?
- How does the scheme deal with setting on logs and other natural FADs?

An alternative to the 'nuclear' option of prohibiting all FAD deployment by other entities would be for the PNA to establish a smaller commercial FAD deployment trial for the purposes of testing the market for FAD leasing and getting a better understanding of the 'business' of FAD use if that was thought to be of use (e.g. deployment and retrieval costs, manufacture costs, management and monitoring costs, economics of use, willingness to pay for leasing, etc). The trial could be designed in coordination with scientists/economists/industry to answer scientific or economic questions (e.g. aggregative capacity of different designs/materials, drift speeds associated with different depths/materials, spatial and seasonal variation in aggregative capacity etc), with FADs leased to industry or position/biomass information auctioned amongst industry to recover costs (in much the same way as research fishing surveys around the world are typically able to sell any catch to recover survey costs). Under this approach, existing commercial vessels working in perhaps 2-3 strategic locations could be contracted to deploy PNA FADs in accordance with a pre-defined schedule (noting that any diversion from the vessel's normal fishing activity is likely to increase costs). Operating a trial, rather than a full-scale FAD deployment operation, would reduce but not eliminate PNA responsibilities (and costs) associated with FAD retrieval, habitat rehabilitation, etc.

3.8.2 SWOT analysis

	Helpful	Harmful
	Strengths	**Weaknesses**

Internal	• Assuming compliance could be guaranteed, prohibiting others deploying FADs allows PNA to control:
	  ◦ The number of FADs in the water;
	  ◦ Their make and construction (non-entangling/biodegradable, etc)
	  ◦ Density in different regions (more or less);
	• Ensures all data from FADs available for scientific analysis (inc. biomass).
		• There are considerable risks to VDS revenues with a fundamental change in FAD deployment and monitoring
		• As the owner of the FAD, PNA would assume any legal MARPOL responsibility as well as costs associated with retrieval and/or environmental remediation costs
		• PNA has limited internal practical knowledge of FAD manufacture and deployment logistics and strategies – external expertise would be required to advise on industry preferred manufacturing techniques, logistics
		• Unless sets are controlled, leasing FADs is not a direct control on fishing mortality (the same number of sets could be made on fewer FADs). PNA could choose to reduce the number of FADs in the water, although this would only be an indirect control. Fewer FADs in the water may limit capacity of PNA to cover the fixed costs of running the scheme.
		• Compliance arrangements would be required to stop other vessels setting on other vessels' FADs;
		• How to deal with sets on logs, natural flotsam and FADs which drift in from outside PNA? Would these be prohibited?

	Opportunities	**Threats**
External	• Provides some opportunity on the economics of FAD use through industry willingness to pay • Would provide for a stronger information base to allow analysis of FAD impacts (impacts of FAD density, aggregative	• External drift of FADs from the EPO would remain a compliance challenge • Potential for third parties to deploy FADs on the high seas • Potential for vessels to deploy their own FADs and not report to PNA (observers report it is not uncommon for vessels to deploy FADs at night while steaming, while the observer is asleep;

	capacity of different FAD types, etc)	alternatively, companies could increase deployments on third party vessels) • Beaching events and habitat damage would lead to community and public criticism of PNA • The costs of FAD retrieval and environmental remediation following beaching are unknown (and may be very considerable) • The impacts on VDS revenue is uncertain (although opportunities for downside movement appear much stronger than upside) – the economics of FAD use is presumably optimised

3.8.3 Summary analysis

This is arguably one of the least attractive options. It does not address the key environmental issue (FAD setting) and it draws Parties into a harvesting related business requiring considerable capital outlay (even if only as a JV partner) in which they lack crucial information about the benefits of their services and have no clear competitive advantage. As the owners of large numbers of FADs, Parties are also exposed to uncertain contingent legal liabilities.

3.9 Status quo

Under this option, PNA would introduce the agreed information strengthening, FAD registration, marking, monitoring and environmental measures (e.g. non-entangling FADs) agreed at the Brisbane workshop, but would not seek to introduce a specific 'economic' measures to limit FAD usage (other than those agreed through WCPFC). The FAD closure would be retained. Rents associated with FAD usage would be collected through the VDS, with industry allowed to optimise its own FAD usage within the parameters allowed by the national and regional management framework. The assumption under this model is that allowing industry maximum flexibility to optimise its own FAD usage would ultimately result in strengthened capacity to bid on VDS days and therefore maximise revenue to PNA. If non-entangling and biodegradable FADs could be introduced, this would go a long way towards addressing current environmental issues associated with FAD deployment. Such measures would also provide a solid foundation from which to address the more difficult management problems of addressing the environmental issues with FAD setting.

3.9.1 SWOT analysis

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal	• Allows Parties to focus attention on critical initial improvements – strengthening information from industry, strengthened FAD registration, marking, monitoring, environmental measures – while building the information base to develop longer term 'economic' measures and plan administrative arrangements (e.g. improvements to FIMS).	• Would need to maintain FAD closure in interim
	Opportunities	**Threats**

External	• FAD design regulation could be supported by other interested parties such as WCPFC.	• FAD use escalates in the short term (outside of the closure period) resulting in lasting damage to key target stocks • Other interested Parties may be tempted to expand their role in FAD management beyond the regulation of design and construction

3.9.2 Summary analysis

The introduction of baseline level reforms - agreed information strengthening, FAD registration, marking, monitoring and environmental measures – would provide a stronger information base and enhanced capacity for Parties to manage FAD use in their waters. As a result, these measures are likely to be both a high valuable, and necessary, first step in establishing a longer term management regime. However, on their own these measures do not allow Parties to directly control the environmental impacts of (or optimise revenue from) FAD setting. Accordingly, additional measures will be necessary to achieve all of the Parties objectives.

4 General Observations and Conclusions

By design, the SWOT analysis 'cast the net wide' in examining possible future PNA FAD management options. The intent was to examine the widest possible suite of alternative options with a view to identifying the option (or combination of options) that will best meet PNA's long term objectives for the management of the WCPO purse seine fishery, and therefore worthy of more detailed consideration in Phase 3. Although that meant time was spent exploring options that are unlikely to be viable in practice, the exercise has been useful in highlighting both the critical needs and attractive design features of an effective PNA FAD management framework, as well as options and features to avoid.

To that end, key observations and conclusions from the Phase 2 analysis which should guide the development of a future FAD management scheme (and therefore the work of Phase 3) include:

- **Need for clear objectives** – although we have assumed some generic objectives for the purposes of the SWOT analysis, there is a need for the precise objectives underpinning any future PNA FAD management scheme to be discussed an agreed amongst Parties at the outset. These objectives must reflect the goals of Parties (not harvesters) and include all environmental costs in the evaluation of alternatives. Collectively agreeing clear objectives will assist in program design, strengthen 'ownership' of the approach and assist with monitoring of progress;

- **Parties should avoid the establishment of two competing instruments or rights** – consistent with the outcomes of the Brisbane PNA FAD Workshop that (i) any new FAD management regime should not be designed as a revenue raising measure and (ii) the primary instrument for revenue raising should be the VDS, Parties should avoid the creation of a separate FAD right in the fishery which undermines the efficient operation of the VDS market, and/or cannibalises VDS rents. Global fisheries history is littered with real world examples of tension between two competing rights constraining overall economic returns from the fishery and/or undermining management effectiveness. These include, for example, retaining pot limits in a quota managed crustacean fishery such that fishers are not able to catch their quota with maximum efficiency (e.g. Queensland spanner crab fishery), or tensions in quota managed fisheries where unavailability of bycatch species quota constrains target species catches. In this case, a number of options reviewed would, in effect, create a second right in the fishery which would serve to compete with the VDS (e.g. 'buoy' days, limiting the number of FADs). These options should be avoided. The type of FAD setting regime contemplated in section 2 seeks to avoid creating a second right by structuring any future FAD setting right as an adjunct (or sub-right) tied to the existing VDS. Through the type of 'price discovery' process outlined in section 2, there is scope to optimise economic returns from both the primary right (VDS) and the sub-right (FAD setting).

- **Parties should oppose FAD charging by any other management agency** – The right to deploy and set on a FAD in PNA waters is currently, in effect, a sub-right (or freedom) of the PNA licensing regime. Freedoms around FAD usage are currently (explicitly or otherwise) factored into prices paid for VDS days. Charging for FAD usage by other agencies (WCPFC, flag State, etc) will alter the nature of existing right and will, all other things being equal, expropriate potential revenues currently collected through the VDS.

- **The environmental and economic costs of FADs should be borne by those who use them -** – the right to deploy and set on FADs is, in effect, a freedom of the existing licensing regime (albeit now subject to the fairly ineffectual 350 FAD/vessel WCPFC limit). Under current arrangements, vessels reap the economic benefit of FAD fishing (an unknown proportion of which will flow through the Parties in VDS fees), but bear few of the environmental and economic risks. Instead, these risks are largely borne by the Parties (in the case of economics, the risks are to VDS fees if excessive mortality of BET results in broad scale constraints on the purse seine fishery) and the wider environment (in the case of risks to non-target marine life and marine debris). Any future PNA FAD management regime should seek to ensure that (a) environmental risks are minimised to the extent practical and (b) Parties are adequately compensated for all economic risks associated with FAD use.

- **The PNA FAD management framework should recognise, and manage, the two distinct sources of environmental and economic cost associated with FAD use**:
  - Costs associated with <u>FAD deployment</u> (e.g. incidental entanglements, marine debris beaching, impacts on stock dynamics); and
  - Costs associated with <u>setting on FADs</u> (e.g. impacts on vulnerable tuna species; impacts on non-target species such as sharks).

  The first group of costs is best dealt with by measures which seek to directly mitigate impacts such as changes in gear design (e.g. non-entangling FADs, biodegradable FADs, requiring retrieval of the FAD in the absence of biodegradable design). While there may be some residual impacts on target species stock dynamics from FAD deployment (noting that these can be mitigated to a large extent indirectly through effective limits on FAD setting), reducing the broader environmental impact of FADs being in the water substantially reduces the need to regulate numbers deployed.

  The second set of impacts is best dealt with through a regime which limits (and optimises economic returns from) FAD setting.

- **From an economic point of view, the thing of most interest to Parties is FAD sets** (not FAD deployments, assuming environmental costs of deployment can be largely mitigated through gear design) – arguably the key risk to economic returns under the VDS is a deterioration in the status of BET (or YFT), which requires a management response which constrains catches of the main target species, SKJ (e.g. through a reduction in the TAE or increase in the duration of the FAD closure). Fishing mortality impacts on the more vulnerable tuna species arise only where a FAD is set upon, rather than when the FAD is deployed (albeit there may be some impacts on stock dynamics and catch rates where very large numbers of FADs are deployed). To that end, the main focus of any future PNA FAD management regime should be to control and manage FAD sets, not FAD deployments. For this reason, Parties should resist any efforts by external agencies to control the FAD setting regime in the fishery. This presupposes that the environmental impacts of FAD deployment can be largely mitigated through gear design and limits on FAD setting will place enough downward pressure on deployments that the impacts of FAD density on stock dynamics are limited.

Determining the 'right' quantity of FAD setting in the VDS is an economic question which requires determination through a two-fold process of price discovery about net harvester benefit of FAD use that can be captured by Parties ($) compared with a countervailing subjective but agreed assessment of environmental risk ($) to the parties from FAD use.

- **The commercial leasing scheme envisaged in the original TORs is likely to be challenging to implement in practice and carries with it considerable risks to Parties** – although its undoubtedly an innovative, 'thinking outside the square' idea, a broad scale commercial FAD leasing scheme which would see Parties (either solely or with a JV partner) take responsibility for FAD deployment in the WCPO offers limited and uncertain benefits to Parties and carries with it considerable risks. Parties have limited internal infrastructure or know-how around FAD deployment, and even with a well-positioned industry JV partner, there is considerable downside risk that vessel level economics (and therefore capacity to pay for VDS days) will be negatively affected. Taking responsibility for FAD deployment also exposes Parties to considerable contingent legal, environmental and PR risks associated with FAD ownership. If the intent of the scheme is to better control and manage FAD usage and optimise economic returns to Parties, this can better done through a comprehensive FAD management regime which focuses explicitly on the two main types of economic/environmental impacts described above and under which revenues from FAD fishing are optimised (within risk parameters agreed by Parties) within the framework of the VDS.

- **Need to consider practical implementation and sequencing** – moving from where we are now to where Parties would like to be is a big package of work, some of which we currently don't have the information to design properly. To that end, there is a need to consider sequencing the proposed reforms, and importantly the correct order of implementation. As a general rule, there will be a range of base level reforms required to provide better information on, and control over, FAD use before progressing with a more sophisticated FAD setting regime to optimise VDS returns. These issues will be further considered in Phase 3.

5 Proposed focus of Phase 3

The observations above indicate that the optimal approach to the design and implementation of an effective FAD management regime has three inter-related parts that are sequential:

1. Gather greater information on the actual levels of FAD deployment and setting in the WCPO as well as any information on the relative economics of FAD versus free-school fishing under the VDS. Generate 'guestimates' of the environmental costs and risks that can be attributed to FAD deployment and FAD setting respectively. These guestimates should be re-run to model the impacts of different levels of possible FAD use.
2. Develop a <u>preferred regulatory instrument</u> for managing the issues associated with FAD Deployment. These are expected to take the form of specifications for non-entangling and biodegradable FADs and work with other Agencies such as WCPFC to ensure that only FADs meeting those specifications are deployed in the WCPO.
3. Develop a <u>complementary economic instrument</u> for managing the issues associated with FAD setting. The FAD setting regime for the VDS would be under the exclusive control of the

Parties collectively and would add value to the VDS (Day revenues under the FAD setting regime would more than compensate for any estimated environmental costs and risks associated with the level of FAD setting authorised). Note that the economic information does not currently exist to implement such a regime at present. Furthermore, current arrangements for the allocation and pricing of Days under the VDS are not well suited to the production of this critical economic information. An economically sophisticated FAD management regime requires a sophisticated and competitive Day market to support it.

The elaboration of the content of these three related sub-projects is the focus of the Phase Three Report.

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PNA FAD Management Scheme

Phase 3 Report

November 2018

MRAG asia pacific

About MRAG Asia Pacific

MRAG Asia Pacific is an independent fisheries and aquatic resource consulting company dedicated to the sustainable use of natural resources through sound, integrated management practices and policies. We are part of the global MRAG group with sister companies in Europe, North America and the Asia Pacific.

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Contents

1 INTRODUCTION 1

2 A NOTE ON CHANGING OBJECTIVES 2

3 PROPOSED PNA FAD MANAGEMENT SCHEME 3

3.1 Overall strategy 3
3.2 The Business of FAD Management 4
3.3 PNA FAD Business Customers are also PNA Day Customers 5
3.4 The Commercial Imperative of PNA 6
3.5 Refining the VDS to Better Manage the Effects of FAD Use on VDS Revenues 6
3.6 Regulating the Use of FADs 7
3.6.1 FAD Design 7
3.6.2 Limiting FAD Deployment per Vessel 7
3.7 Integrating FAD Right Pricing into the VDS 8
3.7.1 How Multizone FAD Days could be Sold by Auction 9
3.7.2 Multi-zone Auction Returns for FAD/non-FAD Days 9
3.7.3 Price Discovery and FAD Days 10
3.7.4 Pricing Single Zone FAD Days 12
3.7.5 The Relationship Between Multi-zone and Single zone FAD Day Pricing 14
3.8 PNA FAD Management: Next Steps 15
3.8.1 Information Collection and Analysis 16
3.8.2 Regulation of FAD Design and Deployment 16
3.8.3 Setting the Scene for Possible Economic Measures… 17

4 REFERENCES 18

1 Introduction

This report is the third and final in a series of reports designed to develop the architecture of a future scheme for the management of fish aggregation devices (FADs) in the purse seine fishery in PNA waters. This report is intended to be read in the context of the previous two reports which:

1. Consolidated the latest available information of FAD usage in the WCPO purse seine fishery including historical catch and effort on FADs, density and distribution of FADs, numbers deployed, FAD design and manufacture, FAD tracking systems and ownership, leasing and trading arrangements. Broadly, the first report concluded that PNA (and the wider WCPO) is generally 'behind the 8 ball' on FAD management across a range of areas and that a broad range of reforms are required to ensure Parties are well-positioned to manage FAD use in their waters and optimise economic returns; and
2. Examined the relative strengths and weaknesses of a range of different options for the future management of FADs with the intention of identifying the most attractive option, or combination of options, for more detailed consideration in Phase 3.

To that end, the aim of this report is to put 'some meat on the bones' of the preferred framework identified in Phase 2. Broadly, the Phase 2 report concluded that the optimal approach to the design and implementation of an effective FAD management regime has three inter-related parts that are sequential:

1. Gather greater information on the actual levels of FAD deployment and setting in the WCPO as well as any information on the relative economics of FAD versus free-school fishing under the VDS. Generate 'guestimates' of the environmental costs and risks that can be attributed to FAD deployment and FAD setting respectively. These guestimates should be re-run to model the impacts of different levels of possible FAD use.
2. Develop a preferred regulatory instrument for managing the issues associated with FAD deployment. These are expected to take the form of specifications for non-entangling and biodegradable FADs and work with other agencies such as WCPFC to ensure that only FADs meeting those specifications are deployed in the WCPO.
3. Develop a complementary economic instrument for managing the issues associated with FAD setting. The FAD setting regime for the VDS would be under the exclusive control of the Parties collectively and would add value to the VDS (Day revenues under the FAD setting regime would more than compensate for any estimated environmental costs and risks associated with the level of FAD setting authorised). Note that the economic information does not currently exist to implement such a regime at present. Furthermore, current arrangements for the allocation and pricing of Days under the VDS are not well suited to the production of this critical economic information. An economically sophisticated FAD management regime requires a sophisticated and competitive Day market to support it.

It is not the intention in this report to go into substantial detail on the first two components of the future management regime. The PNAO and Parties are already well-focused on these issues and plans are in place to progress them (either independently through something like an Implementing Arrangement, and/or through the WCPFC in the case of non-entangling, biodegradable FADs). Rather, the main focus of this report is to further develop the proposed FAD set management regime, and in particular arrangements for deriving optimal long term revenue to Parties from the use of FADs in their waters.

As outlined in the Phase 2 report, getting from where we are now to where we need to be is a very big package of work, some of which we do not yet have the information to design effectively at this stage. To that end, the types of management reforms outlined in this report, if accepted by the Parties, will need to be implemented sequentially, commencing with measures to improve our understanding of FAD use economics and measures to reduce environmental impacts of FAD deployment (through regulation of gear design). These measures alone may take several years to introduce and bed down.

With that in mind, the FAD set regime proposed here does not need to be introduced in the very near term. Assuming no dramatic change in FAD use in the fishery and that stocks of key target species remain at or above B_{MSY}, Parties should focus their immediate attention on the first two components of the reform package. The scheme proposed here then, which necessarily involves some sophisticated market economics, effectively represents the second stage of a reform process, once the bedrock reforms are operating effectively. To that end, we expect the proposal to establish a FAD set regime to be a 'slow burn' with Parties allowing themselves time to think through the implications and how best to implement it given their own circumstances.

Nevertheless, if implemented effectively, our analysis indicates that a FAD set regime operating as a subordinate right within the existing VDS framework has every potential to achieve the objective of the Ocean Partnerships for Sustainable Fisheries & Biodiversity (OPP) project (under which this work is funded) – namely the development of a long-term transformational 'business' for PNA Parties supporting sustainable fisheries and optimal economic returns from FAD use in the purse seine fishery within the WCPO.

2 A note on changing objectives

It is important to note that when the TORs for this work were first developed, the prevailing scientific advice was that bigeye tuna (BET) was overfished and subject to ongoing overfishing (Harley et al, 2014). Mortality of juvenile BET taken in association with FADs was a key contributor, and a range of options to reduce mortality were being considered including some equivalent to extending the FAD closure to-5-6 months. With that in mind, a key objective for this work – in addition to developing a transformative business enterprise – was to allow for the introduction of arrangements that would contribute to BET stock recovery, while at the same time minimising any disproportionate burden on Parties.

Since that time, an updated scientific assessment incorporating new growth parameters has provided a considerably more optimistic picture of stock health. Not only are BET not overfished, they were most likely never subject to overfishing (McKechnie et al, 2017). With that in mind, some of the context and the main drivers for the project have changed. The 4^{th} month of the FAD closure has been removed (reducing some of the economic impact on individual Parties) and within the WCPFC there has been an apparent shift towards managing the ecological impacts of FADs.

Nevertheless, despite the change in urgency surrounding FAD management reforms, the essential interests of the Parties at the higher, collective level remain the same – that is, if FADs are to continue as part of the purse seine fishery landscape in the WCPO, Parties need (i) good information on their use in order to manage them effectively, (ii) they need to ensure that the ecological impacts of FAD use are minimised to the extent practical and any residual impacts/costs are borne directly by FAD users and (iii) they need to optimise the long term revenue they receive from FAD usage in their waters on behalf of their people.

To that end, the essential task remains the same.

3 Proposed PNA FAD Management Scheme

3.1 Overall strategy

Although some of the measures required to comprise a future PNA FAD management scheme are complex, and some involve reasonably complicated market economics, at the higher level the basic strategy is relatively straightforward:

1. As a first step, **Parties should put in place measures which ensure they have a sophisticated, near real time understanding of FAD use in PNA EEZs (including its biological, ecological and economic dimensions) and the capacity to manage that usage in a dynamic way that best suits their individual and collective interests**. These 'bedrock' reforms should be established at the earliest possible opportunity and include:
    a. Effective (i.e. full) FAD registration, marking and monitoring (including a prohibition on setting on FADs within PNA waters where the buoy is not registered);
    b. Near-real time tracking of all FAD buoys within PNA's area of interest (without geofencing);
    c. Requirements for vessel operators to provide comprehensive information on FAD use in the fishery (deployments, design, interactions, buoy swaps, etc);
    d. A 'type approval' process for buoys and buoy manufacturers which ensures that (a) buoys used in PNA waters are capable of providing information of interest to Parties and (b) information of interest to Parties is provided automatically by buoy manufacturers; and
    e. Verification of vessel reporting by PNA observers.

2. Either in parallel, or immediately following the bedrock reforms above, **Parties should introduce measures which seek to minimise the ecological impact of FAD *deployment* and, to the extent that impacts cannot be reduced to zero, ensure that any residual environmental costs associated with deployment are borne directly by FAD users**. In practice, these reforms should focus on:
    a. Gear design – e.g. requiring the use of non-entangling and biodegradable FADs to minimise incidental mortality of vulnerable species (sharks, turtles) and the impacts of marine debris respectively; and
    b. Ensuring FAD 'owners' are legally responsible for retrieving FADs at the end of the productive life and/or to avoid beaching events (or alternatively required to offset the retrieval and remediation costs if undertaken by third parties).

3. Finally, once the above two sets of measures are in place, **Parties should introduce arrangements which allow them to directly manage the greatest risk to their long term revenue from FAD use in the purse seine fishery, while at the same time optimising their annual (and long term) revenue streams**. In this case, the greatest risk to long term revenue is a deterioration in stock status of vulnerable tuna species (BET, and to a lesser extent YFT) requiring restrictive measures (e.g. longer FAD closures, reductions in TAE) which impact revenue from the main species, SKJ and YFT. Although the most recent BET stock assessment is substantially more optimistic than previous assessments, the essential truth that a deterioration in BET stock status remains the key risk to Party long term revenues remains unaltered. As set out in the Phase 2 report, **the optimal means to manage fishing mortality from the PS fishery on BET and to optimise revenue from FAD fishing is to introduce a FAD set management regime, operating within the framework of the VDS**.

As discussed above, Parties are already well-focused on the first two reform areas described above and are currently in the process of discussing with Parties the most effective technical and legal means of implementation. In the case of registration, monitoring and tracking reforms, these are likely to be implemented directly by PNA Parties through an Implementing Arrangement or similar agreement. In the case of 'eco' type FADs, some of these measures may be best progressed through the WCPFC.

On that basis, this report focuses its attention on the third component of the reform package, setting out the 'business case' for the introduction of a PNA FAD set regime operating within the framework of the VDS. While it is not a typical 'business case' (i.e. upfront capital investment and staffing projections, marketing plans, revenues and ROIs, etc), the FAD set regime proposed here (and underlying price discovery process) would, in our view, deliver optimal long term revenue to Parties associated with FAD use in their waters and to that extent is the best 'business' for them to be in.

3.2 The Business of FAD Management

The overall conceptual framework for this three-part study is that the design of an optimum FAD Management Regime for PNA should be approached as the development of a 'business case' or suite of potential 'business cases'. The objective of that hypothetical 'business' would be to generate the maximum benefits for the PNA and those benefits would not be confined to the financial but would also consider associated social and environmental benefits (and costs). Applying a business case paradigm to PNA FAD management has not been straightforward.

If we commence with the Cambridge English Dictionary definition of business: "*the activity of buying and selling goods and services*" we are immediately confronted with the task of defining the FAD goods and FAD services that would be the stock in trade of various hypothetical FAD businesses. One specific scenario we were asked to consider was that PNA might involve itself in owning and renting FADs/FAD buoys but there are many others.

As with all businesses, each scenario has a particular business owner, legal structure and (depending on its scope) the business would operate within a particular existing legal and regulatory environment that would, in part, dictate its operating costs. The conventional objective for such a business would be to generate a profit for the business owner(s) meaning that revenues would have to exceed costs over time. Costs would include a risk-appropriate rate of return on any capital that owners were required to provide to the business in order to establish it and resource its operational needs.

What became evident in the earlier two phases of the study is that the use of FADs is essentially an adjunct and cost to tuna purse seine harvesting. More specifically, the use of FADs entails five distinct categories of potential costs to purse seine harvesters who wish to use FADs:

i. Construction
ii. Deployment
iii. Operation (especially telecoms costs)
iv. Recovery
v. Reporting/Compliance costs recovered by fisheries management agencies monitoring and regulating the deployment, setting on and recovery of FADs.

The study found that many of these costs were poorly understood and are likely to be volatile. Both the design and use of FADs are rapidly evolving technologies and, although there is general recognition that a FAD management regime is necessary, the implementation of that regime is in its infancy and the reporting and compliance costs of operating that regime are both uncertain and absent from any current analyses of the economics of FAD use carried out within the harvesting sector.

By the definition above, the FAD 'customer' would have to find that (on average) the sum of these additional costs to their businesses would be out-weighed by the benefits of FAD use. The FAD customer, in this context, is a purse seine harvester or harvesting business. These customers are already extensively involved in construction, deployment and operation of FADs. They also have established commercial supply relationships with existing businesses developing and manufacturing ever-improving FAD satellite buoys and the telecommunications networks they connect to.

If PNA were to become a successful new entrant into the FAD manufacture and deployment sector it would have to be more efficient at producing these goods and services than their prospective customers (harvesters) who are already carrying out many of these FAD business activities 'in-house'. Alternatively, PNA would have to be more efficient at supplying the FAD goods and services already purchased (out-sourced) by these prospective customers from their existing suppliers. Even when the broad FAD sector is broken down into subsets of goods and services it is very difficult to identify one in which PNA is likely to be more efficient than the incumbents:

- either the FAD services are provided 'in-house' as an integrated part of a wider harvesting business which allows for the sharing of overhead and operational costs in FAD construction, deployment, operation and recovery with other aspects of the harvesting business;
- or the 'out-sourced' goods and services are supplied by specialised electronic manufacturers or very large telecommunications businesses.

3.3 PNA FAD Business Customers are also PNA Day Customers

As discussed in the Phase 2 Report, PNA faces a serious economic dilemma as it contemplates entering the FAD business. This is because PNA's potential FAD customers are already buyers of PNA Vessel Days and the price those customers pay for Days already factors in the costs and benefits of any FAD use already funded and managed by those Day customers. Any change to this status quo commercial arrangement that drives up the costs of FAD use to harvesters will drive down their willingness to pay for Days by the same amount.

In summary, for PNA to enter the FAD business, it will have to displace harvesters from their existing FAD 'businesses' in which they have some clear competitive advantages. It is hard to see how this displacement could be achieved without generating a fair degree of resentment from harvesters who are also Vessel Day customers. Assuming that this displacement proceeded, however, to the extent that the new PNA FAD regime is less beneficial to harvesters than the status quo, Vessel Day prices would go down. There is no commercial rationale to PNA entering a FAD business to generate profits that are equal to, or less than, the loss of profits in their associated and core Vessel Day Business.

The analysis in the Phase 2 Report is that there is no immediately implementable PNA FAD deployment business model where the expected benefits clearly outweigh the possible costs. Furthermore, although it is safe to assume that existing FAD use arrangements are economically beneficial to harvesters, it is not safe to assume that those existing arrangements are economically beneficial to fisheries 'owners' collectively, once all environmental and economic risks (excluded from the present calculations of harvesters) are properly considered.

This does not mean that it would not be possible to develop a PNA FAD business model in the medium term where expected benefits to Parties clearly outweighed costs and risks. However, before such a proposed business model could be properly tested, two things would have to be done:

i. Parties need much better information on the environmental risks and possible associated economic costs that the use of FADs pose to their core Vessel Day business. This relationship is poorly understood but the mechanics of the VDS, operating as it does through Target and Limit Reference Points connected to the Total Allowable Effort Limit, are a blunt instrument that can impose very high financial costs on Parties if the TAE has to be reduced.

These environmental risks and costs are somewhat subjective, so collective agreement about their nature and magnitude is required before any robust agreed analysis of the commercial merits of a particular FAD business model can be carried out by PNA.

ii. Parties also need a way of determining whether the status quo FAD regime (or any alternative to that status quo) is beneficial to them. Parties need to be able to tell that FAD benefits and revenues, whether retained or paid by harvesters, are not just foregone Vessel Day revenues in disguise. The FAD pricing approaches and initiatives being employed by PNA do not presently do this effectively. In fact, any commercial arrangements that allow FAD rights to be sold separately from Day rights will not provide reliable information on the real value of FAD rights to harvesters. Also, the normal position today whereby all Vessel Day rights carry a FAD use right that may (or may not) be used by the buyer also obviously provides no information on the real value of FAD rights to harvesters.

These two points lie behind the recommendations in the Phase 2 Report that PNA focuses in the short term on:

- information gathering;
- the regulation of any significant environmental costs identified and;
- the development of a commercial regime where FAD Days and non-FAD Days could be sold through a single market.

In this market, FAD setting rights encapsulated in a FAD Day could not be separately traded from the Day itself.

3.4 The Commercial Imperative of PNA

An initial finding that PNA would not (at this time) be a competitive entrant into a FAD business already conducted by its harvester customers does not mean that PNA can safely ignore that business or business sector. The insight that PNA could reduce its Day revenues over time by a poorly conceived foray into a FAD business highlights the fact that FAD businesses generally (including those already in existence) are a real competitor with the VDS for fisheries rents. The commercial imperative for PNA is to ensure that the maximum level of economic rent from the purse seine fishery is channelled towards, and captured by, the VDS. Anything that increases the level of risk to VDS revenues or reduces the level of those revenues over time should be actively opposed by PNA. The use of FADs may be positive or negative for VDS revenues over time and may even generate both outcomes at the same time at different places within the fishery. FAD use is simultaneously a threat and an opportunity to the PNA VDS business.

The study indicates that there are many environmental/economic spill-over costs from FAD use that are not factored into the demand for FAD use by harvesters because those costs are borne by fisheries owners (Parties) rather than harvesters (at least at present). For example, FAD users are not compelled to recover their FADs. They therefore avoid the very substantial costs of doing this as well as the costs of funding any enforcement regime that ensured such recovery was done satisfactorily.

An important conclusion reached in Phase 2 was that PNA needs to adapt the VDS to better manage the effects of FAD use on the future level and risk of VDS revenues to the Parties. FADs need to be managed, but the best way of managing the risks of FAD use at this time would not be to enter FAD ownership, deployment or operation business activities directly.

3.5 Refining the VDS to Better Manage the Effects of FAD Use on VDS Revenues

The VDS can be viewed as an integrated bundle of regulatory and economic instruments. The setting of TAEs in response to fisheries data or the licensing of vessels along with the reporting and other legal responsibilities contained in those licences are regulatory instruments. The operation of primary and secondary markets in Vessel Days are economic instruments. Very broadly, environmental risks in the fishery are managed through regulatory instruments and economic benefits from the fishery are captured through economic instruments.

Protecting the VDS from adverse environmental and economic effects of FAD use, and optimising returns, will require the integrated development and use of both classes of instrument.

3.6 Regulating the Use of FADs

Two regulatory initiatives are underway that address FAD design and deployment. These are both worthy of PNA support. However, both are uncertain as to their medium-term effectiveness and may have to be supplemented in future with additional regulatory and economic instruments.

3.6.1 FAD Design

It appears that some of the environmental consequences of FAD deployment (and non-recovery) could be mitigated by requiring FADs to be either biodegradable or at least have limited design life. To the extent that environmental costs can be reduced by better design then those better designs should be required by regulation. These initiatives are not very popular with industry however. This is probably connected to the lax status quo enforcement of any theoretical obligations for harvesters to recover their FADs and remove them from the ocean each year. If this type of rule was rigorously applied, the economics of FAD use by harvesters would be seriously degraded and alternatives to recovery would be more enthusiastically supported by harvesters.

3.6.2 Limiting FAD Deployment per Vessel

The most common international control measure on FAD use is to limit the number of FADs that can be deployed by a single vessel. It is notable that the limits proposed for the Western and Central Pacific Ocean by the WCPFC of 350 per vessel appears to comfortably accommodate existing practice in the fishery. It is not a constraint on current practice but a barrier to expansion of FAD deployment by each vessel. This cap appears to be acceptable to industry.

One reason for this acceptance could be related to the phenomenon of FAD saturation. Scientific data is somewhat sketchy, but it appears that the Catch per Unit Effort (CPUE) benefits of FAD use diminish with FAD density and, beyond a certain point, there may even be a negative relationship between FAD density and CPUE (see, for example, the analysis in Escalle et al, 2018). Although more data is required for the WCPO, this relationship is intuitive in that if tuna schools have more FAD 'shelter' options and those options are used by the fish then there will be fewer fish under each FAD on average. However, the fact that agreement can be achieved with industry about limiting FAD numbers to avoid FAD saturation problems does not mean that the negative environmental impacts of FAD deployment have all been satisfactorily addressed.

FAD saturation means that above a certain number of deployments, there is an alignment of interests between harvesters and fishery owners over the number of FADs that should be deployed. The interests of industry collectively are to ensure that FAD deployment numbers improve (rather than detract from) CPUE and high CPUE is supportive of high Vessel Day prices. Similar alignment does not exist at the other end of the FAD deployment spectrum. Imagine if increasingly restrictive FAD deployment numbers are regulated so that (at least at certain times and places in the fishery) there was a very significant CPUE advantage and harvesting profitability premium from having rights to the limited supply of FAD deployments allowed. Having a FAD right in those circumstances may be the difference between being a competitive or uncompetitive harvester in the fishery.

At that point, a FAD right becomes economically indistinguishable from an access right and two rival access rights have therefore been created (the right to set on a FAD and the Vessel Day). Assuming both are necessary for harvesting success, a 'Mexican stand-off' has been created over how surplus fishing profits should be attributed to the different access rights. This conflict would be very dangerous for PNA, especially if PNA is not in control of both access rights. However, even if PNA controls both the restrictive Day access right and the restrictive FAD deployment right, any lack of transparency about how harvesters 'price' each access right means that PNA may miss out on significant value.

For instance, if the FAD right was detachable from the Day right, harvesters may try to transfer FAD rights from the west (where they would have a low value) to the east (where they would have a high value) and attach them to an eastern Vessel Day right (that would have a relatively low value in the absence of the right to use FADs). If eastern Parties sought to counter this problem by insisting that they would be the sole source of FAD rights in their zone, then a multi-zone Day scheme (and its significant value benefits) would be handicapped. In those circumstances, eastern sellers of single-zone Days and single zone FAD rights would have no easy way of determining what FAD premium they were actually receiving.

That is why regulatory FAD management instruments cannot be allowed to become a de-facto economic instrument.

3.7 Integrating FAD Right Pricing into the VDS

The dangers of separate economic instruments for FAD use and Vessel Days suggest that PNA needs to refine its core business (the sale of Days) to accommodate FAD Days and non-FAD Days as variants of an integrated access right (the Vessel Day). The introduction, and the successful defence, of this framework is necessary to protect the economic performance of the VDS if FAD use is to be authorised within it.

An integrated approach to the sale of Days (whether for FAD fishing or otherwise) preserves the maximum depth of market which is necessary for all PNA Parties to receive maximum sale price for their Vessel Days. Separate markets for FAD and non-FAD Days are to be avoided for market depth reasons alone. Second, an integrated approach is also necessary to ensure that no FAD Days are sold that do not carry a price premium adequate to compensate for the any environmental effects of FAD fishing on the VDS. 'Adequate' in this context means a price premium agreed as satisfactory by all Parties because those environmental effects are borne collectively.

This integrated approach does not exist at present. Notwithstanding some Days sold through the 'pool' arrangement, most Days are sold through nine separate market processes as single-zone Days and there is no agreed environmental premium that should be attached to the right of a harvester to use FADs when fishing those single-zone Days. As has been extensively discussed by Parties, maximum depth in the Day market would be attained by selling standardised multi-zone Days contributed by Parties from their respective PAEs to a single electronic Day auction. However, it is not expected that all Days would be sold in this market. Parties have indicated that they wish to continue to support domestic arrangements directly with single zone Days or to maintain single zone bilateral arrangements with foreign fishers.

Consequently, Parties would be free to determine what proportion of their PAE was committed to the multi-zone auction but membership of PNA would oblige them to permit access to their zone of the holders of multi-zone Days (somewhat analogous to the FSM Arrangement). Preliminary thinking is that a multi-zone market for 10,000 Vessel Days (less than a quarter of supply) would still create a highly competitive market that would provide an invaluable benchmark for the other three quarters of Days that were sold on bilateral single zone bases.

The multizone auction as envisaged would receive bids from pre-authorised buyers and determine a clearing price for the supply of Days to be sold in the auction. All successful bidders would pay the clearing price (the lowest successful bid). Prospective buyers could make multiple bids for different numbers of Days at different prices. All successful bids would have to be paid for at the clearing price.

3.7.1 How Multizone FAD Days could be Sold by Auction

It is relatively straightforward to adapt the proposed multizone Day auction design to accommodate the simultaneous sale of FAD and non-FAD Days within a single electronic auction event. Bidders would be able to make multiple bids at multiple prices as in the base auction concept above. All prospective buyers would have to identify each bid as being for either a FAD Day or a non-FAD Day. All FAD Day bids would be discounted for the purposes of Day allocation by the price premium per Day that PNA determined was applicable in that particular auction. For example, if the FAD Day premium was determined to be $3000 per Day, then when both FAD and non-FAD Day bids are ranked from highest to lowest in order to establish the clearing price that all bidders will pay in the auction, then $3000 would be deducted from all FAD Bids in that process to establish their allocative ranking with non-FAD bids in the same auction.

Having determined what bids were successful (above the clearing price) and those that were unsuccessful (below the clearing price) then successful bidders would be required to pay for all of the FAD and non-FAD Days they had bid for. Non-FAD Days would incur the clearing price and FAD Days would be charged at the clearing price plus $3000 (in the example above). First, note that whether they bid for a FAD or non-FAD Day successful bidders would pay no more than they actually bid. Second, note that in this process, the number of FAD Days produced by the auction would be a function of the bidding process rather than a hard numerical limit set by the Parties.

3.7.2 Multi-zone Auction Returns for FAD/non-FAD Days

The multi-zone auction would determine the number and allocation of FAD and non-FAD Days within the auction pool to buyers. Parties would receive an averaged return for all Days committed to a particular auction from their PAEs. If half of the Days in the auction were sold as FAD Days (following the setting of the FAD premium of $3000/Day by the Parties collectively) then each Party would effectively receive returns equal to 50% of their Days at Clearing Price plus 50% of their Days at Clearing Price plus $3000. Note that Parties would not nominate the proportion of their Days committed to the auction that should be sold as FAD Days and the split between FAD and non-FAD Days (once established by the auction retrospectively) would be exactly the same for all auction participants.

There are two important principles underlying this assumption:

i. There would be no formal allocation of FAD Days amongst the parties. Effectively all Days within all PAEs are potentially a FAD Day. This reflects the current position. Ideally, the number of FAD Days sold in a given year should reflect the total economics of FAD fishing to Parties collectively (not to harvesters individually or collectively).
ii. Costs of FAD fishing are shared costs to a large extent and those shared costs are shared in proportion to the relative PAEs of the Parties. The corollary of this assumption is that the benefits of FAD fishing should therefore be shared on the same basis (as far as practicable). That is, both the costs and benefits of FAD fishing should be spread across the entire fishery even though FAD setting is not spread over the entire fishery.

As discussed in the Phase 2 Report, a FAD Vessel Day would entitle the holder to set on FADs during that Day. A Vessel Day does not stipulate the number of sets that the holder can make in that Day (normally one or two). Similarly, a FAD Day would not stipulate how many sets in that Day would be on FADs (normally one or two). If a harvester found that they had more FAD Days than they could use, the FAD rights could not be sold separately from the Vessel Day to which they were attached. If a harvester had 'expensive' FAD Days they did not need, they could sell those Days on a secondary market and attempt to buy 'cheaper' non-FAD Days in that secondary market.

3.7.3 Price Discovery and FAD Days

The merit of selling both FAD and non-FAD Days simultaneously through a deep multizone Day auction (as briefly outlined above) is that it will generate the best information about what bidders are really prepared to pay for both FAD and non-FAD Days in circumstances where it is very difficult to cross-subsidise one type of bid from the other. Important information will be collected about the net benefit harvesters expect to receive from FAD fishing (shown as the difference between the price bid for FAD Days and non-FAD Days). If it wished, PNA would be able to analyse this price spread by individual bidders as well as in average.

The key question PNA must answer is whether the available premium for a FAD Day as revealed in harvester bids is sufficient to compensate Parties for the range of environmental costs and risks associated with FAD fishing. The complication in that decision is that the size of the environmental effect per FAD set is likely to be affected by the total number of FAD sets occurring in the fishery. This complication can be mitigated to an extent because the PNA decision about the appropriate level of FAD premium to be required of bidders could be made after the auction bids have been received. PNA may have an initial view on the level of FAD premium that would be required to place a FAD Day bid on par with a non-FAD Day bid, but this initial price premium per Day could be adjusted up or down once the pattern of bids for both Vessel Day categories was seen. The size of the premium may also be adjusted over time based on the status of the BET stock (and to a lesser extent YFT stock) and the extent to which fishing mortality needs to be adjusted to achieve stock management objectives.

Ranking bids in the auction process above provides very valuable insight to PNA about the shape of the demand curves for both FAD Days and non-FAD Days (and their substitutability). As discussed elsewhere with PNA, having obtained this demand information, there is a strong case not to charge bidders what they actually bid but to require all bidders to pay the same clearing price. 'Surplus' profits available above the clearing price are a powerful driver of dynamic efficiency in the fishery. Innovations that can generate returns above the norm are encouraged by this Day pricing strategy even though those above-normal returns are often whittled away quite quickly by the spread of that innovation and migrate to the Vessel Day clearing price (in other words, allowing 'surplus' profits to be invested in innovation ultimately benefits the Parties because profitable innovations tend to be copied by other vessels which improves average fleet-wide profitability, in turn strengthening capacity to pay for VDS days. By contrast, although capturing these 'surplus' profits upfront may increase short term revenue, it ultimately stifles innovation placing longer term downward pressure on VDS prices). Second, when bidders who do not expect to be setting the marginal clearing price know they will be required to actually pay what they bid, they will tend to reduce the size of those bids and PNA thereby loses insight into what their customers are truly willing and able to pay for Vessel Days.

The same broad logic for pricing all multizone Days at the same level applies to why a standard FAD Day premium should be applied to all multizone FAD Days also. The information emerging from the fishery suggests that there is a broad east-west gradient to the benefits of FAD Fishing. FAD use benefits are high towards the eastern end of the fishery and decline to lower levels in the west (Figure 1; Figure 2). No doubt, better information over time will flesh out this crude picture. When a multizone Day is sold, bidders attach an average value to that bid. On some days, return from using the Vessel Day will be above the bid price and on other days in other places the actual return achieved may well be less than the price paid for the Vessel Day. This is true whether the Day purchased is a FAD Day or a non-FAD Day.

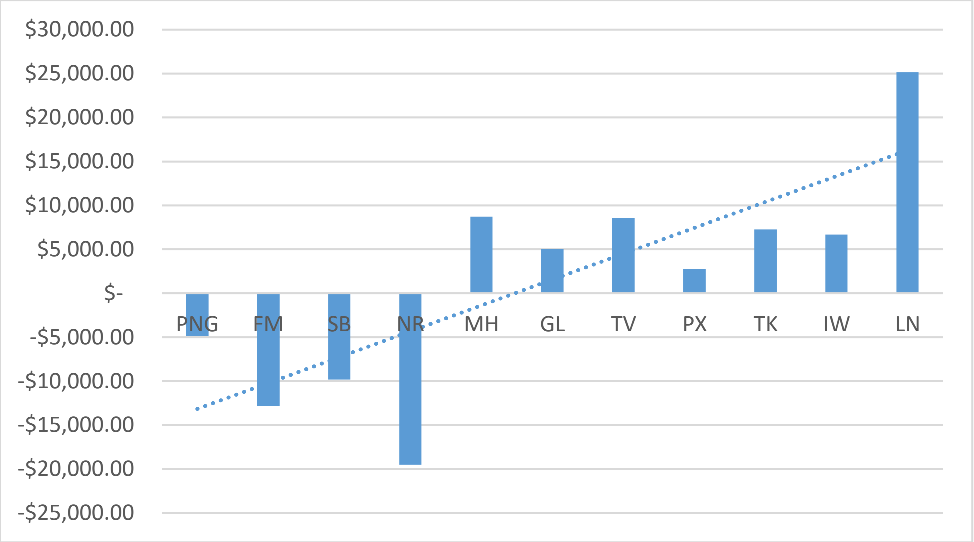
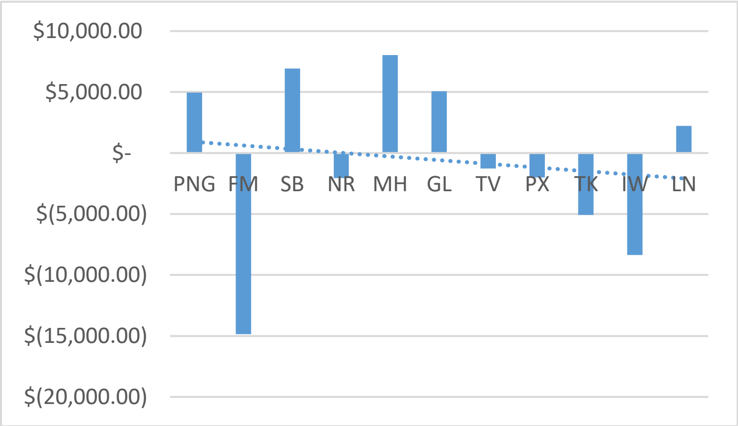
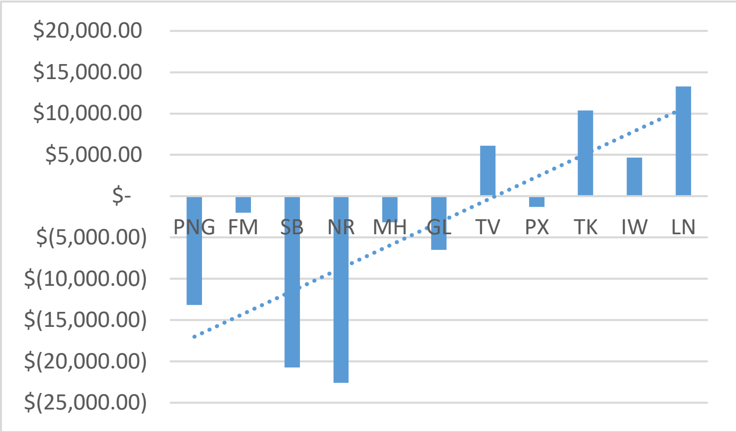


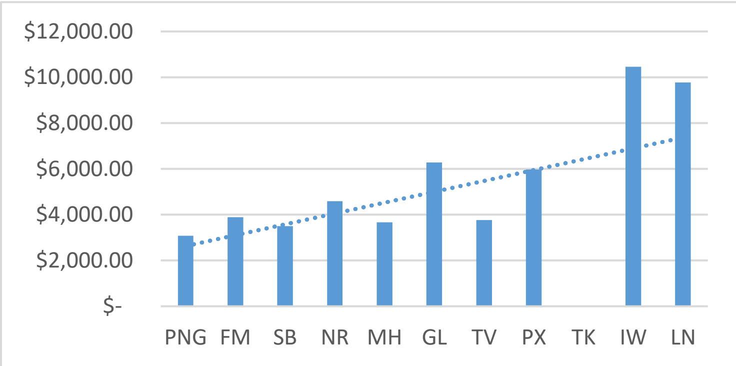
Figure 1: Difference in the average expected revenue from a drifting FAD set compared to a free school set in each PNA zone (plus international waters - IW), 2016-2017, based on catches of the three main tuna species (SKJ, YFT and BET). For zones with positive differences (i.e. above the zero line), the expected revenue from dFAD sets exceeded free school sets; for zones with negative differences (i.e. below the zero line), the expected revenue from free school sets exceeded dFAD sets. Zones are broadly structured in a west to east order. The majority of effort in international waters was assumed to be in the eastern high seas. The three Kiribati zones are examined separately (GL, PX, LN). Palau was not included given the limited number of recorded sets. Data is based on observer reports of catch of the three main tuna species (SKJ, YFT and BET) by set type (dFAD or unassociated), by fish size (SKJ: <3lbs; 3-4lbs; 4-7.5lbs; <7.5lbs; YFT: <3lbs; 3-7.5lbs; 7.5lbs-20lbs; >20lbs; BET: <3lbs; 3-7.5lbs; 7.5lbs-20lbs; >20lbs) by zone, averaged for the years 2016 and 2017. Differential prices were applied to each species and fish size based on market prices, pegged to a Bangkok price of US$1,500/t for 4-7.5lbs SKJ. A price premium of 20% was applied to YFT, although this may be conservative. Note, the graph depicts differences in revenue only, so costs per set would need to be known to examine overall profitability per set. The dotted trend line is a simple linear regression.



(a)



(b)



(c)

Figure 2: Difference in the average expected revenue from a drifting FAD set compared to a free school set in each PNA zone (plus international waters - IW), 2016-2017, for each of the three main species individually: (a) skipjack, (b) yellowfin and (c) bigeye. Methodology used was consistent with Figure 1 above. Note for bigeye the expected revenue from a dFAD set exceeds the revenue from a free school set for each zone. Also note that much of the overall east-west trend in revenue from dFADs Vs free school sets is driven by strong trends in YFT/BET catches, rather than SKJ.

3.7.4 Pricing Single Zone FAD Days

As mentioned previously, while the benefits of using a FAD Day are different in the EEZs of different Parties, given the shared nature of stocks the environmental costs are much more constant and apply to the entire fishery, not just the EEZ where the FAD Day was used. The question arises as to how individual Parties should apply the pricing information ‘discovered’ in the course of operating an annual multizone electronic auction in pricing their own single zone Vessel Days sold on a bilateral basis. Multizone Days have some fundamental advantages over their single zone counterparts and would normally be expected to sell for a premium (anecdotal evidence from Parties participating in ‘pooling’ arrangements confirms the existence of a ‘real world’ premium). Once the multizone Vessel Day auction is up and running, single zone bilateral negotiations are likely to be affected by the benchmark set by that auction (held shortly prior to the beginning of each fishing year). As is the case now, single zone non-FAD Days are likely to be sold for different prices above an agreed floor price for the sale of any Day by Parties.

Whatever the bilateral single zone price for a non-FAD Day, the FAD Day premium should always be added (at minimum) to the bilateral single zone non-FAD Day price in that zone. If a Party did not apply the minimum price premium to FAD Days in its zone, it would be gaining a pecuniary advantage at the expense of all other Parties by facilitating the creation of shared environmental costs that had not been compensated for within the Day price charged to the FAD user. Individual Parties in the East of the fishery may wish to charge a higher FAD premium per FAD Day than the one imposed in the multizone auction. The non-FAD single zone price is likely to be below average in those eastern sites and the benefit of using FADs is likely to be above average. The combined bilateral FAD Day price of (non-FAD Day price plus FAD Day premium) is not likely to exceed the price of a multizone FAD Day but the composition of that combined price is likely to be quite different.

Parties in the East of the fishery could be expected to sell a high proportion of bilateral Days as FAD Days and should expect to receive a FAD Day premium above the multizone auction FAD Day premium applying to all bilateral FAD Days sold.

Box 1: The 'business' of selling FAD Day rights: A worked example

As discussed in the Phase 2 report and above, Parties are expected to receive optimal long term returns from FAD use in their waters where:

1. Parties have good information on FAD use and economics in the fishery (both costs and benefits);
2. Risks to the main tuna stocks from FAD setting are appropriately managed (which, for the more vulnerable tuna species, sensibly requires a precautionary approach);
3. The extent of FAD setting is managed through an economic instrument subordinate to, and which does not impede the efficient operation of, or compete for revenue with, the VDS;
4. There is strong competition amongst harvesters for VDS rights, including FAD day rights.

Below is a worked example of how the 'business' of selling and managing FAD days within the framework of the VDS might operate in practice.

- Parties contribute 10,000 VDS days to a multi-zone electronic day auction, based on an agreed formula. The multi-zone day auction would be managed efficiently by an agreed entity;
- Registered bidders (fishing companies and any other agreed bidders) place bids for packages of multi-zone days. Bidders nominate if the days are to be FAD days or non-FAD days. Bidders may bid on multiple packages of days at different prices. Assuming strong competition for multi-zone days, the total days 'bid for' is likely to substantially exceed 10,000. Let's assume for our purposes, bids are placed for 40,000 days;
- PNA Parties would agree a price premium for a FAD day based on their judgement of the economic costs (and risks) associated with FAD fishing (e.g. the impact on the BET stock and the risk that costly fishery-wide measures would need to be introduced if the BET stock approached a LRP). The price premium could be adjusted over time based on experience and stock management considerations (e.g. whether BET mortality needed to be reduced). The price premium is ultimately at the discretion of Parties, so can be adjusted as necessary once bids are received and evaluated. Let's assume for our purposes, Parties agree a FAD day premium of $3,000;
- Once the premium is fixed, all bids for FAD days would be discounted by the agreed premium to achieve a 'standardised' Day price. All bids for the 40,000 days would then be ranked from highest to lowest.
- Amongst the bids for the 40,000 days, the price for the 10,000th day is $12,000 – this is then the 'clearing price'. All bids at or above the line must pay the clearing price. Any FAD Day bids above the line must also pay the associated the $3,000 FAD Day premium (i.e. successful bids for non-FAD days will pay $12k; successful bids for FAD Days will pay $15k). Revenues to Parties from Day sales will be distributed proportionate to the number of Days they contributed to the multi-zone Day pool.
- Amongst the successful bids for 10,000 Days, 5,000 are for FAD days. Both FAD days and non-FAD days are able to be fished in any PNA Party's waters. The benefits to Parties are both (a) revenue, including a likely premium associated with multi-zone Days and (b) good

information on harvesters' relative willingness to pay for FAD days relative to non-FAD Days.

- Parties then sell the remaining ~30,000 Days in the TAE through their normal single zone (or pooled) Day markets. Let's assume Parties have agreed a single zone benchmark price of $10,000. Bidders in single zone markets should be asked to nominate whether they wish to purchase Days with or without associated FAD rights. All non-FAD Days should be sold at or above $10,000. All FAD Days should be sold at or above $13,000. Parties in the east may choose to apply a higher FAD Day premium if sufficient demand exists.

Parties should note that this is simply one approach to the sale of FAD Days within the framework of the VDS. This approach has the benefit of avoiding difficult allocation processes amongst the Parties, instead using an economic instrument to effectively control the number of FAD Days sold. Nevertheless, the approach does not apply hard limits to the number of FAD days (leaving open the possibility that more than a desirable number of FAD Days are sold) and it's possible that some Parties may benefit from FAD Day premiums more than others. To that end, it's worth noting that other options exist – for example, allowing each Party to sell an equal proportion of their PAE as FAD Days (using information from the multizone auction to establish the price premium) (see section 3.7.5) – and Parties should work through the alternatives to arrive at a model that all Parties can support.

3.7.5 The Relationship Between Multi-zone and Single zone FAD Day Pricing

In the Phase 2 Report, the dangers of allowing third Parties (outside of PNA) to effectively control the number and price of FAD Days within the VDS was highlighted. Parties could be left to carry the environmental and other costs of FAD fishing while a third party could capture the benefits of FAD fishing, even to the extent of cannibalizing Vessel Day revenues. The analysis above indicates the presence of a significant potential internal threat to the VDS as well as the previously discussed threat from without. The costs of FAD fishing attach to the fishery but the benefits of FAD fishing are more tightly associated with specific localities within the fishery. This creates the opportunity for individual Parties who have such localities within their EEZs to attempt to sell high volumes of FAD Days for that EEZ and maximise the FAD premium they receive overall.

The Multi-zone auction does not seek to maximise FAD Day revenues. Rather it seeks to ensure that any FAD Days sold carry a premium adequate to compensate Parties for the full environmental costs of any FAD Day. Because these costs are affected by the extent of FAD fishing in the entire fishery, the premium has to be set on the basis of projections about that fishery-wide extent (in particular assumptions about the number of likely FAD sets). If those projections are broadly correct, then any bilateral FAD Days sold at the same, or higher, premium than the one charged in the Multi-zone auction will not cause any uncompensated adverse effects. Aggregate demand for FAD Days will be throttled back to 'acceptable' levels by the price premium charged across the fishery. If demand turns out to be higher than expected, the premium charged in the following year can be increased accordingly, setting a new FAD Day premium benchmark across the fishery at that time. In other words, the FAD Day price discovery mechanism proposed has a potential self-correcting capability if used thoughtfully across years.

There are two threats to the effectiveness of this mechanism:

i. Unlike the FAD Day premium in the multi-zone auction, the bilateral FAD Day premium does not rest on solid foundations. Parties are guided by benchmark Day prices but are not bound by them. Accordingly, a Party could argue that it is charging a $3000 premium for bilateral Day prices as required, whereas some, or all, of the $3000 was underwritten by softness in the underlying non-FAD Day price underneath it. A party adopting such a strategy is in danger of self-deception in that they may find it very difficult to tell whether the greater FAD premium revenues obtained are truly greater than the associated Day revenue losses. Remember that all Days sold currently are effectively FAD Days that carry a variable FAD premium depending where they can be used. Requiring all Parties in future to identify bilateral Days as FAD or non-FAD means that there will be no market based non-FAD Day price benchmark to work with initially. All things being equal, Parties may be able to sell the new FAD Days above the old benchmark price, but non-FAD Days may command a price below the old average.

ii. A Party may elect to disregard the standard $3000 FAD premium obligation. This danger increases if the FAD premium were to rise significantly over time (perhaps because of number of bilateral FAD Days being issued). This is another way of describing rising socialised FAD costs relative to privatised FAD benefits. The incentive to shirk a fair share of those costs rises in those circumstances and more free-riding can be expected.

If avoidance of the agreed imposition of an effective FAD Day price premium breaks down because of either of these threats or perceived inequality amongst Parties, then PNA would be obliged to develop and impose some form of regulatory mechanism for FAD use.

One alternative, for example, would be to agree an annual limit on the number of FAD days able to be sold annually at the collective level, and share these equitably in proportion to a Party's PAE. The number of FAD Days would be based on an assumed number of FAD sets per day (which may change over time) and changes in the status of vulnerable tuna stocks. Let's assume in a hypothetical example that Parties agree that 15,000 FAD Days will be sold (from within the overall TAE). Parties contribute 10,000 Days to a multizone auction, 5,000 of which are sold as FAD Days at a premium of $3,000. The sale of 5,000 FAD days in the multizone auction leaves 10,000 FAD days to be sold through single zone and 'pool' processes. Let's assume the TAE was 40,000 Days, so 30,000 days are left to be sold through these processes. Under this approach, each Party would be able to sell 33% of its PAE as FAD Days (i.e. collectively 10,000 FAD Days). This approach means that no more than the agreed number of total FAD Days can be sold as FAD days (i.e. limits on fishing mortality are more 'guaranteed') and avoids (to some extent) a difficult allocation process amongst Parties. It also avoids Parties with more 'attractive' FAD waters capturing the bulk of the premium from FAD fishing while the costs are borne collectively by Parties. Under this approach, while Parties in the east may find it easy to achieve the $3,000 premium for FAD Days (or more), Parties in the west may not. In that case, Parties in the west would be free to sell 'surplus' FAD Days to Parties in the East who are likely to achieve the FAD premium. In that way, the collective benefits for FAD use are spread more equitably amongst the Parties.

The key issue here is that the practical and equity issues of alternative approaches to implementing a FAD Day scheme should be explored by the Parties in detail before settling on a model that all Parties can support. Given the considerable time and effort likely to be required in designing and implementing the 'baseline' FAD reforms described above and relative good health of the BET stock at present, Parties are in a position where they can let these issues 'percolate' while they focus on bedding down baseline reforms. Nevertheless, an unexpected deterioration in the status of BET (or YFT) would make entering the 'FAD set management business' more urgent.

3.8 PNA FAD Management: Next Steps

Although, there appears to be little merit in PNA entering a FAD deployment business directly, existing FAD 'businesses' are both a potential threat and opportunity to the core business of PNA i.e. the VDS. This is a situation that demands close attention by PNA. In the short term, that attention requires three steps:

i. The collection and analysis of information on the effects of FAD fishing (positive and negative)

ii. Development of appropriate regulatory instruments to protect VDS returns from adverse effects of FAD fishing
iii. Development of appropriate economic instruments to prevent FAD use from channelling fisheries rents away from Parties to FAD right holders

3.8.1 Information Collection and Analysis

PNA needs much more detailed information on the levels and pattern of FAD use in the WCPO Purse Seine Fishery. This includes information on the numbers of FADs deployed FAD distribution and density, numbers of FAD sets and where, numbers of FADs recovered and the fate of non-recovered FADs. Timely information on trends in these numbers is very valuable. This basic quantitative information is necessary for even rudimentary cost/benefit analysis of FAD use.

Adding a cost/benefit overlay to the quantitative data above is difficult. Dealing with the benefits side of the equation, first, the primary benefit is improved CPUE for harvesters but, as discussed, this benefit may be affected by the spill-over cost of harvesters on each other by the phenomenon of FAD saturation. If on closer study, FAD saturation proves to have a significant impact, it may confound the benefit expectations of individual harvesters from their FAD use investments. Second, current evidence indicates a broad east to west declining trend in the benefits of FAD use. More detail around this trend is required. Third, CPUE is not the sole determinant of harvesting economics; catch composition by species and size within species are also important. These two factors may not be constant in all locations within the fishery. Fourth, many benefits of FAD fishing are not easy to quantify because they are lumped under an integrated vessel operation profit centre. For instance, FAD fishing may save fuel between sets but may cost fuel during deployment and recovery phases.

On the costs side, as with benefits above, to the extent that FAD use is an integrated part of harvesting operations, harvesters will find it technically difficult to separate FAD deployment, use and recovery costs from an imaginary non-FAD cost structure. Second, the environmental costs of FAD fishing on Parties is very hard to estimate. As mentioned in the Phase 2 Report, these costs are in two distinct categories (those related to deployment/recovery/non-recovery and those related to setting). The economic significance of these effects depends on the underlying state of the fishery and its associated ecosystem to absorb these effects. In other words, there are circumstances where, say, the same level of impact on the fishery in the form of elevated mortality may be minor or major.

It is clear from these comments, that PNA will struggle to collect the information needed to carry out an unassailable cost/benefit analysis of FAD use in the short term. PNA must nevertheless work with whatever information it has and make appropriate collective use of the precautionary principle to establish agreed assumptions about FAD costs and risks that will underpin the PNA position on the regulation of FAD use or the pricing of FAD use in its fishery. It is normal that resource owners are required to make cost/benefit judgements about the management of the resources they own with highly imperfect information. Such is the case here, and given the significance of sustainable VDS earnings to the Parties, the sensible response is to adopt a generally cautious approach to the management of any FAD related threats to the VDS.

3.8.2 Regulation of FAD Design and Deployment

PNA is already appropriately engaged in discussions about the regulation of FAD design and deployment (numbers of FADs per vessel). This engagement needs to constantly refer to an agreed set of PNA assumptions about FAD use costs and risks and the drivers of those costs and risks. Those assumptions will change over time as better information becomes available.

Regulation always imposes some costs on the regulated in order to mitigate some costs of concern to the regulator. PNA must be mindful that the costs imposed on harvesters are a net benefit to VDS revenues over time (i.e. are less than potential costs to VDS revenues over time). PNA must be especially vigilant about any FAD regulatory instrument that has an associated charging regime. Any charging regime (especially one operated by a third party) has the potential to cannibalize or tax available VDS revenues.

3.8.3 Setting the Scene for Possible Economic Measures…

PNA FAD Management is inseparable from the art of managing comprehensive costs and benefits and discovering honest information about the costs and benefits to others of their FAD use is best done through a competitive market with observable prices. The relevant market is the market for Vessel Days which currently is not set up to sell FAD Days and non-FAD Days on a transparent footing that generates useful information about the premium that could be recovered by PNA from FAD use rights in its fishery.

The structure and processes of the Vessel Day market are still evolving and all that is needed is for the design of any improvements to this market to incorporate the capacity to sell FAD Days and non-FAD Days without compromising maximum market depth for Vessel Days generally. As indicated in this Report, such design modifications are potentially straightforward. The first opportunity for such modification appears to be in tweaking the proposed design and implementation of the multizone Vessel Day auction under discussion by PNA. The application of price information derived from the multizone auction process to single and 'pooled' Day market processes should be carefully worked through amongst Parties to arrive at a model all Parties can support.

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