2nd MEETING OF THE FAD MANAGEMENT OPTIONS INTERSESSIONAL WORKING GROUP

Pohnpei, Federated States of Micronesia

28 – 30 September 2016

MONITORING OF FADS DEPLOYED AND ENCOUNTERED IN THE WCPO
Consultancy Report

WCPFC-2016-FADMgmtOptionsIWG02-04

15 September 2016

Purpose

1. This paper tables a final draft report of a consultancy to produce *a Report on Monitoring of FADs Deployed and Encountered in the WCPO*.

Background

2. The FAD Management Options IWG (FADMgmtOptions-IWG) was established in December 2014 and three of its terms of reference are related to FAD marking and monitoring namely:
   - FAD marking, and identification and use of electronic signatures (TOR b)
   - FAD monitoring, tracking and control (TOR c)
   - Advise on options for FAD marking and monitoring for WCPO wide application (TOR e).

3. The Commission in agreeing to the 2016 Workplan for FADMgmtOptionsIWG (WCPFC12 Summary Report, Attachment V) agreed that a consultancy would be undertaken on FAD marking and monitoring.

4. A call for proposals based on the agreed terms of reference was circulated by the Secretariat on 19 May 2016 (WCPFC Circular 2016/21). The consultancy was awarded to MRAG-Australia in July 2016.

5. The consultancy firm, MRAG-Australia, will present the report to the FADMgmtOptionsIWG02 meeting in 28 – 30 September.

Recommendation

6. The Working Group is invited to

   a. Note there are three issues set out in the FADMgmtOptions-IWG terms of reference (Dec 2014) which are related to FAD marking and monitoring;

   b. Discuss and consider the final draft consultancy report and its recommendations; and

   c. Develop recommendations for WCPFC12 which takes into account the consultancy report and the FADMgmtOptions-IWG terms of reference.

Monitoring of FADs Deployed and Encountered in the WCPO

Final Draft Report

September 2016

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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Acronyms and abbreviations

aFAD	Anchored FAD
BET	Bigeye tuna
CCM	Members and Cooperating Non-members (of the WCPFC)
CMM	Conservation and management measure
CPUE	Catch Per Unit Effort
dFAD	Drifting FAD
EEZ	Exclusive economic zone
EM	Electronic monitoring
EPO	Eastern Pacific Ocean
FAO	UN Food and Agriculture Organisation
FAD	Fish aggregation device
FADMgmtOptions-IWG	FAD Management Options - Intersessional Working Group
FFA	Forum Fisheries Agency
FIMS	Fisheries Information Management System
FSMA	Federated States of Micronesia Arrangement
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Convention for the Conservation of Atlantic Tuna
IOTC	Indian Ocean Tuna Commission
IUU	Illegal, unreported and unregulated fishing
nFAD	Natural FAD
NPV	Net present value
PNA	Parties to the Nauru Agreement
RFID	Radio Frequency Identification
RFMO	Regional Fisheries Management Organization
ROP	WCPFC Regional Observer Program
SKJ	Skipjack tuna
SPC	Secretariat of the Pacific Community
tRFMO	Tuna RFMO
VDS	Vessel Days Scheme
VMS	Vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Commission
WCPF-CA	Western and Central Pacific Fisheries Convention Area
WCPO	Western and central Pacific Ocean
YFT	Yellowfin tuna

Executive Summary

WHY MARK FADS?

The need to better understand the number and nature of FADs in the WCPO, as well as the impacts of FAD fishing, is both clear and immediate. Until an accurate account is made of the number of FADs deployed in the fishery, as well as their technical and physical specifications, effective management of FAD fishing is difficult. Likewise, until the full life history of individual FADs is capable of being tracked throughout their life, effective scientific analysis of key scientific questions (e.g. aggregative capacity of FAD types; impact of FAD density and distribution on stock dynamics) is not possible. Effective management of FADs and their impacts on target, non-target species and ecosystems is needed to meet CCMs legal obligations under the WCPF Convention.

WHAT OPTIONS ARE AVAILABLE?

The options available to implement a FAD marking system can essentially be divided into two categories: (i) physical or manual marking, in which a unique identification number is permanently attached to the FAD and (ii) electronic marking, in which a unique identification number associated with the satellite buoys attached to FADs (mainly dFADs) is used to provide a unique marking. A combination of both systems may also be used to better meet management objectives.

A physical or manual marking applied in a permanent way to the FAD itself has the advantage of ensuring the unique ID stays with the FAD, and therefore the life history can be tracked, even where associated satellite buoys are changed (as reportedly happens frequently). Satellite buoy tracking has the advantage of delivering extremely valuable information for scientific, management and compliance purposes (e.g. near-real time position information; sea surface temperature; course; speed; volume of fish if sonar buoys are used) and is potentially the most cost-effective solution, however a number of practical challenges (e.g. frequent buoy swapping, sometimes remote from the catching vessel; unknown levels of industry compliance with reporting requirements) mean that marking through satellite buoys alone is unlikely to be effective at this stage. Accordingly, some form of permanent physical unique ID on the FAD itself is required where the life history of the FAD needs to be tracked (e.g. for various scientific analyses).

A system that combines both a physical marking on the FAD, together with a requirement to allow access to satellite buoy position information, appears to be the optimal approach.

COST-BENEFIT ANALYSIS

The institutional and business compliance costs of a spectrum of marking and monitoring options were assessed, assuming around 50,000 FADs annually deployed in the WCPO.

	Painting	Tag	Acoustic	Electronic	Combined Painting/electronic
Average annual cost	$603,713	$558,713	$10,098,463	$413,903	$644,403
Total per FAD (50,000)	$12.07	$11.17	$201.97	$8.28	$12.89

Of these, a system-based on satellite buoys only is likely to be the cheapest given the main costs (satellite buoys and airtime) are already covered by industry, however the practical challenges associated with buoy swapping and the potential loss of the life history of the buoy mean the system is unlikely to be effective in the short term. Systems based on industry manually marking FADs (e.g. with epoxy paint) and pre-printed tags are likely to be the next most cost effective and have the advantage of the ID remaining with the FAD itself. The costs of a combined manual marking/electronic (satellite buoy) scheme are only marginally higher than a manual marking system alone because the marginal costs of the additional satellite buoy information are very small. To that end, a combined manual/electronic marking system is likely to deliver best value for money.

Aside from providing a better understanding of the ecological impacts of FAD fishing, the implementation of a FAD marking system which provides a clearer picture of the number, nature and impacts of FAD fishing in the WCPO arguably better positions WCPFC members to meet MSY stock management objectives for target species. Cost-benefit modelling shows that only very minor improvements in members' capacity to achieve stock management objectives are required to offset the cost of implementing any of the FAD marking systems. Using alternative stock projections for BET and YFT as a hypothetical example, we estimate that improvements in the likelihood of meeting MSY stock management objectives of less than 1% are required to offset the costs on most systems. Depending on the extent to which an effective FAD marking scheme improves management capacity, net present values of several hundred million dollars are possible (largely because in high value fisheries even small improvements in management performance can produce substantial economic benefits).

PROPOSED WAY FORWARD

A key challenge in the design of any unique FAD ID system is the absence of any practical examples which have been operating sufficiently long to assess their practical effectiveness. Nevertheless, the need to better understand and manage increasing FAD usage is such that a 'starting point' is required, which can be refined and improved over time as the technology develops and lessons are learned from initial implementation. To that end, we propose the following way forward:

Step 1: Introduce a manual marking scheme which requires the registration of all FADs deployed and encountered in the WCPO, and the application of a permanent, unique identifier on the FAD itself. The scheme should cover all types of FADs (anchored, drifting, natural) and will require a number of supporting measures to ensure integrity (e.g. prohibition of the deployment of FADs in the absence of an observer; prohibition on setting on FADs that do not carry an authorised unique ID). Field tests in conjunction with industry and observers should be undertaken to determine the optimal configuration of the marking requirements (e.g. size of lettering, colour and background, position on FAD, type of materials, etc).

Step 2: Recognising the substantial scientific, management and compliance benefits associated with accessing satellite buoy data, the WCPFC should explore with PNA options to allow for information generated through the current (and possibly ongoing) satellite buoy tracking trial to be provided to SPC to allow for scientific analysis. Given the 'port-to-port' nature of the tracking requirements and the substantial proportion of FAD activity in PNA waters (up to 95% of FAD sets), full compliance with the PNA scheme would cover the majority of FADs in the WCPO (except for those in Indonesia and the Philippines). Based on the early results of the PNA trial, CCMs should consider whether additional measures are needed to monitor buoys not covered under the PNA scheme.

Step 3: Recognising the potential benefits associated with alternative tagging technology (e.g. easier identification of FADs in pre-dawn sets; monitoring compliance with FAD closures/set limits) undertake practical trials to explore their utility as a longer term marking option. Although RFID technology continues to improve, the option with the most immediate potential at this point appears to be acoustic tagging (which has detection ranges up to 1km).

Steps 1 and 2 above can be implemented concurrently. Trials for step 3 can be undertaken relatively quickly after step 1 is implemented. The pressing need to better understand the number and nature of FADs in the WCPO however means that the introduction of step 1 should not be delayed to await the analyses under step 3.

1 Introduction

The management of fish aggregation devices (FADs) and the mitigation of the impact on tuna stocks, in particular on juvenile bigeye and yellowfin tuna and non-target species and bycatch species has emerged as one of the key issues in tropical tuna purse seine fisheries management over the past two decades. The impacts of FAD associated sets on both target and non-target species, as well as changes in effective fishing power, have been reviewed extensively (e.g. MRAG, 2009; Scott and Lopez, 2014; Davies et al, 2014) and have attracted considerable attention amongst the tuna Regional Fisheries Management Organisations (tRFMOs), their members and associated stakeholders.

As part of the move by members of tRFMOs to better manage and monitor the impacts of FAD fishing, there has been increasing interest in strengthening capacity to mark and monitor individual FADs through the application of unique, permanent identification (IDs). The International Convention for the Conservation of Atlantic Tuna (ICCAT), the Inter American Tropical Tuna Commission (IATTC), the Indian Ocean Tuna Commission (IOTC) and Western and Central Pacific Fisheries Commission (WCPFC) all now have FAD Working Groups and IATTC members have now adopted a scheme for FAD marking. In part, this move to monitor and manage FADs has been driven by a desire to develop improved scientific understanding of the impacts of different FAD types, materials and configurations, while at the same time getting a better understanding of the number and nature of FADs being used, laying the foundation for more sophisticated management and compliance of FAD fishing activity.

For an anchored FAD (aFAD) or an industrial drifting FAD (dFAD), to be economically useful for the artisanal fleets or the industrial purse seine fleet, these FADs have to be able to be located so that they can be fished on. For aFADs this is not a real problem as the FAD location is recorded when the FAD is set and unless it breaks free will remain at the original location. In the Indonesia and the Philippines most fishing is on anchored FADs and this technology does not require a satellite beacon to be able to be fished and serviced. However, dFADs are deployed and then drift across the ocean and are tracked using satellite technology and most having satellite buoys attached, and nowadays some have sonar/satellite buoys attached. If a drifting FAD (dFAD) cannot be tracked then it cannot be located by the vessel and fished on.

The current project arose from discussions at the WCPFC FAD Management Options Intersessional Working Group ("the IWG") who recognised the potential benefits associated with the capacity to uniquely identify individual FADs. The IWG acknowledged that a number of different approaches to uniquely identifying FADs exist, each with their own implementation costs and benefits and unique challenges in application. With that in mind, the IWG sought the preparation of a report analysing the "*need and viability of a common marking system for FADs deployed / encountered in the WCPO*" and, in particular, providing advice on the following questions:

1. *Is there any merit (e.g. a positive cost / benefit analysis) of establishing a manual FAD marking system for the specific purpose of enabling improved scientific data collection?*
2. *If there is merit in establishing a manual FAD marking system, what would be the most efficient way of implementing such as system?*
3. *What would be proposed definitions for "FADs deployed" and "FADs encountered", in any future data reporting by vessel operators?*

The full Terms of Reference for the study are included at Annex 1.

This report sets out the results of the study and analysis of the above questions and provides recommendations on a strategy that the WCPFC might consider to move this issue forward.

Following this introduction, section 2 sets out the background and context for the current project including the types of FADs used in the WCPO and the reasons for marking FADs, section 3 looks at a number of alternative options for marking and monitoring FADs, section 4 looks at options being progressed by other relevant groups (e.g. other tRFMOs, regional groups within the WCPO), section 5 examines the relative costs and benefits of different FAD marking options, while section 6 sets out the strengths and weaknesses of each option and proposed a way forward.

2 Background and context

2.1 FAD definitions

Although the final question listed in the terms of reference above, it is helpful for the reading of this report to address the various FAD definitions upfront. To that end, for the purposes of this report we have used the definitions set out below. For FADs 'deployed' and 'encountered', we recommend these definitions, or something close to them, form the starting point for discussions in any measures related to data reporting.

2.1.1 Fish aggregating device (FAD)

For the definition of a FAD, we have used the agreed definition set out in WCPFC CMM 2009-02, namely "*any object or group of objects, of any size, that has or has not been deployed, that is living or non-living, including but not limited to buoys, floats, netting, webbing, plastics, bamboo, logs and whale sharks floating on or near the surface of the water that fish may associate with*".

2.1.2 FADs 'deployed'

A FAD deployed is any FAD that is physically placed or deposited in the water by a vessel engaged in or supporting the activities of fishing in the WCPO. These vessels may include purse seine vessels, long line vessels, service vessels, carrier vessels or vessel operated by companies not involved directly in fishing but that deploy FADs for the purpose of on-selling them to the commercial fishing industry.

2.1.3 FADs 'encountered'

A FAD encountered is any FAD (anchored, drifting, man-made or natural) which a vessel comes across and/or interacts with in the course of fishing. An encountered FAD may or may not be registered or have a satellite buoy attached. If the FAD is registered and has a buoy attached the captain and observer should both record the encounter and the registration numbers of the FAD and buoy. If the FAD is not registered and does not have a buoy attached, the vessel may elect to mark and register the FAD and deploy a buoy on the FAD. Living FADs or dead mammal FADs should not be fished on.

2.2 What types of FADs are used in the WCPO?

In the WCPO, FADs are used by both industrial and artisanal fleets. Artisanal FADs are usually set in shallower or closer inshore waters to make the aggregated fish more easily accessible for artisanal fleets (Figure 1).

Figure 1: FADs used by industrial and artisanal fleets in the WCPO (Source: SPC).

The nature, design and construction of industrial FADs used in the WCPO purse seine fishery have been described by a number of authors (e.g. Itano et al, 2004; Abascal et al, 2014; Yasfiandayani 2013), but can broadly be categorised into three types:

Anchored FADs (aFADs)

As the name suggests, anchored FADs (aFADs) are tethered to the ocean floor using a weight or anchor of some form. Abascal et al's (2014) analysis of WCPO observer data from 2009-2014 suggests that "*the most frequent aFAD main material design recorded consists of only a Philippine design drum (42 %), followed by the use of metal drums, either in combination with Philippine design drums (11 %) or PVC, plastic sheeting, bamboo canes and floats (6%). The main attachment combination in aFADs are chain, cable rings and weights in combination with cords and tree branches (24%); with cords (12 %); with cords, net hanging and sacking (10%); or without any additional attachment (8 %).*" In most cases, aFADs did not include a satellite buoy.

In South East Asia fish aggregating devices have been traditionally used to catch fish for many years. In Indonesia there are both shallow water and deep water anchored FADs called rumpons and in the Philippines these FADs are called payaos. Most Filipino fishing takes place on aFADs with the netting or mesh suspended below a metal buoy or a bamboo raft (Figure 2 and Figure 4).

In the data set used by Abascal et al (2014) (covering ~6% of associated sets from 2009-early 2014), around 15% of associated sets were made on aFADs.

Figure 2: Anchored FAD types used in the WCPO (Source: NOAA).

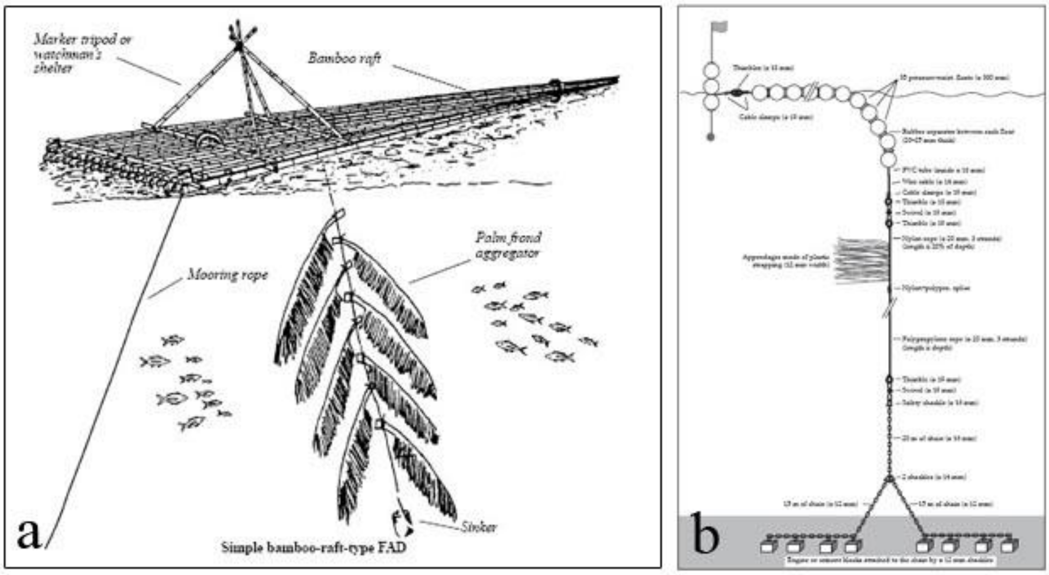


Figure 3: Anchored FAD design and construction (Source: Ataplaut[1])

Drifting FADs (dFADs)

Drifting FADs are deployed by the fishing or support vessel and typically tracked using a satellite buoy attached to the FAD. Abascal et al (2014) indicates that "*floats (81%) and bamboo canes (66%) are the most frequent main materials used in the design of dFADs, and net hanging below the object (92%) is by far the most common attachment, usually in combination with chains, cable rings and weights (68%) and or ropes (67%).*" Of these, around 25% used a combination of both floats and bamboo cane, while 18% used floats only. The rapid development of FAD technology in recent years including the development of sonar buoys and satellite tracking technology has made it easier for companies and vessels to deploy and track drifting FADs, and importantly to know in advance the potential biomass of fish aggregated under each FAD. This technology increases fleet/vessel profitably and leads to more targeted fishing, which in turn will influence stock assessment calculations in the future and potentially the long-term health of the fishery.

Of the associated sets investigated by Abascal et al (2014), sets on dFADs were the most frequent, accounting for 59% of total associated sets. Of these, 46.2% of sets were made on dFADs deployed by the same vessel on a previous trip, 25.8% were deployed by other vessels and 11.7% were deployed by the same vessel on the current trip (Abascal et al, 2014).

Anecdotal evidence indicates that the use of sonar buoys, which transmit information on the presence of fish associated with FADs, has rapidly increased in recent years. Preliminary data collected by the PNA suggests that around 80,000 dFADs with buoys are currently being monitored in WCPO of which 30-35% are sonar capable (M. Brownjohn, pers com). However, this must be taken in the context that in this fishery the industry sets about 15,000 sets on fish per year in total so many of the FADs deployed in the fishery are never set on (source M. Brownjohn, pers com).

[1] https://ataplaut.wordpress.com/2009/11/22/fish-agregation-device-fad/

Figure 4: Drifting FADs made from synthetic netting, bamboo and plastic ribbons prior to deployment (Source: Pew).

Natural FADs (nFADs)

'Natural' FADs refer to naturally occurring logs, debris and other flotsam, as well as whales, whale sharks and other natural objects that can attract aggregations of fish. 'Living FADs' such as whale sharks are beyond the scope of this study, although it is relatively common practice for fishers to attach satellite buoys to logs and other non-living nFADs, and these should be considered in any discussion of marking and monitoring FADs.

Of the sets examined by Abascal et al (2014), 10% occurred on natural objects without a buoy attached and 6% occurred on natural objects with a buoy.

2.3 Why uniquely mark FADs?

The increasing use of FADs by industrial purse seine fleets in all oceans during the last 20 years, together with impact on juvenile target tunas and non-target species, has led to calls from a range of stakeholders for improved arrangements to better understand, manage and reduce the impacts of FAD fishing. An essential first step in this process is to better understand the number of type of FADs currently in operation, and to have some capacity to track the life history of individual FADs. To that end, the case to register and uniquely mark individual FADs is strong and is evidenced by the fact that each tRFMO (as well as other entities such as the PNA and PNG) have established FAD Working Groups charged with developing and implementing FAD marking schemes.

Many of the arguments to support FAD marking are outlined in greater detail in the background documentation and stakeholder submissions to the WCPFC IWG, the IATTC Resolution C-16-01 and ICCAT (Bilbao 2016), and can be categorised into five main areas:

1. Legal responsibilities (domestic, regional and international)
2. Scientific benefits
3. Management and compliance benefits
4. Economic benefits; and
5. Ecosystem related benefits.

2.3.1 Legal responsibilities

In the WCPO there are international, regional and domestic responsibilities/requirements for marking FADs as fishing gear. The marking of fishing gear is referred to in several international instruments, notably:

- the FAO Code of Conduct for Responsible Fisheries, Article 8.2.4*:*

"Fishing gear should be marked in accordance with national legislation in order that the owner of the gear can be identified. Gear marking requirements should take into account uniform and internationally recognizable gear marking systems."

- The UN Fish Stocks Agreement at Article 18(3) (d) provides:

"Measures to be taken by a State in respect of vessels flying its flag shall include ... requirements for marking of fishing vessels and fishing gear for identification in accordance with uniform and internationally recognizable vessel and gear marking systems, such as the United Nations Standard Specifications for the Marking and Identification of Fishing Vessels."

- The FAO Technical Guidelines for Responsible Fisheries - Fishing Operations – 1, Annex III, includes the following proposed system for the marking of fishing gear:

"*6. Fish Aggregating Devices*

6.1 The authorization to fish should also include conditions in relation to the deployment of fish aggregating devices and, in addition to carrying a mark to identify ownership of a FAD, the authorization should relate to the: a) type of FAD; b) location of the allocated datum geographical position; and, c) the fishing activities permitted at the FAD.

6.2 The responsibility for recovery of drifting FAD's should lie with the owner.

6.3 The loss of a FAD (drifting or anchored) should be treated in the same way as lost or abandoned fishing gear."

In 2016, the Parties to the Nauru Agreement (PNA) implemented a provision that companies fishing on FADs in the waters of the PNA member countries had to register their electronic FAD identification (satellite buoy ID) on the PNA Fisheries Information Management System (FIMS). The PNA FAD registration and tracking program is part of a broader trial looking to better understand the numbers and types of FADs in operation, as well as allow for the charging of differential VDS fee rates for 'FAD days'.

In addition, a number of WCPFC CCMs have implemented domestic provisions for FAD marking, including PNG, Kiribati and Japan.

2.3.2 Scientific benefits

An essential prerequisite to understanding the impacts of FAD fishing (e.g. aggregative capacity of different FAD types and materials on target and non-target species; impact on stock dynamics, migration, recruitment, CPUE, etc) is to have a clear picture of the numbers and types of FADs in the fishery, as well as the capacity to robustly monitor the life history of individual FADs (e.g. date and location of deployment, number of times inspected, dates and location of any sets made, catch composition, etc). Being able to accurately track the life history of a FAD relies on the capacity to uniquely identify individual FADs, which in turn relies on the application of a permanent, unique ID. Abascal et al's (2014) preliminary analysis of WCPO observer FAD data highlighted the inability to uniquely identify individual FADs as a key impediment to effective scientific analysis of FAD design on ecosystem and other impacts.

Depending on the type of marking system implemented, scientific analysis made possible (or at least better facilitated) through a FAD marking scheme includes:

- Linking the life history of the FAD with vessel catch logsheet and observer information to examine issues such as the extent to which FAD design and construction and period and location of deployment influence catches of target and non-target species;
- Monitoring the extent to which the density and distribution of FADs influences stock dynamics, including migration, recruitment and schooling behaviour (for example through tagged fish);
- Better understanding how fishers use FADs, the number and type deployed, the zones they are in during the year, the proportion of FADs that are productive, and how FAD/buoy type, density and distribution affect fisher behaviour;
- Monitoring the extent to which the density and distribution of FADs affects catch rates of both free school and FAD associated fish, and assisting with standardising CPUEs;
- Assessing how the increasing use of sonar buoys affects CPUE, and measures necessary to standardise CPUE for stock assessment and other purposes
- Monitoring oceanographic information including sea surface temperature and currents;
- Using sonar buoy information on biomass and species (where possible) to assist in assessing stock status

Similar questions to these are also being asked by other tRFMOs. For example, both the ICCAT and IOTC have research underway to better understand and define a unit of fishing effort for FADs, to standardise FAD set CPUEs, to estimate the catch composition and ecosystem impacts of FADs, and in the Indian Ocean to improve the biomass estimates of the data from echo-sounder/sonar buoys (CECOFAD and SCRS paper 2016/012).

2.3.3 Management and compliance benefits

The increasing use of FADs, particularly coupled with sonar buoy technology, is a 'game changer' for tuna fisheries and a critical challenge for fisheries managers. While FADs are an important component of overall fishing capacity, the number of FADs currently deployed in the WCPO is essentially uncapped and unknown. A number of groups have produced speculative estimates of FAD numbers based on average deployments per vessel etc (e.g. Gershman et al [2015] estimated the number of dFADS deployed in the WCPO in 2013 was between 29,700 and 49,710; PNA suggests the figure may be somewhere in the order of 80,000; informal advice from SPC suggests the figure is closer to 30,000), but these remain unvalidated. Without an accurate knowledge of how many FADs are active in the WCPO and without an accurate knowledge of the impact that these FADs have on the stock dynamics and effective fishing effort etc, it is impossible to develop effective management measures or resolutions that will stabilise these fisheries.

In addition to this, despite FADs being classed as fishing gear under most national legislation and the deployment (and operation) of FADs arguably being captured under the broad definition of 'fishing' in the WCPFC Convention[2], the 'aimless' nature of dFADs means that many FADs are passing through WCPFC CCMs' waters, including territorial waters, without their knowledge, with no requirement for notification and potentially 'owned' by vessels without a license.

Introduction of an effective marking scheme that tracks individual FADs, including FAD ownership, creates conditions for more sophisticated, effective management and compliance of FAD fishing, including:

- improved compliance with existing FAD measures (e.g. set limits and FAD closures);
- improved verification of "free-school" sets

[2] Part I, Article I - "fishing" means: (iv) placing, searching for or recovering fish aggregating devices or associated electronic equipment such as radio beacons; (v) any operations at sea directly in support of, or in preparation for, any activity described in subparagraphs (i) to (iv), including transhipment.

- ensuring industry accountability for FADs that are abandoned or wash up on reefs; and
- tracking of FADs that enter closed areas, or are owned by vessels without licenses for that zone;
- ability to limit FADs by fleet/vessel and reduce the total number allocated;
- track any buoy swapping on FADs;
- track and fishing on FADs during closed seasons or areas.

2.2.4 Economic benefits

The potential economic benefits associated with FAD marking arise at two levels: (i) the level of the fishery and (ii) at the individual member state level.

At the 'whole-of-fishery' level, the introduction of an effective FAD marking scheme arguably better positions WCPFC CCMs to manage and reduce the impact of FAD fishing and thereby provides greater chance of meeting agreed stock management objectives (particularly for key target species such as bigeye and yellowfin). A better chance of meeting stock management objectives, in turn, should lead to overall economic benefits through higher stock biomass, improved catching efficiency and less need for restrictive regulation. The capacity for more sophisticated management of FADs also allows members the opportunity to move away from blanket measures such as the FAD closure period, which may depress overall economic output from the fishery. In addition, limiting the number of FADs deployed may also make an important contribution to optimising the value of the purse seine fishery and for limiting bycatch.

At the member country level, the capacity to mark and track individual FADs together with associated fishing activity provides the capacity to capitalise on higher catch rates associated with FAD sets. This may include:

- charging different rates for 'FAD days' versus 'free school days';
- charging per FAD deployed;
- charging per FAD day in the water;
- selling/auctioning FAD sets or days, and
- selling or auction the rights to deploy FADs.

There are no economic benefits likely to flow to the WCPFC as an organisation from FAD marking or registration.

2.2.5 Ecosystem benefits

There are a number of potential ecosystem benefits that would accrue from better understanding the effects of FAD design and materials and being able to track the fate of FADs. For example, in recent years there has been considerable pressure for the industrial purse seine fleet to move to the adoption of non-entangling FADs (e.g. IATTC Resolution C-15-03; IOTC Resolution 15-08). Registering and monitoring FADs and FAD types would allow for an assessment of improved FAD design using non-entangling materials on entanglements and on bycatch species.

Individual marking and registration of FADs would also strengthen industry accountability for the fate of FADs, including making companies/vessel operators responsible for the recovery of all FADs deployed, including FADs that wash up on beaches and reefs. Companies/vessel operators could also be responsible for the costs of any damage caused by FADs to reefs or coastal businesses such as aquaculture and tourism. In the EPO in 2015 15,000 FADs were estimated to be deployed and only around 8,000 recovered (Hall and Roman, 2016). No doubt some of these unrecovered FADs drifted into the WCPO, others would have sunk, others continue to float around and attract fish and other species, and other will have washed up somewhere in the Pacific.

3 What type of FAD marking options exist?

FAD marking systems available to members of tRFMOs can essentially be divided into two categories: (i) physical or manual marking, in which a unique identification number is permanently attached to the FAD and (ii) electronic marking, in which a unique identification number associated with the satellite buoys attached to FADs (mainly dFADs) is used to provide a unique marking. A combination of both systems may also be used where one system alone does not achieve all of the management system objectives.

Irrespective of which option is chosen, assuming both systems require the registration of all FADs prior to deployment (or are recorded by vessels/observers upon deployment), both systems have the capacity to provide an accurate account of the numbers of FADs currently deployed and encountered in the WCPO. Nevertheless, each operates slightly differently, has different strengths and weaknesses, costs and benefits and practical challenges for monitoring and verification purposes. This section sets out the main features, together with the costs and benefits of a number of systems examined during the course of this study.

3.1 Physical or manual marking

3.1.1 Industry applied marking option

3.1.1.1 Main features

A manual marking system would involve industry applying a unique ID to the FAD itself in a way that remained permanently attached to the buoy and was positioned in a way that gives both the captain and observer the best chance of being able to identify it under normal operating conditions. Ideally, the marking should be applied in a standard format (e.g. size of lettering, colour of lettering and background) which has been field tested to define the best configuration, and using materials (e.g. epoxy based paint) that are resistant to deterioration and fouling.

A number of options exist for the unique ID itself. One option would be to use the unique ID of the original satellite buoy attached to the FAD (for this work, attaching a satellite buoy would need to be compulsory for all FADs deployed in WCPO waters). This would avoid WCPFC (or CCMs) having to allocate numbers themselves. Another option would be design a standalone unique ID, for example incorporating some features that might be of interest (e.g. flag state, date/year of registration). To a large extent the type of unique ID doesn't matter – the key thing is that it's unique and is attached permanently to the FAD itself.

For a manual marking system to work effectively, all FADs should be registered prior to deployment. Details should include the design and specifications of the FAD, unique ID number, and specifications and unique ID of the associated satellite buoy. One option to allow for centralised registration of FADs and allocation of unique standardised IDs (and to create a centralised account of FAD numbers and details) would be for WCPFC to create a specific web-accessible FAD registration and information management database. Under this arrangement, fishing companies would be required to pre-register all FADs they wished to deploy in the WCPO. Upon registration, the database would allocate a unique ID for each FAD, as well as provide a record confirming the registration and details of the FAD (e.g. unique ID #, satellite buoy id #, design/materials, etc). All vessels wishing to deploy FADs in the WCPO would be required to have with them a copy of the registration record confirming the FAD had been registered. Observers could verify the details of the FAD prior to deployment. Companies would submit other key details (e.g. date and location of deployment) either through logsheets, or they may be required to update the WCPFC database within a certain timeframe (e.g. 24hrs) following deployment of the FAD. Details of these records could be independently verified through observer records. This process is outlined in Figure 5.

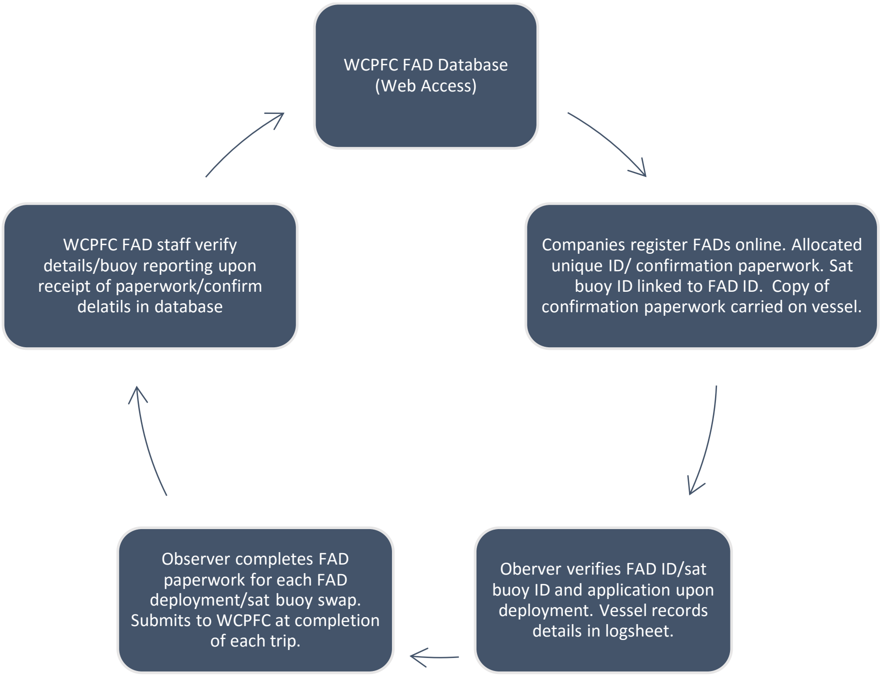


Figure 5: Possible registration and observer validation process for FAD deployment in the WCPO.

Another option would be to rely on the observer recording FAD details at the time of deployment to capture FAD numbers and specifications (and for that to be entered later into a central database), however this may be subject to considerable delays.

A further option would be the creation of a 'hybrid' system which built on existing FAD registration schemes in place in PNA, PNG and elsewhere. Under this arrangement, the details of FADs registered through existing systems in place through CCMs could be drawn upon to create a central account and list of all FADs currently in operation in the WCPO.

Unique IDs would need to be applied prior to deployment, such that the details of the FAD and unique ID could be verified by observers.

As far as possible, the manual marking scheme should apply to all forms of FADs deployed and encountered in the WCPO – i.e. dFADs, aFADs and nFADs. In the case of nFADs encountered at sea (e.g. logs), most if not all vessels have access to the internet on board vessels and could apply in situ for a unique ID number if the vessel wished to make a set on, or continue to monitor, the nFAD. Alternatively, if the satellite buoy ID is used as the unique ID, a permanent marking with the satellite buoy ID could be applied to the nFAD and the details could be recorded online within a prescribed period of time.

3.1.1.2 Benefits

In an electronic world physically marking a FAD might seem like a retrograde step, however the system has a number of important benefits. Perhaps most importantly, the physical unique ID stays with the FAD itself such that the full life history of the FAD can be tracked (i.e. each time the FAD is visited, information on activity can be linked to that FAD). This is essential for a range of scientific analyses which rely on information such as date and duration of deployment, first time fished, number of times fished, number of times inspected, etc. By contrast, systems that rely solely on the unique ID of the associated satellite buoy are vulnerable to losing (or confusing) the life history when buoys are swapped at sea (see section 3.2.1.4).

In addition, requiring each FAD to be registered prior to deployment, with details verified by observers, will create for the first time a credible account of the number and type of FADs currently in operation in the WCPO. Information will also be generated on metrics such as the number of FADs deployed by each vessel/company/flag state.

3.1.1.3 Costs

The main expected costs of implementing a physical marking scheme are set out in Table 1. Costs are broadly divided into institutional costs, largely attributed to the WCPFC Secretariat to establish the system, and business costs, largely related to the cost of industry compliance.

Actual costs are likely to be heavily influenced by any agreements around the design and operation of a FAD management database and registry. For example, if agreement can be reached around some form of 'hybrid' database which draws information from existing databases in place at the CCM level, set up and operational costs may be reduced. For the purpose of undertaking illustrative costings below, we have assumed that a FAD database/registry capable of allocating unique IDs will need to be developed and operated by the WCPFC Secretariat.

Table 1: Estimated costs associated with implementing an industry-applied physical marking system.

Cost component	Cost	Units	Frequency	Av. Cost/yr
Institutional Costs				
Staffing (inc. overheads)				
Management/co-ord.	$150,000	0.5	Annual	$75,000
Database administrators	$27,190	2	Annual	$54,380
IT				
Database development	$125,000	1	Once-off	$12,500
Database maintenance	$15,000	1	Annual	$15,000
Server storage	$130,000	1	Tri-annual	$43,333
Staff computers	$3,000	2	Tri-annual	$2,000
Miscellaneous				
Contingency	$30,000		Tri-annual	$10,000
Business costs				
Staffing				
Management/co-ord.	$1.61	50,000	Annual	$80,500
FAD registration	$1.61	50,000	Annual	$80,500
Application of marking	$1.61	50,000	Annual	$80,500
Marking Materials				
Marker (paint, tag, acoustic tag)	$3.00	50,000	Annual	$150,000
Total				**$603,713**
Total per FAD (50,000)				**$12.07**

Assuming WCPFC operates the database, the main institutional costs are likely to be those associated with database development, maintenance and staffing. Marginal costs associated with office overheads and communications are expected to be fairly limited.

Other institutional costs, such as the cost of updating logsheets and observer workbooks as required, and costs associated with observers involved in the verification of physical markings were considered, although the marginal costs associated with these activities were expected to be low – i.e. these things would happen anyway in the normal course of business.

The main business costs are those associated with compliance and are likely to include the cost of staff time to register FADs and apply markings, the cost of materials, some management time associated with coordinating compliance. Marginal costs associated with the captain's time to record the details of FAD interactions in logbooks was assumed to be small. For the purposes of markings costings, we have assumed that FAD deployment is annual (i.e. each FAD would need to be marked annually).

Staffing costs associated with business compliance were calculated according to assumptions around average minimum wages in key fishing countries (US, JP, CN, TW, KR). Costs were calculated as follows:

- Management/coordination time – 5 minutes per FAD @ 4 X average minimum wage;
- FAD registration time – 10 minutes per FAD @ 2 X average minimum wage; and
- Application time – 20 minutes per FAD at 1 X average minimum wage.

For the purposes of these costings we have assumed 50,000 FADs in the WCPO, although this number could be varied based on whatever CCMs consider to be the appropriate number. A lower number would result in a higher cost per FAD, and vice versa.

A key unknown at the moment is the extent to which FADs are deployed from vessels other than catching vessels (e.g. longliners, carriers, support vessels). If this was allowed to continue, but FADs could not be deployed other than in the presence of an observer (see below), these vessels may need to arrange for observers to be present which would add additional business costs.

3.1.1.4 Practical issues

For a manual marking system to have integrity a number of supporting regulations would be required. These include:

- All FADs to be deployed in WCPO waters would need to be registered prior to deployment, or in the case of an nFAD that was encountered and upon which the vessel wanted to set or monitor, at the time of encounter (in the event the vessel could not access the internet, they could have a block of extra unique IDs that could be deployed and then these would be registered into the system on return or within say 48 hrs of deployment);
- No deployment of FADs other than in the presence of an authorised observer (to allow in situ verification of FAD ID# and details by observer);
- No setting on a FADs without an authorised unique ID marking (as well as reducing incentive to deploy non-registered/authorised buoys, this would incentivise industry to ensure markings were applied in a way that didn't dissociate from the FAD);
- No sets should be made on 'live FADs' (e.g. whales, whale sharks), or dead whales.

In relation to the visibility and configuration of the manual marking system, two different positions have been put forward by stakeholders. For example, one stakeholder's submission suggests that any manual marking system should not make the FAD more detectable by other vessels, given fishing companies go out of their way to avoid FADs being detected by others. Another stakeholder's submission indicates that FADs are a navigation hazard and a manual marking system should assist in identifying the presence of the FAD to shipping. These issues should be discussed by WCPFC CCMs with a view to reaching agreement on a final design for a manual marking system, should one be adopted. Ideally, field testing of various configurations (e.g. letter size, colour and background, material, etc) should occur before a final measure is adopted. This should be done in conjunction with industry and observers.

There may be some scope for companies to apply the same 'unique' marking to different FADs on different vessels using the same paperwork under this system if there was sufficient incentive to do so (e.g. if limits on the numbers of FADs deployed were applied). While the incentives for this are currently probably fairly limited, this would need to be monitored carefully in the context of any future management measures.

There are also practical issues associated with the ability of observer and captains to identify manual markings during pre-dawn sets, when many FAD sets are made (for example, Harley et al [2009] found 94% of sets on FADs in the WCPO occurred prior to 'official' sunrise), as well as issues in being able to apply a permanent marking to FADs given the nature of their construction. If a physical marking system is adopted, the practicalities of any marking specifications (e.g. size of lettering, colour and background, position on FAD, type of materials, etc) should be trialled with industry and observers prior to implementation.

3.1.2 Pre-printed tag option

3.1.2.1 Main features

An alternative to having industry apply a physical marking to the FAD would be for WCPFC (or some other body) purchase pre-printed tags which industry could then apply for or purchase (alternatively WCPFC could make arrangements with a preferred supplier from which industry could purchase authorised tags directly). Under this approach, the pre-printed tags would come with a unique ID and must be attached to the FAD prior to deployment (or alternatively to a nFAD at the time of encounter if the vessel wishes to set on it or monitor it). The tags themselves could either be large enough for observer and captains to read under normal circumstances, or alternatively the tags could be small (to reduce price and allow for easier distribution) with a requirement for the fishing company to apply a marking to the FAD matching the unique ID of the tag in the same manner as the manual marking system described in 3.1.1 above.

Under this approach similar measures to those described in 3.1.1 to ensure integrity of the system would be required – for example, no set could be allowed on a FAD without an authorised tag, and no FADs could be deployed without an authorised observer present to verify that the tag had been applied.

Registration could be undertaken in largely the same manner as that described in 3.1.1.1, with companies registering their unique IDs on a central (or hybrid) database, together with the satellite buoy ID to be used. The database could supply confirmation paperwork, which observers could verify, together with the tagging application, at the time of deployment.

3.1.2.2 Benefits

There are a range of potential benefits from this approach:

- Pre-printed tags with unique IDs would remove the scope for industry to apply the same 'unique' ID to different buoys on different vessels;
- If the pre-printed tag was large and durable enough and applied such that captains and observers could read it under normal operating conditions, it would remove the need for industry to apply their own marking to the FAD. For observers it would also have the benefit of being a standardised marking, rather than potentially having to interpret different types of marking systems applied by different companies;
- Pre-printed tags are likely to be able to be designed in a way that has an attachment system that provides for a permanent attachment;
- A cost could be applied to each tag to cost recover the management of the system, such that costs were neutral to WCPFC and all costs were paid by industry. This concept could also be extended to recover additional costs to fund other activities made necessary through the use of FADs (e.g. FAD research; bycatch mitigation studies etc).

3.1.2.3 Costs

The costs associated with the printed tag option are likely to be similar to those associated with the industry applied marking outlined in section 3.1.1.3. The main additional cost is likely to be in the tags themselves. Preliminary information from plastic tag suppliers suggests that large tags (12" x 24" x 0.25" [610mm x 305mm] three-ply heavy weight) with an attachment to allow permanent fixing to the FAD could be produced for around $80 each, while smaller tags (which would require industry to then apply a physical mark corresponding to the tag number) could be produced for less than $2/tag.

Table 2: Estimated costs associated with implementing a marking scheme based on pre-printed tags.

Cost component	Cost	Units	Frequency	Av. Cost/yr
Institutional Costs				
Staffing (inc. overheads)				
Management/co-ord.	$ 150,000	0.5	Annual	$75,000
Database administrators	$ 27,190	2	Annual	$54,380
IT				
Database development	$ 125,000	1	Once-off	$12,500
Database maintenance	$ 15,000	1	Annual	$15,000
Server storage	$ 130,000	1	Tri-annual	$43,333
Staff computers	$ 3,000	2	Tri-annual	$2,000
Miscellaneous				
Contingency	$ 30,000		Tri-annual	$10,000
Business costs				
Staffing				
Management/co-ord.	$ 1.61	50,000	Annual	$80,500
FAD registration	$ 1.61	50,000	Annual	$80,500
Application of marking	$ 1.61	50,000	Annual	$80,500
Marking Materials				
Marker (paint, tag, acoustic tag)	$ 2	50,000	Annual	$100,000
Shipping	$ 0.10	50,000	Annual	$5,000
Total				**$558,713**
Total per FAD (50,000)				**$11.17**

Additional costs for this option would accrue to WCPFC if they were responsible for collating orders and handling billing costs between industry and the manufacturer. However, if WCPFC identified a preferred supplier / suppliers and industry purchased the tags direct there is unlikely to be any additional costs.

Importantly, tags provide a convenient mechanism to recover the costs of the FAD management system. For example, if the overall system was expected to cost $500,000, and the evidence suggested around 50,000 FAD tags would be purchased, each tag could be purchased for $10 to offset the (institutional) costs. To that end, institutional costs could be neutral.

3.1.2.4 Practical issues

The most efficient process for fishing companies to source tags and to register their details on a FAD database is likely to be for WCPFC to have an arrangement with a supplier for the tags to be sent directly to the address of choosing of the fishing company. Money might either be paid to the

WCPFC for tags, who would then authorise the release from the supplier of the appropriate number of tags to the company, or alternatively funds could be paid directly to the company who would pass on the residual (after their costs were covered) to WCPFC (assuming costs of managing the system were cost recovered through tag sales).

Once received, tags could be applied to FADs and the details entered into the database and registration confirmation paperwork received. Observers would verify tag details prior to deployment.

3.1.3 Acoustic tag option

3.1.3.1 Main features

A further extension to the 'tagging' type approach would be to apply an acoustic or other type of electronically detectable tag to each FAD prior to deployment. This system would operate in a similar way the tagging system described in 3.1.2, however the detection and identification of FADs would be through electronic means (i.e. a receiver or scanner) on the vessel, rather than by the observer and captain. Each tag would be embedded with a unique ID.

A number of possible technologies were examined assessed for potential during the study. RFID tags were initially examined, although technical challenges associated with transmitting radio waves through seawater appear to make the existing technology unsuitable (at this stage) (e.g. Benelli and Pozzebon, 2013). In particular, anecdotal evidence suggests that effective scanning distances appear to be limited to very small distances (e.g. centimetres/inches).

One technology that is proven and may be worth exploration is acoustic tagging. Acoustic tags capable of operating in seawater are comparatively small (~5cm), can be embedded with unique IDs, and can be picked up reliably up to distances of 1km[3]. The process for procuring and registering acoustic tags would be similar to that described for standard tags in 3.1.2.

Figure 6: HTI Sonar 980 series acoustic tag for marine uses (source: HTI Sonar)

3.1.3.2 Benefits

The use of an acoustic tag capable of being picked up automatically by a receiver within a certain range offers a number of benefits, including:

- It removes the need for industry to apply a physical marking (which may become covered with 'gunk' over time, or be in a position that it is inconvenient for the observer/captains to see);

[3] See for example: http://www.htisonar.com/980-series-80-khz-acoustic-tags.html

- it removes the need for the FAD to be identified by the observer;
- it will assist in identifying FAD IDs for pre-dawn sets which may otherwise be difficult with a physical marking. Pre-dawn sets currently account for a substantial proportion of FAD sets;
- acoustic tags can assist with monitoring compliance with the FAD prohibition (for example, if a FAD is detected by the receiver within 1km of the vessels during the FAD closure);
- acoustic tags may assist in detecting submerged FADs that are otherwise undetectable by an observer;
- similar to the tagging option above, unique IDs embedded in each acoustic tag will remove the possibility of duplicate 'unique' IDs being applied which possible under a physical marking system;
- acoustic tags can be programmed to record a range of oceanographic and bio-physical data that would be of value to science (e.g. temperature, currents, etc).

Acoustic tags would also have each of the benefits associated with the tagging option described under 3.1.2, including the capacity to recover costs of managing the system by requiring industry to purchase tags.

3.1.3.3 Costs

In addition to the staffing and database costs identified for the standard tagging approach outlined in 3.1.1.3, the main additional costs are likely to be the hardware and set up costs. Initial exploration with one company (HTI Sonar) indicates that each tag would be in the order of $190 (if large volumes are ordered). In addition, each vessel would require one data logger connected by a short cable and a hydrophone with a computer to view the data. This combined unit would be in the order of $4,000 (without the computer) if around 300 were ordered. Additional costs would also be required for the installation of acoustic receivers and software on fishing vessels.

Table 3: Estimated costs associated with implementing a marking scheme based on acoustic tags.

Cost component	Cost	Units	Frequency	Av. Cost/yr
Institutional Costs				
Staffing (inc. overheads)				
Management/co-ord.	$ 150,000	0.5	Annual	$75,000
Database administrators	$ 27,190	2	Annual	$54,380
IT				
Database development	$ 125,000	1	Once-off	$12,500
Database maintenance	$ 15,000	1	Annual	$15,000
Server storage	$ 130,000	1	Tri-annual	$43,333
Staff computers	$ 3,000	2	Tri-annual	$2,000
Miscellaneous				
Contingency	$ 30,000		Tri-annual	$10,000
Business costs				
Staffing				
Management/co-ord.	$ 1.61	50,000	Annual	$80,500
FAD registration	$ 1.61	50,000	Annual	$80,500
Application of marking	$ 0.81	50,000	Annual	$40,250
Marking Materials				
Marker (paint, tag, acoustic tag)	$ 190	50,000	Annual	$9,500,000
Shipping	$ 1.00	50,000	Annual	$50,000
Receiver	$ 4,000	300	Once-off	$120,000
Installation costs	$ 500	300	Once-off	$15,000
Total				**$10,098,463**
Total per FAD (50,000)				**$201.97**

Tag data would be viewable in real-time and initial advice is that the battery life of an acoustic tag can be up to 10 years.

3.1.3.4 Practical issues

Given the value in acoustic tags, they may be considered 'non-disposable' by fishing companies and therefore fishing companies may wish to apply the same tag to a different FAD, if for some reason original FAD was degraded or no longer of use. A system would therefore be required to track and verify the movement of acoustic tags between different FADs.

3.2 Electronic FAD registration and tracking

3.2.1.1 Main features

Part of the consideration as to whether a manual FAD marking system is required in the WCPO is whether alternative forms of marking system – including electronic marking through associated satellite buoys – could achieve the same objectives more efficiently.

Under an electronic marking and tracking system, the unique ID of the satellite buoys attached to each FAD could be used to identify individual FADs. Each of these buoys has a unique identifier code/number (normally an alpha numeric code) that the manufacturer assigns to the buoy. The buoy can monitor and report a range of information such as location, course, speed, sea surface temperature, and with echo-sounder or sonar buoys they can report on the volume of fish associated with the FAD. Trials undertaken by PNA in 2013 indicate that it is technically feasible for the satellite buoy to send position information to more than one receiver, at no additional charge (over and above the existing costs paid by industry).

Figure 7: Examples of common satellite buoy types used in the WCPO (Source: Zunibal; Satlink)

Satellite buoys can be set to report at any time but most report twice a day unless they are polled by the owner/vessel. Buoys are purchased by industry and industry also pays for the air time required for the reporting.

If the unique ID of the satellite buoy was used as the FAD ID, all FADs would need to be compulsorily fitted with satellite buoys in order to get an accurate account of the number of FADs in the WCPO.

A number of options are available for registration of satellite buoys. Ideally, industry should have access to a secure, web-accessible database to register the details of FADs and associated satellite buoys prior to deployment. Given the PNA has already established an online database of FADs through FIMS, one option would be to discuss with PNA whether it was possible to 'piggyback' off this pre-existing system. If a suitable arrangement could not be agreed, another option would be for the WCPFC to develop its own comprehensive web-accessible database to allow for all FADs and buoys to be registered and position tracked.

In the same way as observers could check the details of physical marking prior to deployment as described above, observers could verify the details of registered buoys prior to FAD deployment.

3.2.1.2 Benefits

Satellite tracking of FAD position (and other information) offers a range of benefits over and above those offered by manual marking alone. The main benefit is the delivery of near-real time FAD position information which can in turn be used for:

- Scientific analysis – e.g. analysis of the impact of FAD density on the migration and catch rates of the main tuna species; analysis of target species and bycatch information based on catch logs, observer data and the life history of the FAD (position, speed, date of deployment etc).
- Compliance – combined with VMS data, satellite buoy position information may have utility in better enforcing the FAD closure and other measures (e.g. FAD set limits);
- Management – position information can be used to allow differential charging of access fees based on whether FAD sets were made; WCPFC CMMs would be able to better track and manage the number of FADs in their waters; ongoing 'fishing' by FADs in different zones during the FAD closure could be tracked and analysed.
- Industry accountability – satellite buoy information could be used to track the position of buoys that wash up on reefs and ensure the deployer of the FAD is able to held responsible.

Importantly, given the main costs of satellite tracking – the initial purchase of the buoys and the communications costs – are already being paid by industry, access to satellite buoy position and other information would allow scientists and managers access to a substantial pool of information at comparatively modest cost.

3.2.1.3 Costs

The costs involved in satellite tracking are likely to be largely dependent on whether WCPFC is able to piggyback off pre-existing systems (e.g. PNA/NFA). If agreement could be reached, for example, to allow SPC access to PNA satellite tracking information, considerable cost efficiencies could be achieved. SPC data indicates that up to 95% of FAD-related activity (catch/sets) in the WCPO occurs in PNA waters (excluding domestic fleets of Indonesia and the Philippines), and the 'port-to-port' nature of the PNA scheme means that, assuming full compliance, the majority of FADs would be incorporated.

Nevertheless, for illustrative purposes, the costs below assume that WCPFC is required to establish its own arrangements to capture satellite buoy data and may therefore represent an overestimate.

Table 4: Estimated costs associated with implementing a marking scheme based on satellite buoys.

Cost component	Cost	Units	Frequency	Av. Cost/yr
Institutional Costs				
Staffing (inc. overheads)				
Management/co-ord.	$ 150,000	0.5	Annual	$75,000
Database administrators	$ 27,190	3	Annual	$81,570
IT				
Database development	$ 200,000	1	Once-off	$20,000
Database maintenance	$ 20,000	1	Annual	$20,000
Server storage	$ 130,000	1	Tri-annual	$43,333
Staff computers	$ 3,000	3	Tri-annual	$3,000
Miscellaneous				
Contingency	$ 30,000		Tri-annual	$10,000
Business costs				
Staffing				
Management/co-ord.	$ 1.61	50,000	Annual	$80,500
FAD registration	$ 1.61	50,000	Annual	$80,500
Application of marking		50,000	Annual	
Marking Materials				
Satellite buoy (marginal costs)	Nil	50,000	Annual	
Total				**$413,903**
Total per FAD (50,000)				**$8.28**

The main difference between the physical and electronic marking options is in the cost of industry compliance, given no staff costs associated with physical marking are required. Although we expect large and more expensive databases to be required to house the additional data generated through satellite buoy information, overall we expect the electronic marking system to be cheaper to implement than the manual marking system.

Importantly, for the purposes of these costings we have assumed that the marginal costs of satellite buoys themselves and associated airtime costs is nil. Advice from PNA suggests that this has been the experience from their FAD tracking trials. Nevertheless, should all FADs deployed and encountered in the WCPO be required to be fitted with a satellite buoy, compliance costs would accrue to industry for those FADs not currently fitted with satellite buoys (e.g. many aFADs).

3.2.1.4 Practical issues

Notwithstanding the considerable benefits associated with accessing satellite buoy information, there are a number of practical challenges which appear to undermine the efficacy of electronic marking alone as an effective FAD marking system. These include:

- Buoy swapping – Preliminary SPC figures show that around 25% of FAD sets are made on FADs deployed by another company, while anecdotal evidence suggests that 'buoy swapping' (i.e. cutting off the existing buoy and swapping it for one of your own) is relatively routine in the WCPO. While it may be possible for observers to record changes in buoys – and therefore to track the 'life history' of the FAD – interviews for this study suggested that observers are frequently not in a position to record buoy changes (e.g. buoys may be changed away from the vessel using helicopters), while practical issues associated with delays in receiving and entering observer data may mean that data is not available in a timely way (e.g. Abascal et al [2014] reported that since the FAD closure in 2009, the coverage of GEN-05 processed forms is c. 6% of the associated sets in the WCPFC-CA between 20°N and 20 °S, excluding Indonesia, Vietnam and the Philippines domestic fleets). If buoy changes are not recorded, the scientific dataset is compromised. These issues were recognised by ISSF in their submission to the IWG which noted "*because many FADs change "owners" -- as they are found by other vessels-- it is important to not develop a marking scheme that only tracks the satellite buoys attached to the FADs. Thus, the marking of the FADs themselves and the tracking of the buoys (issue #3) need to be considered together*";

- Data access complications – there may be complications in getting a complete single complete account of all FADs registered if a single WCPFC database is not used for registration, and likewise there may be complications in verifying ongoing compliance with buoy reporting obligations if access is restricted in much the same way as VMS access is restricted in different zones. It may be possible to work through these issues, but they would need to be carefully thought through by WCPFC members;

- Not reporting of buoy numbers – based on a sample of observer records between 2009 and 2014, Abascal et al (2014) reported that the buoy number is only recorded by observers in 52% of the cases, and a large number of these records are unlikely to be unique identifiers.

Although not a marking complication, the other issue of critical concern should satellite buoy position and other information be accessible to management authorities is the issue of data security. Needless to say, any leakage of this data within industry would be fatal to the success of an electronic system.

Any scheme based on electronic marking of FADs would require the compulsory attachment of satellite buoys to all FADs upon which fishers wish to monitor or set upon. Satellite buoys must be reporting at all times while in the WCPF-CA (fines should apply to for setting on FADs for which sat buoy position reports are not being received by WCPFC).

3.3 A combined physical and electronic system

3.3.1.1 Main features

The combined system picks up elements of both systems described above. A permanent physical marking would be applied to the FAD itself, while the details of the associated satellite buoy would be registered and tracked.

Registration and validation would occur in the same way as that described above for the standalone systems.

3.3.1.2 Benefits

The combined approach is a 'best of both worlds' system in that it combines a permanent physical marking on the FAD itself to ensure life history is maintained, as well as delivering the highly valuable scientific, management and compliance information through satellite buoys. At the same time, the system would provide some information on the extent to which buoy swapping occurs in practice.

3.3.1.3 Costs

The cost of the combined physical/electronic marking system are likely to be similar to the combined marginal costs of both systems (i.e. the baseline costs of physical marking, plus additional database and staffing costs associated with managing satellite buoy data).

Table 5: Estimated costs associated with implementing a combined industry-applied physical marking and satellite buoy tracking scheme.

Cost component	Cost	Units	Frequency	Av. Cost/yr
Institutional Costs				
Staffing (inc. overheads)				
Management/co-ord.	$ 150,000	0.5	Annual	$75,000
Database administrators	$ 27,190	3	Annual	$81,570
IT				
Database development	$ 200,000	1	Once-off	$20,000
Database maintenance	$ 20,000	1	Annual	$20,000
Server storage	$ 130,000	1	Tri-annual	$43,333
Staff computers	$ 3,000	3	Tri-annual	$3,000
Miscellaneous				
Contingency	$ 30,000		Tri-annual	$10,000
Business costs				
Staffing				
Management/co-ord.	$ 1.61	50,000	Annual	$80,500
FAD registration	$ 1.61	50,000	Annual	$80,500
Application of marking	$ 1.61	50,000	Annual	$80,500
Marking Materials				
Marker (paint, tag, acoustic tag)	$ 3	50,000	Annual	$150,000
Total				**$644,403**
Total per FAD (50,000)				**$12.89**

3.3.1.4 Practical issues

The practical issues likely to arise under a combined system are largely a combination of those described above for the standalone physical and electronic systems.

4 What are others doing?

As discussed above, a number of organisations interested in the management of tropical tuna fisheries have recognised the need to improve monitoring and tracking of FAD deployments and have commenced the development of new measures to provide both better scientific information on FAD issues and better capacity to manage the number and use of FADs. For example, each of the four major tropical tRFMOs now have FAD working groups examining these issues (with at least two recently agreeing new measures to provide for the unique identification of FADs), while within the region both PNA and PNG are in the early stages of implementing new arrangements for FAD marking. This section provides a brief overview of these recent developments, together with some initial analysis the strengths and weaknesses of each arrangement based on interviews undertaken for the study.

4.1 IATTC

The IATTC has recently agreed a new FAD marking scheme which relies on the application of a unique physical marking on each FAD. The main details of the marking system are set out in Resolution C-16-01 and state:

"CPCs shall obtain unique alphanumeric codes from the IATTC staff on a periodic basis and distribute those numbers to the vessels in their fleets for FADs that may be deployed or modified, or in the alternative, if there is already a unique FAD identifier associated with the FAD (e.g., the manufacturer identification code for the attached buoy), the vessel owner or operator may instead use that identifier as the unique code for each FAD that may be deployed or modified. The code shall be clearly painted in characters at least 5 cm in height. The characters shall be painted on the upper portion of the attached radio or satellite buoy in a location that does not cover the solar cells used to power the equipment. For FADs without attached radio or satellite buoys, the characters shall be painted on the uppermost or emergent top portion of the FAD. The vessel owner or operator shall ensure the marking is durable (for example, use epoxy-based paint or an equivalent in terms of lasting ability) and visible at all times during daylight. In circumstances where the observer is unable to view the code, the captain or crew shall assist the observer (e.g., share their inventory of FADs to assist in matching each FAD with the identification code), so long as such assistance does not interfere with fishing operations."

The Resolution also includes requirements for data to be collected on FADs, principles for FAD design to limit entanglement of bycatch species, as well as requirements to ensure that vessel owners and operators record and report to National Authorities any interactions with FADs, using standard format to be developed by Commission staff.

This scheme does not incorporate satellite buoy position information at this stage, although the IATTC is reportedly working with vessel owners to get access to the satellite data with a time delay of a few months (M Hall, 2016 pers com). A database capable of registering, storing and analysing FAD life history information is yet to be developed.

While the IATTC scheme appears capable of providing initially for a unique ID on each FAD, an important issue highlighted during interviews was the potential for the 'life history' of the FAD to be lost if the unique ID is applied only to the satellite buoy. For example, if the unique ID was applied only to the satellite buoy and the original satellite buoy was subsequently swapped for another buoy during the period of the FAD's deployment (e.g. by another vessel), the capacity to undertake scientific analysis taking into account issues such as length of deployment may be lost. At this stage, there is no mechanism in place to record the change of buoys or track the original buoy number.

4.2 IOTC

At the 19th Session of the IOTC in 2015, the IOTC adopted Resolution 15/08 which (amongst other things) requires that:

From January 2016, CPCs shall require all artificial FADs deployed or modified by their flagged fishing vessels in the IOTC area of competence to be marked in accordance with a detailed marking scheme, e.g. including FAD marking or beacon ID. The marking scheme shall be developed and considered for adoption by the Commission at its regular annual session in 2016, based on recommendations from the IOTC Scientific Committee as requested by the Commission. The marking scheme should take into account, as a minimum, the following:

- *(a) All artificial FADs shall be marked with a unique identification number, based on a specific numbering system and format to be adopted by the Commission;*
- *(b) The marking should be easy to read before the vessel operator engages in any artificial FAD related activity (e.g. setting on the artificial FAD, retrieving the artificial FAD, servicing the artificial FAD, fishing on the artificial FAD), but if not visible for any reason, (time of day, weather, etc.), the vessel operator shall ensure to obtain the unique artificial FAD identifier as soon as feasible;*
- *(c) The marking should be easy to apply to the artificial FAD, but should be applied in such a manner that it will not become unreadable or disassociated with the artificial FAD.*

The Resolution also requires that:

> *CPCs shall require vessels flying their flag and fishing on DFADs to submit by 1 January 2016, the provisional purchase order for 2016 of instrumented buoys for their purse seine vessels under the confidentiality rules set by Resolution 12/02 (or any subsequent superseding Resolution);*

and

> *CPCs shall require vessels flying their flag and fishing on DFADs to submit, by the end of 2016 the number of instrumented buoys activated, deactivated and active on each quarter during 2016 its purse seine vessel under the confidentiality rules set by Resolution 12/02.*

The Resolution defines an instrumented buoy as "*a buoy with a clearly marked reference number allowing its identification and equipped with a satellite tracking system to monitor its position. Other buoys, such as radio buoys used on DFADs, not meeting this definition, shall be gradually phased out by the 1 January 2017.*"

Advice from the Acting CEO of the IOTC indicates that the scheme is still to be adopted in practice and there are few immediate lessons to be learned.

4.3 ICCAT

ICCAT Recommendation 15-02 established an Ad Hoc Working Group to examine FAD related issues including issues around "*FAD and buoys marking and identification as a tool for monitoring, tracking and control of FADs*". The ad hoc Working Group is required to report on its work with a view to recommend the adoption of appropriate measures at the latest at the 2016 ICCAT Commission meeting.

The 2nd meeting of the Working Group in Bilbao in 2016 suggested the following for a physical marking scheme:

- using the identifying buoy-number provided by the buoy manufacturer;
- recording the identifying buoy-number associated with any newly deployed FAD and the identifying beacon-number associated with any recovered FAD;
- In cases where there is a change of buoy in a FAD, both the ID code of the buoy associated with the FAD and the ID code of the buoy that serves as a replacement need to be recorded;
- establishing a consolidated database of records of FAD activity across all purse seine fleets.

Recommendation 15-02 also requests the ICCAT Secretariat to work with the Secretariats of other tRFMOs in which FAD Working Groups have been established to promote the cooperation between these groups, including through the organization of a joint session in 2016 with the interested tuna RFMOs

4.4 PNA

The PNA has recently commenced a trial under which all FADs deployed by vessels registered on the OVR are required to be fitted with satellite buoys, and to report their position at all times to PNA (irrespective of whether they drift outside PNA waters). The new scheme follows a 'proof of concept' research trial undertaken in 2013 which confirmed it was technically feasible to track FADs through FIMS. The trial also confirmed that no additional communications costs were required, over and above that being paid already by industry, to send position information to a second location.

Registration of satellite buoy details is undertaken directly by industry through PNA's web-accessible information management system FIMS.

The scheme is potentially a very useful one in the context of FAD marking requirements given the high proportion of FAD sets occurring in PNA waters, the 'port-to-port' nature of the tracking requirements, and the low marginal costs associated with satellite buoy tracking. Data provided by SPC indicate that up to 95% of FAD sets and 93% FAD catch occurs in PNA EEZs (Table 6) (excluding FAD-sets by Indonesian and Philippines domestic fleets). To that end, a satellite buoy registration and tracking system that comprehensively covered all FADs associated with vessels on the PNA OVR offers potential longer term opportunities to form the basis of a FAD marking system.

Table 6: Proportion of FAD-related activity occurring in PNA EEZs between 2010 and 2014 (source: SPC)

%	2010	2011	2012	2013	2014
FAD Sets - PNA	95.1%	95.6%	92.7%	92.0%	92.5%
FAD Catch - PNA	93.3%	93.5%	92.2%	89.5%	90.6%

Nevertheless, the scheme is in its early days and faces a number of challenges at present in the context of forming the basis for a WCPO-wide unique FAD marking system:

- Firstly, as discussed above, because there is no permanent marking on the FAD itself and anecdotal evidence indicates a high degree of 'buoy swapping', the extent to which the system could accurately track the full life history of each FAD is unknown. While it is certainly possible that buoy swapping could be tracked through observer reports, there may be considerable delays in having observer data returned and entered into relevant databases (such that data aren't available in a timely way), and the details of swapped buoys may not always be available to the observer. For example, anecdotal evidence suggests that buoys may be swapped using skiffs or helicopters remote from the vessel;
- Second, given the trial is still in its early stages the extent of industry compliance remains unknown. To that end, it is unknown whether FADs registered on the PNA system could be considered an accurate account of all FADs currently deployed.

4.5 PNG

PNG has also recently moved to require the registration and marking of all FADs as part of an overall package to improve the management of FADs in their waters[4]. Unlike the tRFMO and PNA measures above, the PNG arrangements require both a physical marking on the FAD as well as the attachment of a satellite buoy reporting to NFA (including sonar information). The main requirements include:

- It is a requirement that each vessel operator or company must register each FAD, and each satellite buoy, including the make, model, and unique identification number;
- all FADs must be clearly marked with the name and registration number of the vessel that deployed it. The information shall be fixed in such a way that it will remain fixed to the FAD for the life of the FAD;
- The information must be in lettering at least 30cms high and of a colour that contrasts with the colour of the back plate. The plate must be attached to a point on the FAD where in normal circumstances it is visible from opposing directions; and
- Satellite tracking buoys shall be assigned a unique identification number and linked to the registered FAD and the vessel that deployed the FAD;
- The FAD operator shall provide NFA with a direct feed of all data (including but not limited to location, time, ID, associated vessel and sonar data) being transmitted from all buoys affixed to a FAD, whether that satellite buoy is registered with NFA or not
- It is mandatory for any PNG licensed vessel that Observers monitor and record the details of the deployment and use all FADs.
- FADs shall not be deployed from a non-licensed vessel.
- No FAD shall be deployed unless it is registered, and a unique FAD registration number has been allocated by NFA.
- If a FAD, whether natural or artificial is found by a vessel, and a set is made, it is mandatory for a vessel to attach a registered satellite buoy to that FAD;
- The NFA will levy an annual fee for the registration and monitoring of FADs sufficient to cover the costs involved in providing this service, including data analysis and reporting, registration and approval of FADs and monitoring of deployment, use, and retrievals.

Initial advice from NFA suggests that the scheme is still in its early days and will require a settling in period before the effectiveness of the system can be assessed.

5 Cost-benefit modelling

5.1 Introduction and approach

The terms of reference for this study call for a "*quantitative cost-benefit analysis of implementing a spectrum of FAD marking and monitoring systems for FADS deployed / encountered in the WCPO*." In *qualitative* terms, defining the costs and benefits of the various options are relatively easy. Likewise, in quantitative terms defining the costs of implementing various systems is relatively straightforward. However, defining the direct benefits associated with the introduction of a FAD marking system in precise *quantitative* terms is actually quite difficult (particularly when we're talking about benefits such as a better understanding of the ecosystem effects of FADs etc).

[4] PNG National Gazette no G570 (7 Sept 2015) "Management of Fish Aggregating Device (FAD) for the Tuna Fishery in PNG and Reference point Annexures"

Nevertheless, there is a reasonable expectation that economic benefits will accrue from the introduction of better FAD management (including the avoidance of negative economic consequences). Putting aside the 'ecosystem' type benefits, one of the main benefits of a well implemented FAD marking system is that it better positions WCPFC members to meet their stock management objectives (particularly for BET and YFT). This, in turn, should lead to defined economic benefits through, for example, higher stock sizes and fewer fishing restrictions, and should, all other things being equal, produce higher economic returns.

One way of approaching the challenge of quantifying the benefits of a FAD marking system then is to look at some hypotheticals around how much more likely CCMs are to achieve stock management objectives, and the economic benefits that result. For example, if we know the cost of implementing a FAD marking system is X, how much more likely would we need to be to meeting our stock management objectives to make it worthwhile (i.e. to produce a positive economic return?) If only a very small improvement in our chances of meeting stock management objectives is required to offset the costs of implementing the marking system, proceeding with the scheme is likely to be worthwhile (in economic terms). If a very large improvement in our chances of meeting stock management objectives is required, the scheme may not be sensible economically. The 'cost-benefit' judgement to be made then is whether our chances of meeting our stock management objectives exceed the 'tipping point' – i.e. the point at which costs and benefit cancel each other out.

To demonstrate this in a practical way we have focused on BET/YFT and modelled a number of stock recovery/maintenance scenarios and resulting economic outcomes. In essence, we modelled a 'status quo' scenario to assume, with some level of probability, that BET and YFT would be maintained at B_{MSY} (the 'MSY Scenario') at some plausible point in the future. In addition, an alternative scenario with FAD IDs (and therefore greater capacity to manage the effects of FADs) was modelled which assigned a slightly higher probability of reaching the MSY scenario. The difference between the status quo scenario and the scenario with FAD IDs in place equates to the benefits of the FAD marking system, and could be measured in dollar terms. Both the costs and benefits can be translated into net present value (NPV) terms and allow for a standard cost-benefit comparison.

Importantly, the approach is not meant to be definitive. Rather, the approach is at best an 'educated hypothetical' designed to provide some sense of the extent to which the chances of meeting stock management objectives must improve to outweigh the costs of implementing the FAD marking system.

5.2 Methodology

5.2.1 Cost-Benefit Analysis framework

In a typical project, an investment is made upfront and a NPV of this investment is quantified. In this case, many of the costs assumed under a FAD ID system were variable and on an annual basis. Much of the upfront investment cost was centred on database development to have appropriate data management systems in place. All estimated subsequent changes in stock status were then considered the system's benefits. To estimate the NPV, it is important to understand that as time passes, costs and benefits become progressively and relatively less valuable. These costs and benefits are discounted by a chosen rate to take into consideration future risks and the value of investing money now to obtain benefits in the future.

Estimating the NPV of a project can be calculated through the following formula:

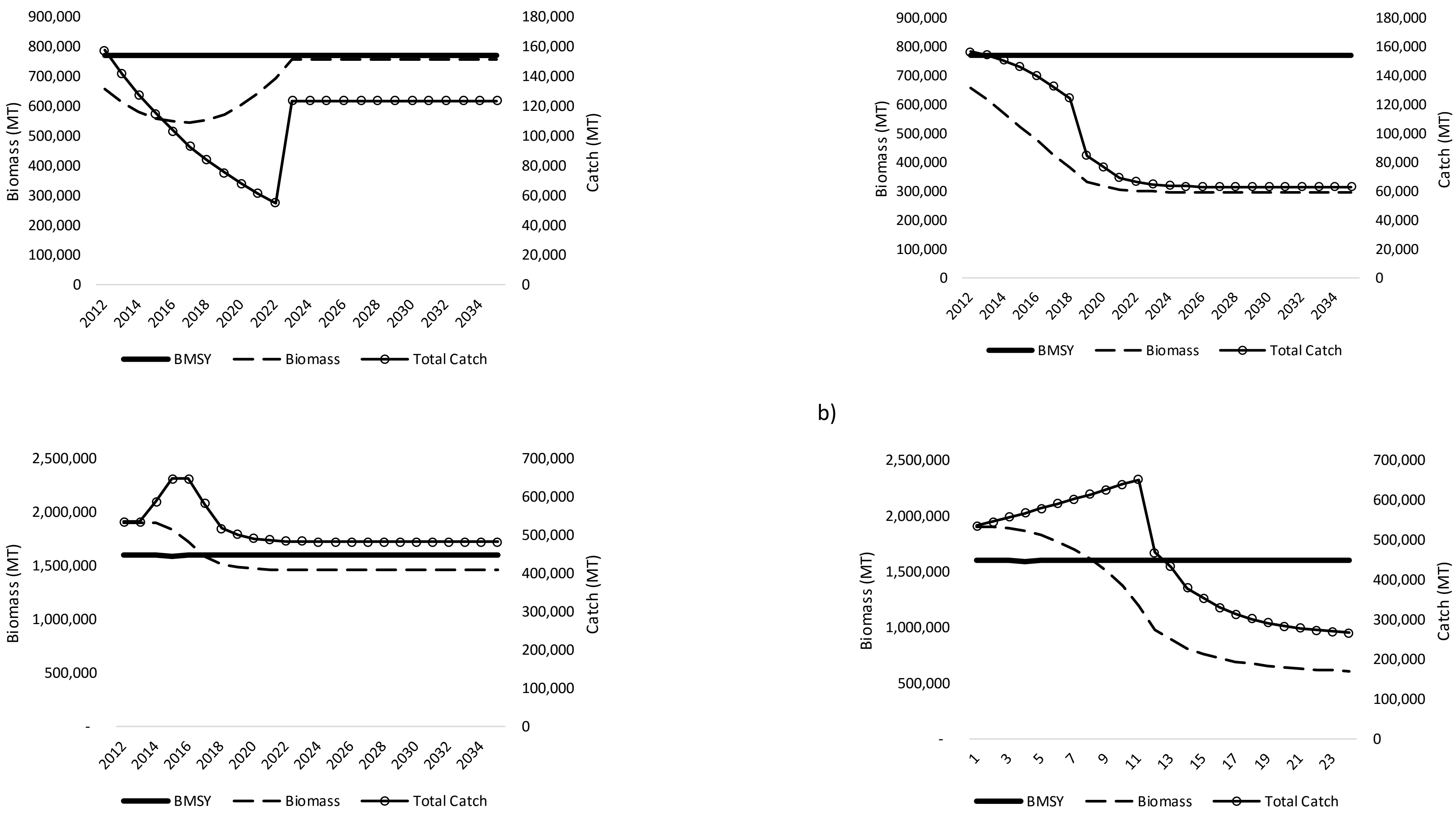
$$NPV = \left(\sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \right) - C_{t=0}$$

where B is the benefits at time t (annually in this analysis), C is the costs, and r is the discount rate (where 0 < r <1) and this is all with respect to any investment costs made upfront for the project ($C_{t=0}$).

The temporal scale for this analysis was 23 years (to 2035). As shown in **Error! Reference source not found.**, the B_{MSY} scenarios reach a plateau within a 10-year period. However, it was important to consider the long-term benefits of reaching that plateau. Hence, the analysis continued beyond the period of essentially no marginal change.

5.2.2 Modelling harvest strategy scenarios

For both BET and YFT, a strategy achieving an MSY Scenario within a plausible timeframe and a 'Poor Scenario' to levels around ½ MSY for BET and ¾ MSY for YFT were modelled. SPC's MULTIFAN-CL data (SPC, 2014) and standard bioeconomic techniques (Bjørndal and Munro, 2012) were used to estimate the impacts that harvest levels in any given year would have on overall stock status. An assumption was made that some combination of management measures (including FAD IDs) was effective in restricting harvest to levels required to achieve B_{MSY} (and thus the MSY Scenario). The model outputs illustrating these two different harvest strategies for each species can be seen in **Error! Reference source not found.**.



a) b) c) d)

Figure 8 Possible stock status scenarios 2012 – 2035: a) BET MSY Scenario; b) BET Poor Scenario; c) YFT MSY Scenario; d) YFT Poor Scenario.

5.2.3 Estimating revenues and rents from each scenario

The modelling above considers the entire stock and total catch in the WCPO (i.e., catch from all sectors not just purse seine). Given FAD ID costs will only directly impact the purse seiners, the model only considered benefits relevant to that sector (and is therefore arguably conservative if benefits also flow to the longline sector). Therefore, a proportion of total catch from the fishery was assumed to be taken by purse seine vessels. This was based on previous catch proportions shown in past reports by SPC (e.g. Williams and Terawasi, 2015).

Associated revenues from this catch were then estimated using market prices from Thai customs import data[5]. These were adjusted from delivery prices to establish an ex-vessel price.

To understand the real benefit from any increase in revenue, the costs of associated catches must be taken into consideration. This was estimated using figures from MRAG Asia Pacific (2016) which provided figures on a percentage of economic profit resulting from each dollar gained in revenue.

According to standard bioeconomic theory, a higher biomass results in more efficient fishing. That is, the stock is "thicker" and therefore has a higher catch per unit of effort (Bjørndal and Munro, 2012). On this basis, a compounding annual increase of 2% on economic profits gained was modelled into the MSY Scenarios and the opposite (2% decreasing) was modelled into the Poor Scenarios.

5.2.4 Probabilities of the scenarios and benefits beyond the status quo

As shown in the sections above, both BET and YFT had the two separate scenarios modelled; 'MSY' and 'Poor'. Depending on the management system implemented, each scenario could have different assumed probabilities of occurring. Through any combination, the total sum of the probabilities of the scenarios would be 100% (i.e., it is 100% likely that either one of the scenarios would occur). For example, under the status quo (no FAD ID system), it could be assumed that the MSY Scenario was 20% likely to occur and therefore, the Poor Scenario was 80% likely.

The expected value of that outcome was then estimated using essentially a weighted average. Using the example above, the MSY Scenario economic profits estimated were 20% and Poor Scenario benefits were 80% likely. Therefore, the weighted average economic profit would be:

(0.2 x MSY profit) + (0.8 x Poor profit) = weight average economic profit.

Importantly, it was then assumed that all of the possible types of FAD ID systems would increase the likelihood (to varying degrees) that the MSY Scenario would eventuate (over the status quo). For example, implementing the physical painting marking system could change the likelihood of achieving the MSY Scenario to 25% (compared to the status quo of 20%) and the Poor Scenario likelihood would thus reduce to 75%. The associated weighted average economic profit for the new system was calculated through same method as shown above.

These weighted average economic benefits were then inserted into the model as the assumed benefits resulting from the varying FAD ID systems. Once taking into consideration each system's associated costs, the difference in net benefit over and above the status quo was then considered the overall benefit of the particular FAD ID system.

The actual likelihoods of either stock status scenario occurring is difficult to quantify precisely. However, the structure of the model allows for calculating an estimated 'tipping point' to show what change in the MSY Scenario's likelihood would need to occur to outweigh the costs of a FAD ID system. This allows decision makers to make a judgement on whether the necessary change in

[5] http://internet1.customs.go.th/ext/Statistic/StatisticIndex2550.jsp

likelihood is plausible and therefore, if the FAD ID system is economically viable. As shown below, the necessary change is consistently minimal.

5.3 Results and discussion

Table 7 and Figure 9 set out the results of the cost-benefit analysis, assuming different levels of improvement in WCPFC members' capacity to achieve their MSY stock management objectives under different marking options. For example, if a manual marking system based on industry registering FADs and applying a unique ID based on painting leads to a 10% improvement in WCPFC members' capacity to meet stock management objectives, we would expect a positive NPV of $145.76m. If the same system resulted in a 50% improvement in the ability to meet stock management objectives, the NPV would rise to $763.55m. Importantly, in all cases except the 5% and 10% improvement scenarios for acoustic tagging (which requires higher investment in tags), the NPV is expected to be positive.

Table 7: Cost-benefits assessment of different FAD marking systems assuming different improvements in WCPFC CCMs' capacity to meet MSY stock management objectives.

Marking system		5%	10%	20%	30%	40%	50%
Manual	Painting	$68.54m	$145.76m	$300.21m	$454.66m	$609.10m	$763.55m
	Tags	$68.13m	$145.36m	$299.80m	$454.25m	$608.70m	$763.15m
	Acoustic	-$84.00m	-$6.78m	$147.67m	$302.12m	$456.57m	$611.02m
Electronic (Sat. buoy)		$70.29m	$147.51m	$301.96m	$456.40m	$610.85m	$765.30m
Combined (Paint-Elect.)		$66.62m	$143.84m	$298.29m	$452.74m	$607.18m	$761.63m

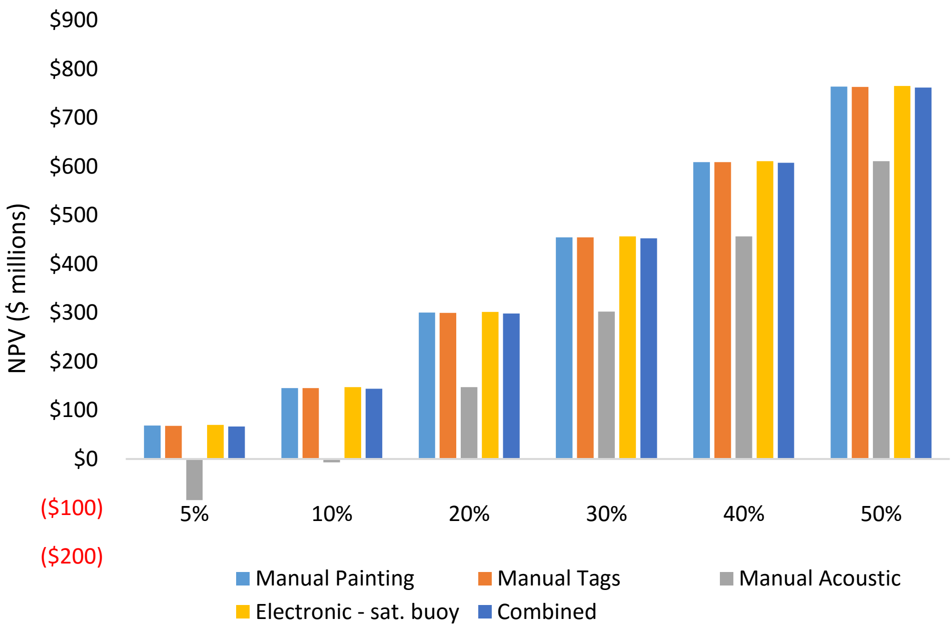


Figure 9: Estimated net present values associated with different marking system under different levels of assumed improvement in capacity to meet stock management objectives.

The other important question from an economic point of view is "what is the 'tipping point' at which costs and benefits could be expected to cancel each other out?". Or in this case, "how much more likely would we need to be to meet MSY stock management objectives for a marking system to make economic sense?". Table 8 sets out the results of this analysis. For example, for a combined marking system based on industry-applied manual marking and satellite buoy tracking to make economic sense, WCPFC members would need to be only 0.69% more likely to meet their MSY stock management objectives. In all cases except acoustic tagging, the extent to which WCPFC members' capacity to meet stock management objectives needs to improve for the benefits of FAD marking to outweigh the costs is less than 1%. This is the case because of the very high overall value of BET/YFT stocks and the substantial improvements in economic return made possible through only small improvements in management performance.

Table 8: Net present value 'tipping points' for each marking system, expressed the percentage improvement in likelihood of meeting MSY stock management objectives required for benefits to outweigh costs.

Marking system	Manual			Electronic	Combined
	Paint	Tags	Acoustic	(Sat. buoy)	(Paint/sat. buoy)
'Tipping point'	0.56%	0.59%	10.44%	0.45%	0.69%

6 Analysis and proposed way forward

6.1 Is there a need for a common marking system for FADs deployed and encountered in the WCPO?

From legal, scientific and management perspectives there is clear need to better understand, regulate, and manage FAD activities in the WCPO. There appears to be little dispute about this in principle by any of the stakeholders interviewed and, in the context of both increasing FAD usage and declining biomass of key target species affected (e.g. BET), most recognise the need for immediate action.

The starting point for better FAD management must be the introduction of a system that builds a complete picture of the number and type of FADs in operation in the WCPO, as well as providing a mechanism that allows the life history of the FAD to be tracked throughout its life. To that end, there is a clear need to introduce a requirement for all FADs deployed and encountered in the WCPO to be registered and marked in a way that provides for permanent, unique, non-corruptible identification of the FAD itself.

Once the number and type of FADs is known with accuracy, and the life history of individual FADs can be tracked, evidence-based management decisions can be taken consistent with the WCPF Convention objectives to ensure the sustainable management of target stocks and associated ecosystems.

In practical terms then the question is not so much whether a unique FAD ID system is required, but which system, or combination of systems, provides greatest value for money while ensuring integrity.

6.2 Strengths and weaknesses of different marking systems

6.2.1 Physical marking system

The strength of a physical or manual marking system is that it will attach a permanent unique identifier to each individual FAD and, regardless of whether the associated satellite buoy is subsequently removed or tampered with, the FAD movement and fishing information can be recorded by observers (i.e. the life history of the FAD can be tracked and monitored).

Because of the business costs associated with applying and registering the physical marking, the manual marking system is likely to be more expensive than electronic marking through satellite buoys alone, but it is essential if the outcomes sought from a FAD marking system are to be realised – i.e. an accurate account of the number and type of FADs and a means of effectively tracking life history. There is also a strong case that for those companies wishing to use FADs as a means of improving profitability, complying with marking and management requirements designed to reduce or offset the negative consequences of FAD usage is simply a cost of doing business.

To have integrity, a physical marking system must be supported by a range of supplementary verification and compliance measures set out in section 3.1.1.4. Registration of FADs could either be through a purpose-built, centralised, web-accessible database developed and maintained by WCPFC, or as part of a hybrid system which drew on FAD marking arrangements already in place amongst some CCMs (which may be more cost effective, as long as any hybrid system can deliver a complete picture of FADs in use). Either way, a credible, accurate account of the number and type of FADs in the WCPO would need to be able to be generated.

6.2.2 Electronic marking

An electronic system using the unique ID of the satellite buoy associated with each FAD arguably has the potential to be the most efficient method of marking, however a number of practical challenges mean that, on its own and at this stage, the system may not be effective as a permanent, unique identifier of the FAD itself. In particular, anecdotal evidence suggests that 'buoy swapping' occurs frequently (including at times away from the catching vessel) such that the life history of the FAD itself may be lost, or at least confused. Preliminary analysis of observer data between 2009 and 2014 indicated that the satellite buoy ID was recorded in only 52% of FAD sets (Abascal et al, 2014) and, while this proportion could probably be increased with requests for observers to place increased emphasis on tracking these numbers, it is not clear at this stage whether the system is sufficiently robust to track individual FADs through multiple buoy swaps etc in a timely manner. In addition, early evidence from PNA trials of FAD tracking indicate that full compliance with the requirement to register and provide position reports from satellite buoys is yet to be achieved.

Nevertheless, information provided by satellite buoys including position, course, speed, sea surface temperature (and biomass from sonar buoys) has the potential to be extremely valuable for scientific, compliance, management and industry accountability purposes (and may at some point in future be capable of serving as a unique FAD identifier). To that extent, while an electronic marking system on its own may be not be sufficient to provide for a robust, permanent unique ID for individual FADs, access to satellite buoy information should be sought.

A critical corollary to accessing satellite buoy information is the need to ensure data security. This information has considerable commercial value, and any leakage is likely to be fatal to industry's participation. Accordingly, irrespective of which option is chosen to access satellite buoy information, essential minimum standards to data security must be developed and demonstrated prior to roll-out.

6.2.3 Combined physical/electronic system

A combined physical/electronic marking system provides, in effect, the best of both worlds. The physical marking on the FAD itself provides a permanent, unique ID that carries through even where the satellite buoy is changed, while the satellite buoy information provides valuable scientific, compliance and management information. The fact that industry is paying the main costs of satellite buoy information already – i.e. the purchase of the buoys themselves and the associated airtime – means that (assuming agreement can be reached for industry to supply the data) the information can be accessed at very modest marginal cost.

6.3 Proposed way forward

One of the challenges in recommending a robust, cost effective marking scheme for FADs in the WCPO is that there are no existing templates that have been implemented for a sufficient period of time to learn useful lessons from. While the IATTC and IOTC have agreed marking schemes, and the

PNA and PNG have recently commenced their own trials, all are in their very early days with few clear results at this stage.

Nevertheless, the need to better understand and manage increasing FAD usage and impacts is such that a 'starting point' is required, which can be refined and improved over time as the technology develops and lessons are learned from initial implementation.

To that end, we propose the following way forward:

6.3.1 Step 1: Introduce a manual marking scheme

The need to 'draw a box around the problem' is essential and urgent, as is the need to begin the implementation of a framework that allows for the better management of FADs. What's required in the immediate term is the introduction of a system that allows the number of FADs deployed and encountered in the WCPO to be accurately estimated, while also facilitating the tracking of the full life history of individual FADs for scientific purposes.

As a first step, the following measures should be adopted:

- Introduce a measure requiring all man-made FADs deployed in the WCPO to be registered and marked with a permanent, unique identifier prior to deployment, or in the case of encountered FADs (if a vessel wants to set on it, or monitor it) at the time of encounter;
- Registration should be undertaken by fishing companies directly into a secure, web-accessible database. The database can either be operated centrally through WCPFC, or through a 'hybrid' arrangement using existing FAD registries in place through CCMs.
- Upon registration, which will include inputting the details of FAD and company/vessel ownership into the database as well as the associated satellite buoy number, fishing companies should receive a unique ID for each registered FAD, together with confirmation that the FAD has been registered. The unique ID could be a standalone number allocated through the database, or could use the unique ID associated with the satellite buoy[6];
- Following registration, the unique ID allocated by the database should be applied to each FAD (not the FAD buoy) in a way that is:
    - Permanent – i.e. it is durable, weather-resistant, non-corruptible and will not dissociate from the FAD;
    - Provides the greatest chance of being easily identifiable to the captain and observer under normal operating circumstances;
    - Ideally, does not make the FAD more visible to other companies' vessels.

  Ideally, trials should be run prior to the introduction of any measures which test different configurations of manual marking (e.g. size of lettering, colour and background, position on FAD, type of materials, etc). These should be run in conjunction with both industry and observers.

To ensure the integrity of the system, and to build a better picture of FAD deployment and usage, a number of supporting measures would be required. These include:

- Prohibit the deployment of FADs unless an authorised observer is present (in order to allow for verification of registration and ID);
- Prohibit the setting of any FAD that does not carry an authorised unique ID (to reduce incentives to deploy unregistered FADs and to ensure the marking is applied permanently);

[6] In the event that the satellite buoy ID was preferred as the marking, and all aFADs were not required to have a satellite buoy attached, some system would be required to allocate unique IDs for these.

- Require satellite buoys be compulsorily attached to all man-made dFADs deployed in the WCPO. Where sets are made on natural FADs (e.g. logs) a satellite buoy should be attached to the FAD prior to the set (or immediately after). The position location of all aFADs should be reported to the Commission;
- Require vessels to report all changes in ownership of FADs (e.g. where FADs are traded between companies);
- Require vessels to report any changes to buoys on FADs in logsheets. Consequential changes to both vessel logsheets and observer workbooks will be required to facilitate industry and observer reporting of FAD IDs.

WCPFC, together with Indonesia and the Philippines, should also consider the utility of attaching satellite buoys to aFADs in case they break free and then they can be tracked.

While manual marking is not without its challenges (e.g. identification of FAD IDs during pre-dawn sets), the advantage of this system is that it provides a starting point to understand the number of FADs in the fishery and to track their deployment. If there are issues with industry providing satellite buoy data or in FADs being re-buoyed then the basic information is still there and can be built on overtime as the electronic processes are tested and developed.

6.3.2 Step 2: Secure access to satellite buoy position information

Access to satellite buoy position information will be enormously valuable for scientific, compliance, management and industry accountability purposes, and can potentially be accessed at relatively modest marginal costs (given industry are already paying the satellite airtime, which is likely to be the main cost). WCPFC CCMs should consider ways to allow relevant parties access to satellite buoy information, while at the same time building on utilizing existing systems and where possible minimizing costs. To that end we recommend:

- WCPFC should explore with PNA an agreement to allow for satellite buoy information collected through their current (and potentially ongoing) trial to be made available to SPC for analysis. We note that up to 95% of FAD sets in any year occur in PNA waters (albeit FADs may not be in PNA waters for 95% of their life) and information from the PNA system should account for a very substantial proportion of the FAD position information. Moreover, given the ‘port-to-port’ nature of the monitoring requirements (i.e. buoy information is required to be reported irrespective of location), full compliance with the PNA scheme would deliver information on the vast majority of FADs (excluding Indonesia and the Philippines). Ideally, generic scientific analysis commissioned through the WCPFC and derived from the PNA satellite buoy position information should be made available to all WCPFC CCMs. The PNA satellite buoy position information will also have considerable compliance and management utility, although these benefits will be captured through PNA’s own internal arrangements, and near-real time information does not need to be made available to the wider WCPFC membership.
- Notwithstanding the considerable coverage of the PNA system, FADs will be deployed by vessels not covered under the PNA system, and/or drift into areas outside PNA waters (e.g. high seas, non-PNA FFA members, Indonesia, Philippines, US and French Territories). Based on the early outcomes of the PNA trial, WCPFC CCMs should consider whether additional arrangements are required to acquire and track FAD satellite buoy information not already covered by the PNA trial. Key considerations would be, for example, the proportion of dFADs not covered by the PNA system, and whether there were other benefits available through independent FAD tracking (e.g. CCMs may wish to know how often FADs draft through their zones deployed by vessels not licensed in their zone). The data access and

confidentiality issues around the tracking of FADs are complex however and would need to be thought through very carefully.

- In developing any satellite buoy tracking arrangements, protocols need to be developed to ensure the security of information. This is essential to the integrity of the system and industry acceptance.

6.3.3 Step 3: Further investigate and trial alternative marking systems

A number of marking schemes exist that are potentially useful alternatives to the manual marking system described in step 1 above. Perhaps the most immediately available technology is acoustic tagging, although other technologies such as RFID tagging continue to develop. These technologies, if they are able to be implemented cost effectively across the fishery, potentially offer considerable advantages over manual marking alone (e.g. easier and more certain recognition of FAD ID; easier identification of pre-dawn sets; better compliance with the FAD closure, etc). We recommend that funds be sought to undertake practical trials of alternative marking systems at the earliest opportunity, probably commencing with acoustic tagging.

At the same time, trials should be run to examine the possibility that the unique ID associated with the satellite buoy, together with the tracking of FADs by observers through the normal process, could be used to adequately track the life history of FADs (in a way that maintains capacity to undertake effective scientific analysis).

We note that this approach is generally consistent with the existing IWG recommendation that "*the Commission should consider developing a FAD marking and identification scheme that applies to FADs as well as any associated satellite buoys and incorporates electronic signatures where possible. As a first step the submission of electronic identification information should be completed in a pilot project to ensure the confidentiality of the data. Result of that project should be reported to the Commission*."

Steps 1 and 2 above can be implemented concurrently. Trials for step 3 can be undertaken relatively quickly after step 1 is implemented. The need to 'draw a box around the problem' however means that the introduction of step 1 should not be delayed to await the analyses under step 3.

Importantly, none of these systems is likely to be implemented with inevitable 'hiccups' so, where possible, practical trials of each different component should be undertaken beforehand, (e.g. how large do the manual marking characters need to be to be visible by observers/captains under normal operating circumstances?; where are they best placed on the FAD?; if a tagging system is adopted, what material is best for the tags?). Moreover, the WCPFC should ensure the practical operation of the system is subject to ongoing review (e.g. through the IWG or TCC) such that any initial teething problems can be addressed and the system can be refined and improved as lessons are learned over time.

7 References

Abascal, F., Fukofuka, S., Falasi, C., Sharples, P. and Williams, P. (2014). Preliminary analysis of the Regional Observer Programme data on FAD design. WCPFC Scientific Committee Tenth Regular Session Majuro, Republic of the Marshall Islands 6-14 August 2014. WCPFC-SC10-2014/ST-IP-09. 38pp.

Benelli, G. and Pozzebon, A. (2013). RFID Under Water: Technical Issues and Applications, Radio Frequency Identification from System to Applications, Dr. M. I. B. Reaz (Ed.), InTech, DOI: 10.5772/53934. Available from: http://www.intechopen.com/books/radio-frequency-identification-from-system-to-applications/rfid-under-water-technical-issues-and-applications

Bjørndal, T. and G. Munro 2012. The Economics and Management of World Fisheries, Oxford, Oxford University Press.

Davies, T., Mees, C. and Milner-Gulland, E. (2014). The past, present and future use of drifting fish aggregating devices (FADs) in the Indian Ocean. Marine Policy. 45 pp. 163–170

Gershman, D., Nickson, A. and O'Toole, M. (2015). Estimating the Use of FADs Around the World: An updated analysis of the number of fish aggregating devices deployed in the ocean. A report from the Pew Charitable Trusts.

Hall, M. and Román, M. (2016). The Fishery on Fish-Aggregating Devices (FADs) in the Eastern Pacific Ocean – Update. Inter-American Tropical Tuna Commission Scientific Advisory Committee Seventh Meeting La Jolla, California (USA) 09-13 May 2016 Document SAC-07-03e

Harley, S., Williams, P., Hampton, J. (2009). Analysis of purse seine set times for different school associations: a further tool to assist in compliance with FAD closures? WCPFC-SC5-2009/ST-WP-07 (available at http://www.wcpfc.int/node/2126).

Itano D., Fukofuka S. and Brogan D. (2004). The development, design and current status of anchored and drifting FADs in the WCPO. 17th Meeting of the Standing Committee on Tuna and Billfish. 9-18 August 2004. Majuro, Marshall Islands. FTWG INF–FTWG–3. 26 pp.

MRAG Asia Pacific (2016). Towards the quantification of illegal, unreported and unregulated (IUU) fishing in the Pacific Islands region. 101pp.

MRAG Ltd (2009). FAD Management: A study of the impacts of fish aggregating devices (FADs) and the development of effective management strategies for their responsible use by industrial tuna fishing fleets. A report prepared for the WTPO. 153pp.

Scott, G. and Lopez, J. (2014). The Use of FADs in Tuna Fisheries. A report to the European Parliament's Committee on Fisheries. 66pp.

Williams, P. and Terawasi, P. (2015). Overview of Tuna Fisheries in the Western and Central Pacific Ocean, Including Economic Conditions – 2014. Scientific Committee Eleventh Regular Session Pohnpei, Federated States of Micronesia 5-13 August 2015. WCPFC-SC11-2014/GN WP-1 Rev 1 (28 July 2015).

Annex 1: Terms of Reference

Prospectus for obtaining consultant services to evaluate aspects related to Fish Aggregating Devices employed of fished upon in the Western and Central Pacific.

Purpose: The purpose of this contract is to provide a report to inform the WCPFC Commission and the relevant subsidiary bodies on aspects related to the use and monitoring of FADs deployed and encountered in the WCPO.

Objectives: Evaluate, based on as broad a spectrum of existing information sources, the need and viability of a common marking system for FADS deployed / encountered in the WCPO.

Provide a quantitative cost-benefit analysis of implementing a spectrum of FAD marking and monitoring systems for FADS deployed / encountered in the WCPO.

In completing the above respond to the following questions:

1. Is there any merit (e.g. a positive cost / benefit analysis) of establishing a manual FAD marking system for the specific purpose of enabling improved scientific data collection. (The analysis shall include administrative and business compliance costs)

2. If there is merit in establishing a manual FAD marking system what would be the most efficient way of implementing such as system?
(What are the design specifications and projected costs for implementing an effective manual FAD marking system?)

3. What would be proposed definitions for "FADs deployed" and "FADs encountered", in any future data reporting by vessel operators?

Deliverable(s): A report shall be provided in draft to the Secretariat by the date designated below. The Secretariat will review the draft and provide comments within 30 calendar days. The consultant shall respond to all comments made and provide a final draft within 30 calendar days of receipt of the Secretariat draft review.

Annex 2: Measures to mark and monitor FADs used by other organisations

Jurisdiction	FAD definitions	Compliance measures	Marking scheme
IOTC (15/08)			From January 2016, CPCs shall require all artificial FADs deployed or modified by their flagged fishing vessels in the IOTC area of competence to be marked in accordance with a detailed marking scheme, e.g. including FAD marking or beacon ID. The marking scheme shall be developed and considered for adoption by the Commission at its regular annual session in 2016, based on recommendations from the IOTC Scientific Committee as requested by the Commission. The marking scheme should take into account, as a minimum, the following: (a) All artificial FADs shall be marked with a unique identification number, based on a specific numbering system and format to be adopted by the Commission; (b) The marking should be easy to read before the vessel operator engages in any artificial FAD related activity (e.g. setting on the artificial FAD, retrieving the artificial FAD, servicing the artificial FAD, fishing on the artificial FAD), but if not visible for any reason, (time of day, weather, etc.), the vessel operator shall ensure to obtain the unique artificial FAD identifier as soon as feasible; (a) The marking should be easy to apply to the artificial FAD, but should be applied in such a manner that it will not become unreadable or disassociated with the artificial FAD.
	This Resolution defines an instrumented buoy as a buoy with a clearly marked reference number allowing its identification and equipped with a	CPCs shall require vessels flying their flag and fishing on DFADs to submit by 1 January 2016, the provisional purchase order for 2016 of instrumented buoys for their purse seine vessels under the confidentiality rules set by Resolution 12/02 (or any subsequent superseding Resolution)	

	satellite tracking system to monitor its position. Other buoys, such as radio buoys used on DFADs, not meeting this definition, shall be gradually phased out by the 1 January 2017	CPCs shall require vessels flying their flag and fishing on DFADs to submit, by the end of 2016 the number of instrumented buoys activated, deactivated and active on each quarter during 2016 its purse seine vessel under the confidentiality rules set by Resolution 12/02	
IATTC (Resolution C-15-03)	For the purposes of this Resolution, the term “Fish-Aggregating Device” (FAD) means anchored, drifting, floating or submerged objects deployed and/or tracked by vessels, including through the use of radio and/or satellite buoys, for the purpose of aggregating target tuna species for purse-seine fishing operations.		No later than 1 January 2017, CPCs shall require the owners and operators of their applicable flagged purse-seine fishing vessels to identify all FADs deployed or modified by such vessels in accordance with a Commission identification scheme detailed in footnote 1 of Annex 1. CPCs shall obtain unique alphanumeric codes from the IATTC staff on a periodic basis and distribute those numbers to the vessels in their fleets for FADs that may be deployed or modified, or in the alternative, if there is already a unique FAD identifier associated with the FAD (e.g., the manufacturer identification code for the attached buoy), the vessel owner or operator may instead use that identifier as the unique code for each FAD that may be deployed or modified. The code shall be clearly painted in characters at least 5 cm in height. The characters shall be painted on the upper portion of the attached radio or satellite buoy in a location that does not cover the solar cells used to power the equipment. For FADs without attached radio or satellite buoys, the characters shall be painted on the uppermost or emergent top portion of the FAD. The vessel owner or operator shall ensure the marking is durable (for example, use epoxy-based paint or an equivalent in terms of lasting ability) and visible at all times during daylight. In circumstances where the observer is unable to view the code, the captain or crew shall assist the observer (e.g., share their inventory of FADs to assist in

			matching each FAD with the identification code), so long as such assistance does not interfere with fishing operations.
PNG (Gazettal No. G.570; 7/9/15)	"Fish aggregating device" (FAD) means a man-made or partially man-made floating, semi-submerged or submerged device, whether anchored or not, intended to aggregate fish, and includes any natural floating object on which a device has been placed to facilitate its location	**4.4 FAD LIMITS** The maximum number of drifting FADs allocated by NFA per licensed purse seine vessel shall not exceed 100 for a single licensing period without replacement. These may be deployed regionally and shall report to NFA /PNA FIMS No FAD shall be deployed during the FAD closure period described above. At other times, deployment must be conducted in accordance with the following requirements; 1. All PNG licensed vessels are subject to 100% observer coverage. It is mandatory for any PNG licensed vessel that Observers monitor and record the details of the deployment and use all FADs. 11. FADs shall not be deployed from a non licensed vessel. iii. No FAD shall be deployed unless it is registered, and a unique FAD registration number has been allocated by NFA. iv. NFA may publish criteria, by notification in the National Gazette and notified to license holders, concerning the allocation and deployment of FADs. v. All FAD deployments shall be notified to the NFA in the form required by the NFA, within 24 hours of their deployment. **4.8 REQUIREMENTS FOR RETRIEVING FADS** 1. The NFA is to be given notice of, and the opportunity to place an observer to monitor, all FAD retrievals. 2. The vessel master must provide FAD retrieval information to the NFA in the form required by NFA, within 24 hours of retrieval.	**4.5 FAD MARKING** 1. All FADs must be clearly marked with the name and registration number of the vessel that has deployed it. This information shall be fixed in such a way that it will remain fixed to the FAD for the life of the FAD. 2. The information must be in lettering at least 30cm high and of a colour that contrasts with the colour of the back plate. The plate must be attached to a point on the FAD where in normal circumstances it is visible from opposing directions. 3. Unique identification number from satellite buoys attached to FADs shall be linked to the FAD and a unique FAD registration number allocated by NFA. **4.9 FAD MONITORING** 1. Satellite tracking buoys shall be assigned a unique identification number and linked to the registered FAD and the vessel that deployed the FAD. 2. The FAD operator shall provide NFA with a direct feed of all data (including but not limited to location, time, ID, associated vessel and sonar data) being transmitted from all buoys affixed to a FAD, whether that satellite buoy is registered with NFA or not.

		4.11 FOUND FAD I. If a FAD, whether natural or artificial is found by a vessel, and a set is made, it is mandatory for a vessel to attach a registered satellite buoy to that FAD. **5.1 FAD REGISTRATION** 1. It is a requirement that each vessel operator or company must register each FAD, and each satellite buoy, including the make, model, and unique identification number. 2. Vessel owners must apply to NFA for the registration of each FAD and satellite buoy in the form required by NFA, including any required fee. 4. The NFA shall keep a register of FADs deployed or tracked by any vessel licensed to fish in PNG waters in order to manage the number of deployed FADs, both anchored and drifting, and may use this data for fishery management, science, and compliance purposes, including sharing that data with other states, and regional organizations. 5. Due to the largely aimless movement of drifting FADs the PNG registry and tracking requirement for FADs for any vessel licensed to fish in PNG includes national waters, other countries EEZs, and the high seas. 6. It is a requirement that the vessel operator or company notify NFA of any proposal to turn off satellite monitoring services for a buoy and provide the NFA seven7 working days to respond. 7. If a response has not been received within that 7 day period the service may be turned off. 8. A response within that 7 day period may, under this Policy, may be to the effect:	

		a. that the vessel operator or company be required to maintain satellite monitoring services for a period of up to 60 days; *b.* that NFA be given the opportunity to take on responsibility for satellite monitoring services; *c.* that the vessel operator or company be required to remove and FAD if it is grounded, or recover a buoy if it has moved into an area where FAD fishing is not permitted. 9. Where additional buoys are introduced during the year whether they are newly approved buoys or to replace lost buoys they must be registered before or upon their first report. 10. Each person or company seeking to use a FAD in the regions waters must register a satellite buoy and undertakes that to meet the requirement of this Policy, they shall authorize and require each buoy service provider to parallel report to NFA in the prescribed format. 11. A list of type approved satellite buoy manufacturers will be made available by NFA upon request. **5.2 FAD REGISTRY AND MANAGEMENT FEES** I. The NFA will levy an annual fee for the registration and monitoring of FADs sufficient to cover the costs involved in providing this service. 2. Those costs will cover FAD management, including: *a.* data analysis and reporting, *b.* registration and approval of FADs, *c.* monitoring of deployment, use, and retrievals, *d.* and may include satellite tracking outside of Papua New Guinea once disowned by the deploying vessel.	

		3. The vessel operator or owner shall pay all costs for FAD and satellite hardware, and all associated communications and reporting costs necessary to meet the requirements of this policy. **5.3 REPLACING LOST FADS** I. A vessel master shall notify the NFA that a FAD has been permanently lost by providing the following information: *a.* The date and position of last reported position or sighting of the FAD; *b.* The location (latitude and longitude) recorded in degrees and minutes of last known position *c.* The FAD number, satellite buoy identification number; and *d.* FAD Construction material. 2. The NFA will review this information and may give approval to deploy a replacement FAD depending on the circumstances. 3. Where a FAD is found to be beached or on a reef, the company who deployed it may be required to remove the debris or ensure the debris is removed, or may be required to reimburse any costs associated with the removal. 4. Industry is strongly encouraged, and may be required under this Policy, to recover and recycle FADs and components to avoid marine debris.	
ICCAT (Recommendation 15-02)			An ad hoc Working Group is established with the following Terms of Reference: d) Assess the developments in FAD-related technology, including with regard to: FAD and buoys marking and identification as a tool for monitoring, tracking and control of FADs.

			e) Identify management options and common standards for FAD management, including components of FAD management plans, the regulation of deployment limits, characteristics and use of FADs, such as marking and activities of support vessels and evaluate their effect on ICCAT managed species and on the pelagic eco-systems, based on scientific advice and the precautionary approach. This should take into consideration all the fishing mortality components, the methods by which FAD fishing has increased a vessel's ability to catch fish, as well as socio-economic elements with the view to provide effective recommendations to the Commission for FAD management in tropical tuna fisheries. 3. The ad hoc Working Group shall report on its work with a view to recommend the adoption of appropriate measures at the latest at the 2016 ICCAT Commission meeting. 7. The ICCAT Secretariat should work with the Secretariats of other tuna RFMOs in which FAD Working Groups have been established to promote the cooperation between these groups, including through the organization of a joint session in 2016 with the interested tuna RFMOs