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Anchored fish aggregating devices for artisanal fisheries in South and Southeast Asia: benefits and risks

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Anchored fish aggregating devices for artisanal fisheries in South and Southeast Asia: benefits and risks

Steve Beverly, Don Griffiths and Robert Lee

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Foreword

For centuries fishers have known that fish are attracted to and congregate around naturally occurring floating objects. By fishing close to these, they can often bring back fish for their families. They have also learned that by placing their own floating objects in the sea that fish would aggregate around them making catching easier. These man-made objects are called Fish Aggregating Devices or FADs and they can be either drifting or anchored.

Since FADs can improve fish catches, governments and national fisheries agencies in the Asia region are examining the merits of using anchored FAD programmes. Their policy objectives are typically improved food security through better availability of localized aquatic animal protein, increasing the reliability of income from fishing for artisanal fishers and the creation of employment in coastal areas through fish and aquatic product trading and processing.

In the last decade or so, FADs for both artisanal and commercial/industrial fisheries have proliferated in Asia and the Pacific region. In some areas this has caused concern about the potential negative impacts on fisheries and the marine environment. This has led environmental and conservation groups to lobby for FAD-free caught tuna, particularly in industrial type tuna fisheries.

This publication responds to requests from governments within the region for additional information on the use of anchored fish aggregating devices for artisanal fisheries. It was produced by the Spanish-funded and FAO-executed Regional Fisheries Livelihoods Programme (RFLP), which is conducting activities in Cambodia, Indonesia, the Philippines, Sri Lanka, Timor-Leste and Viet Nam.

The book highlights the potential benefits of well co-managed anchored FAD programmes, which can contribute to overall food security. It covers the planning and background research requirements and emphasizes the importance and need for holistic and inclusive community consultation and monitoring processes and the development of enabling policies. The book also covers the environmental concerns and possible negative ecosystem impacts of unplanned and poorly managed programmes, which inevitably lead to unsustainable resource exploitation and financial and economic losses.

An Advisory note was also developed as a summary and findings of this book to promote responsible planning, implementation and monitoring of anchored fish aggregating devices for artisanal fisheries in line with the FAO Code of Conduct for Responsible Fisheries (http://www.fao.org/docrep/005/v9878e/v9878e00.HTM). It provides recommendations to governments, fisheries agencies, donors and other key stakeholders on the technical, socio-economic and environmental aspects to be considered before deciding on whether to embark on a FAD programme.

Hiroyuki Konuma
Assistant Director-General and Regional Representative
FAO Regional Office for Asia and the Pacific

Preparation of this document

This report was supported by the Spanish-funded and FAO-executed Regional Fisheries Livelihoods Programme (RFLP), which is conducting activities in collaboration with the line agencies for fisheries in the Kingdom of Cambodia, the Republic of Indonesia, the Republic of the Philippines, the Democratic Socialist Republic of Sri Lanka, the Democratic Republic of Timor-Leste, and the Socialist Republic of Viet Nam.

The RFLP's objective is to reduce the vulnerability of small scale fishers in South and Southeast Asia by:

- Introducing co-management mechanisms for sustainable utilization of fishery resources;
- Improving safety at sea and reducing vulnerability of fisher communities;
- Improving the quality of fishery products and market chains;
- Strengthening existing and diversifying alternative income opportunities for fisher/fishing families;
- Facilitating access to micro-finance services for fishers, processors and vendors; and
- Sharing knowledge and advocacy in support of livelihoods development in order to reduce the vulnerability of fisher/fishing communities and to promote sustainable fisheries resource management.

The primary stakeholders and target beneficiaries are (i) coastal fishers, processors, traders and their families, their organizations and their communities, including the local authorities and; (ii) government organizations and institutions responsible for the administration, management and development of the coastal fisheries at local, district/province and national levels.

The RFLP outcome will be: 'Strengthened capacity among participating small-scale fishing communities and their supporting institutions towards improved livelihoods and sustainable fisheries resources management'.

Several RFLP countries are, or are considering, using FAD programmes to improve food security and to contribute to the livelihoods of coastal communities. RFLP supported the development of a stand-alone advisory note and this publication to provide well balanced guidance and information for South and Southeast Asian countries that are considering supporting similar anchored FAD programmes.

The authors would like to thank Jose Parajua, Simon Funge-Smith, Rudi Hermes and Steve Needham for their constructive feedback to this document.

Abstract

Fish Aggregating Devices, also known as FADs, have been used to attract fish, making them easier to catch and reducing fuel costs when searching for schools of pelagic fish. FADs are used by both industrial fishing fleets fishing the high seas for tunas and tuna-like species, as well as by artisanal fishing communities as a means of providing for their food security and livelihoods.

It is necessary to distinguish between industrial anchored and drifting FADs used by large purse seiners and artisanal anchored FADs, because the scale of operation and the objectives are different. Different quantities of fish are caught and different types of fishing gear are used. The size selectivity of aquatic species caught, including sharks and turtles, and other endangered, threatened or protected species, is influenced by the type of gear used for fishing. In addition, industrial FADs are used in large numbers all over the high seas, while artisanal anchored FADs are usually located near coastal fishing communities and are important for local food security, nutrition and livelihoods.

Some countries in Southeast Asia are embarking on anchored FAD programmes to boost fish production and to increase food security. This document provides supplementary detailed analyses of the benefits, risks and threats related to the implementation of FAD programmes and specifically for artisanal anchored FADs. The analysis shows that while anchored FADs can bring important benefits to fishing communities in terms of food security and livelihoods, it is necessary to properly plan the intervention as there are many pitfalls which can cause programmes to become unsustainable, resulting in losses for both governments and fishing communities. FADs can also be a source of pollution, and can obstruct navigation and other fishing activities, leading to social conflict.

Chapter one of this publication gives a brief background on FADs and the purpose of this publication. Chapter two describes what a FAD is and explains some of the main differences between artisanal anchored (fixed) and industrial anchored and drifting FADs. Chapter three explores the benefits, risks and threats associated with FADs. These include fisheries management and economic and financial as well as socio-economic issues. Gender and climate change are also covered/treated in this chapter.

A series of annexes in this publication provide specialist technical information. Annex 1 offers details on how to choose a site for a FAD programme and how to construct and install an artisanal anchored FAD, as well as links to where additional FADs information can be found. Annexes 2, 3 and 4 present case studies on FADs from Niue, the Southwest Indian Ocean and the Comoros, while Annex 5 gives some guidance on good fishing practices around FADs for artisanal fishers with some common species, fishing methods, fish handling and sanitation practices. References and further reading are provided at the end of the publication.

Finally, the FAO 1995 Code of Conduct for Responsible Fisheries and its supplement on Technical Guidelines for the Implementation of the Code of Conduct – Fishing Operations provides guidance on the installation of FADs. Countries wishing to implement FAD programmes should take these into account.

Abbreviations and acronyms

^{o}C	Degree centigrade
cm	Centimetre
CPUE	Catch per unit effort
FAD	Fish aggregating device
FAO	Food and Agriculture Organization (United Nations)
IFREMER	French Institute for the Exploitation of the Sea
IGO	Inter-governmental organization
ILO	International Labour organization (United Nations)
IRD	French Institute for Research and Development
kg	Kilogram
l	Litre
lb	Pound
m	Metre
mm	Millimetre
MPA	Marine Protected Area
NGO	Non-governmental organization
nm	Nautical mile
RFLP	Regional Fisheries Livelihoods Programme
NZD	New Zealand Dollar
RFMO	Regional Fishery Management Organization
SPC	Secretariat of the Pacific Community
SWIOP	Southwest Indian Ocean Project
t	Tonne
UNDP	United Nations Development Programme
USD	United States Dollar

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1. Introduction

In their quest to improve food security, some countries in South and Southeast Asia are promoting the deployment of fish aggregating devices, also known as FADs. For any government considering investing in and supporting a FAD programme it is critical that the programme is viewed as one element within the overall fishery, which is to be managed using an ecosystems approach to fisheries management. A FAD programme must be approached in a holistic manner so that resource management and environmental, socio-economic and technical aspects are given proper consideration. Otherwise the FAD programme will be unsustainable and will result in financial and economic losses and possible negative impacts on aquatic resources and the marine environment in which they live.

Properly planned and implemented FADs programmes require due diligence in identifying risk, adequate research, consultative stakeholder processes and involvement of fishers in catch and effort monitoring and the formulation of good policies and regulations that can bring financial and economic benefits to the fishing communities and support sustainable fisheries livelihoods and management.

Anchored FADs can however be an important tool for the development of sustainable artisanal and small-scale commercial fisheries, increasing localized catches at reduced costs and thereby improving food security and livelihoods for coastal communities in developing countries.

Figure 1. Bringing yellowfin tuna ashore, the Philippines.

"In reviewing the history of development of small-scale tuna fisheries, one of the few initiatives that has been successful and continues to contribute to the success of small-scale fisheries is the FAD. Despite decades of small-scale tuna development efforts, FADs remain one of the few innovations that allow small-scale fishers to economically take advantage of the region's large tuna resources. Other attempts may have had sporadic success or special applicability in one country, but overall, nothing comes close to producing on-going benefits to small-scale tuna fishers as the FAD."

Bob Gillett (2003).

However, most tuna stocks are fully exploited, some are overexploited and the status of many tuna and tuna-like species other than the principal tunas is highly uncertain or simply unknown.[1] The same can be said for other pelagic fishes that congregate close to FADs. Therefore, the intensification of their exploitation raises a serious concern. While artisanal tuna fisheries probably make only a small contribution to the overall exploitation and "fishing mortality," the fact is that tuna resources are limited. Therefore, like any other fishing method, gear or auxiliary gear, the utilization of FADs requires proper planning and effective management, monitoring and regulatory control measures.

There is a tendency to treat all FADs as essentially being the same. However, drifting FADs and anchored FADs have quite different uses, impacts, and management concerns. This publication is focused exclusively on anchored FADs used by artisanal and small-scale fishers using small-scale fishing methods. It, therefore, does not cover industrial anchored or drifting FADs, such as those used by purse seine fisheries.

Figure 2. A fisher with his bamboo *payao*, Timor-Leste.

The purpose of this publication is to provide guidance to national fisheries agencies in countries in South and Southeast Asia when they consider the planning, implementing and sustainable management of anchored shallow and deep water FAD programmes.

This publication should be useful for government fisheries officers, fisheries managers, artisanal and small-scale commercial fishers, marine departments, fishing cooperatives, non-governmental organizations (NGOs), inter-governmental organizations (IGOs), and regional fisheries management organizations (RFMOs).

[1] FAO. 2012

2. What are fish aggregating devices (FADs)?

Fishers have long known that fish congregate around naturally occurring floating logs or other debris, including dead whales. This aggregating phenomenon, called *thigmotropism*[2] is not completely understood, but it has been suggested that floating objects aggregate fish because they provide a refuge from predators, a meeting place for schooling companions, a place of orientation, a substrate for species undergoing a change from pelagic to other modes of existence, a feeding place, or that they duplicate natural aggregators such as *sargassum* seaweed.[3]

One study suggests that feeding on the organisms that attach themselves to FADs is not important to the fish that aggregate at FADs.[4] There is an alternate theory to the idea that FADs are a meeting place, which suggests that drifting objects represent a means of reaching relatively rich areas, where larvae and juvenile fish have an increased chance of survival.[5] Whatever the cause, knowledge about such aggregating behaviour led to the innovative idea of anchoring something similar to a floating log or other such objects in the sea, so that the aggregated fish could later be located and provide food for fishers and their families.

It is necessary to distinguish between industrial anchored and drifting FADs used by large purse seiners, and artisanal anchored FADs, because the scales of the operations and objectives are very different. The main differences

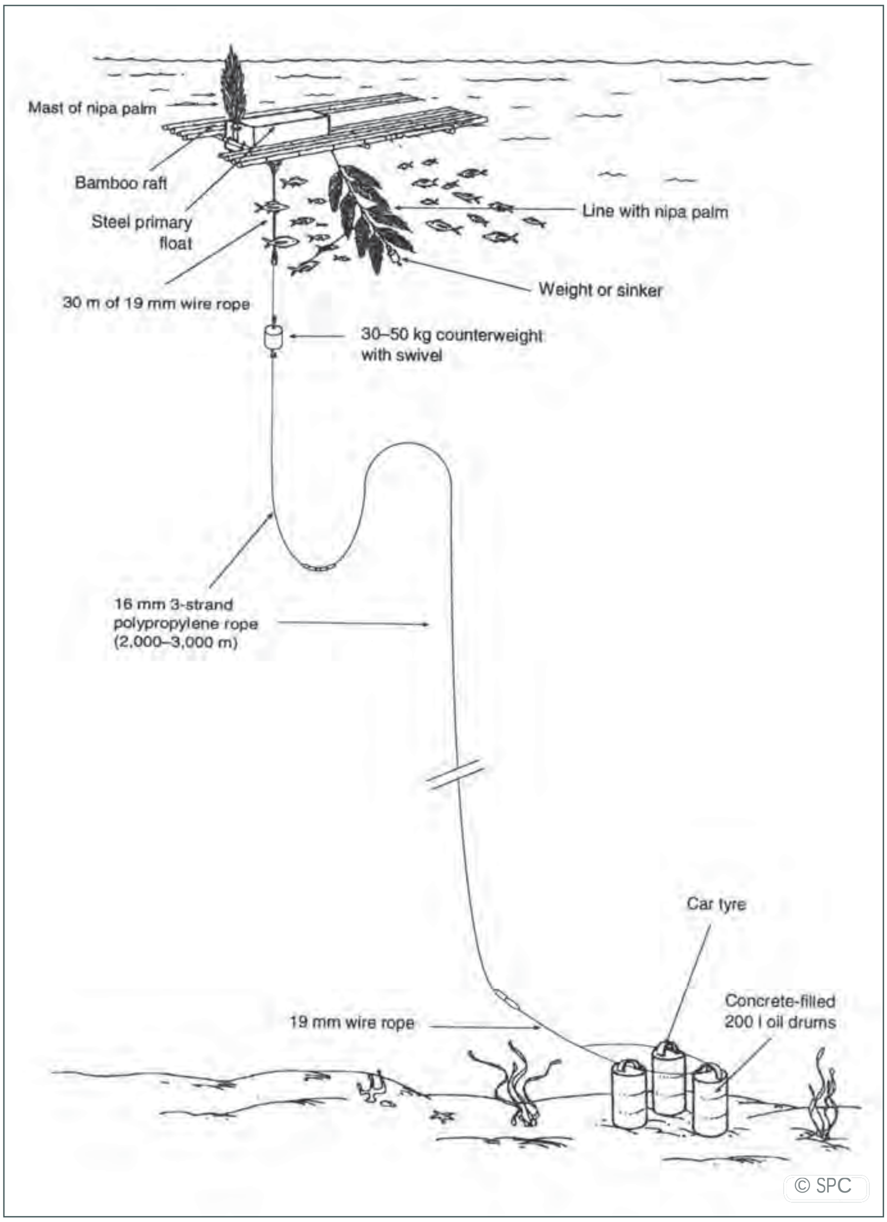


Figure 3. A *payao* FAD.

[2] Vassilopoulou *et al.* 2004
[3] Hunter 1968, Rountree 1989, Buckley and Miller 1994, Vassilopoulou *et al.* 2004, Dagorn and Freon 1999, Hall *et al.*1999, and Soria *et al.* 2009
[4] Ibrahim *et al.* 1996
[5] Castro *et al.* 2002

are the quantities of fish that are caught and the different types of fishing gear that are used. The use of different gear influences the size selectivity of the aquatic species, as well as sharks, turtles and other endangered, threatened or protected species, that arecaught by the fishing gear. In addition, industrial FADs are used in large numbers all over the high seas, while artisanal anchored FADs are usually located near coastal fishing communities and are important for local food security, nutrition and livelihoods.

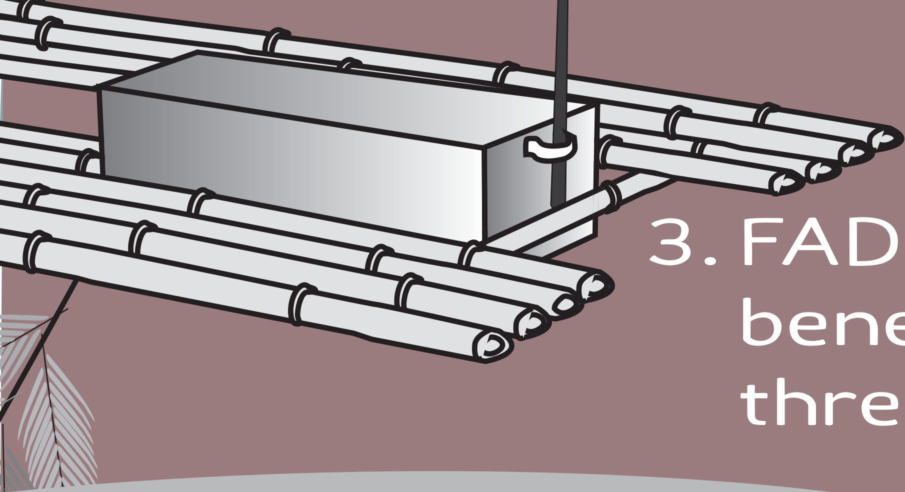
FADs are man-made drifting or anchored buoys or rafts that attract and aggregate fish and other marine organisms.

Industrial FADs can be either anchored (sometimes referred to as AFADs), or drifting FADs (sometimes referred to as DFADs).[6] Industrial anchored FADs are used extensively in hand line fisheries, ring net fisheries, purse seine fisheries and pole and line fisheries, particularly in Indonesia, Papua New Guinea, the Philippines, and the Solomon Islands. They are usually set offshore in depths ranging from 2 000 to 2 500 metres (m). Primarily, industrial anchored FADs are used by the commercial fleets that deploy them.

Drifting FADs drift freely with the currents and are deployed for the exclusive use of the boat or fleet that set them afloat. These FADs are equipped with radio buoys (sometimes called FTBs or FAD tracking buoys) which send radio signals on pre-set frequencies known only to the owner and boat captain. In this way, the vessel that deployed the FADs can always track them and usually other vessels are unable to do so unless the transmitting frequencies are known. Currently, there are thousands of industrial drifting FADs and anchored FADs in the oceans[7] and the majority of the tuna catches made by purse seine vessels globally are taken in aggregations under drifting FADs.[8] The large numbers and the uncontrolled growth of these types of FADs are a cause for international concern. For this reason, the International Sustainable Seafood Foundation (ISSF), the Parties of the Nauru Agreement (PNA), SPC, the Forum Fisheries Agency (FFA), and the World Wide Fund for Nature (WWF), among others are working with tuna fleets and the private sector to reduce the environmental impact of DFADs in the world's oceans and to improve fishery management and conservation in fisheries that use FADs, including the reduction of bycatch associated with FAD fishing. Despite the recent rapid expansion of FAD fisheries, to date, little research has been undertaken to evaluate their benefits. What little has been undertaken has focused primarily on the technical design of FAD structures. Additional studies, particularly on the negative and positive environmental and socio-economic impacts of FAD fisheries are urgently needed.

Figure 4. Different FAD buoys (from left to right *Payao*, Spar buoy and Indian Ocean FAD).

[6] Itano *et al.* 2004
[7] Moreno *et al.* 2007
[8] Fonteneau *et al.* 2000



3. FAD programmes - benefits, risks and threats

3.1 Benefits

With coastal demersal and reef fish resources under high fishing pressure, FADs can offer alternative fishing opportunities and reduce fishing of demersal species by transferring fishing efforts to near shore pelagic fish, especially tuna. This can be most effectively done with a network of FADs anchored close to the coast at the edge of the continental shelf along the migratory routes of neritic fish species (tunas and other tuna-like species) thereby providing better access to tuna for subsistence and small-scale commercial fishers.

In the Pacific Island countries and territories, the benefits of FAD programmes have been described as: increased fishery production, reduced pressure on reef resources, import substitution, export creation, sports fishing opportunities, commercial development, cottage industry development, increased employment, reduced fuel consumption, safety at sea and maintaining an interest in fishing.[9]

Figure 5. Billfish caught at a FAD.

Socio-economic benefits of a FAD programme for Reunion Island in the Indian Ocean were cited as: increased fish landings, development and modernization of the fishing fleet, development of local boat building, improvement of work conditions and safety, possible job creation, decrease in search time and fuel use, stabilization of bottom resources exploitation, and an increase in the number of days fishers are covered by social welfare.[10]

In November 2011, the French Institute for the Exploitation of the Sea (IFREMER), French Polynesia's Ministry of Marine Resources, SPC, and the French Institute for Research and Development (IRD) held an international conference in Tahiti on "Tuna Fisheries and FADs" to review the use of FADs worldwide.[11] This meeting was attended by nearly 150 participants from 40 countries and three oceans and the Mediterranean Sea.

The conference identified socio-economic, environmental, and political drivers as the primary motivations for domestic anchored FAD programmes with likely benefits being:

- Increased fishing efficiency;
- Increased catch per unit effort (CPUE);
- Reduction in fishing costs (mainly fuel) due to the reduction in search time and thus improved earnings for fishers;
- Increased food security through high quality ciguatera-free fish;
- Reduction of dependency on fish imports;

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[9] Anderson and Gates 1996, and Sharp 2011
[10] Detolle *et al.* 1998
[11] Taquet 2011

- Possible development of exports;
- Improved safety at sea;
- Opportunities for development of recreational and charter-tourism;
- Opportunities for scientific monitoring of marine ecosystems;
- Reduced pressure on coastal ecosystems by transferring fishing efforts from coastal fish to offshore fish; and
- FAD programmes can become a mechanism to promote the organization of fishing communities and cooperatives.

3.1.1 Food security

With population growth, rising food prices, climate change impacts both on land and in the sea, food security is already a priority for many governments and their coastal communities. Small-scale fisheries have always played an important role in providing livelihoods for coastal communities in the countries of Southeast Asia, as well as high quality protein, vitamins, minerals, essential oils, fatty acids and calcium, which are all necessary and irreplaceable nutrients for healthy brain and corporal development. In rural areas, much of the fish consumed is caught by artisanal or subsistence fishers, and some is sold, contributing to the livelihoods of small-scale commercial fishers. Anchored FADs are a very important tool that can provide food and livelihoods for coastal communities in developing countries. FADs are one of the few innovations that allow small-scale fishers to economically take advantage of pelagic fish resources, and anchored FADs have the potential to make a valuable contribution toward filling any potential shortfall in fish needed for food security.

FADs can enhance food security and livelihoods of fishing communities.

3.1.2 Economics

Fishing around anchored FADs for high value pelagic species can be very cost effective in terms of time and money spent compared to fishing in the open sea where there are no FADs. Searching for fish or birds (which can indicate the presence of pelagic fish schools) consumes substantial quantities of fuel and time. In fisheries where FAD programmes have been installed, fishers can go directly to the FAD or FADs. For example, in Reunion Island, small open boats fishing around FADs consumed 30 percent less fuel than fishing on the open sea for the same species, and fishers using FAD fishing techniques other than trolling were able to increase their per day fishing effort from two hours to five hours.[12] Some FAD programmes permit fishers in small boats to tie off to FAD buoys, where they can employ more effectively various mid-water fishing techniques such as vertical longline, chumming, and jigging. This allows them to continue fishing for hours without burning any additional fuel, and they can wait out periods when fish are not biting, rather than having to return to port or to continue looking for fish.

Catch rates around anchored FADs are generally better than in the open sea. For example, fish landings in Reunion Island increased 143 percent in the eight year period after anchored FADs were first introduced.[13] Catch rates in the Maldives were 4 to 47 percent higher around anchored FADs than in open water in terms of numbers of fish and 5 to 114 percent higher in terms of fish weight.[14] In Niue, a recent economic analysis of inshore and offshore FAD fishing showed that offshore trolling around anchored FADs produced an average CPUE of 17.83 kg/hour and inshore trolling around FADs produced a CPUE of 8.69 kg/hour compared to trolling offshore and inshore in open water both of which produced a CPUE of 6.29 kg/hour.

FADs used for artisanal fisheries for food security can provide economic benefits if well managed.

An analysis was done on the cost–benefits of Niue's FAD programme for an eight year period from 2001 to 2008 and found that, at an average price of NZD7.50/kg for troll caught fish, the net annual average gain to the fleet from fishing around FADs compared to fishing in open water was NZD70 614. Of this, NZD63 441 was attributed to anchored offshore FADs. The analysis showed a net annual average fuel cost saving from trolling around FADs of NZD1 125 per boat. These figures may not seem large, but must be put into context. In 2011 Niue had a population of only 1 398 inhabitants. Cost–benefit analysis for Niue's anchored FAD programme for a two year period (conservative estimate of FAD longevity) indicated that a government investment of NZD39 729 provided an economic return of NZD95 813 to the country. This would justify a future government investment in the FAD programme of NZD134 658 over a two year period.[15]

[12] Detolle *et al.* 1998
[13] Detolle *et al.* 1998
[14] Naeem and Latheefa 1995
[15] Sharp 2011

Anchored FADs are very popular with recreational and sports fishers and divers and this popularity can be used to the advantage of small-scale commercial fishers. Tourism activities can be an alternative source of livelihood for fishers, who can take tourists and sport fishers out to FADs for recreational fishing or for big game fishing. Following this trend, SPC and the Cook Islands Ministry of Marine Resources have developed a programme to train local artisanal fishers as fishing guides.[16] Sport fishing involving catch and release practices is an environmentally friendly and income generating pursuit. Spear fishing (skin or scuba diving) is another alternative for fishing around FADs, but this should be approached with caution as there may be conflict between fishers and spear fishers as was recently seen in the Cook Islands. This resulted in a ban on spear fishing around anchored FADs.[17] There are also opportunities for community based FADs to be rented or leased to sports fishing enterprises.

3.1.3 Safety

The safety of fishers is enhanced when they fish near FADs. Their position will be known if they fish at an anchored FAD and have informed someone where they were going. If they don't return when expected, someone will be able to tell the search and rescue agency where to start the search, thus reducing the search area and cost. If they are able to tie their boat to FAD their eventual rescue will be much easier. Tying to an anchored FAD, however, is not allowed in many places and should only be done in an emergency situation. Even if they can't transmit a message and nobody reports them missing, other fishers are likely to come along and they will eventually be rescued, as FAD is a gathering point for fishing activity. However, nothing replaces proper training in sea safety and good safety at sea practices. Fishers should always inform someone of their plans – departure and arrival times and destination – before heading to sea. National safety at sea regulations should be followed at all times and where such regulations do not exist then international best practices should be used.[18]

Anchored FADs can enhance safety at sea for small-scale fishers.

3.1.4 Management

As well as providing a means to shift fishing efforts away from lagoons and reefs, anchored FADs can be useful in the management of Fishery Management Areas (FMA) and Marine Protected Areas (MPAs) by offering an alternative fishing option to gill nets, traps, beach seines, and destructive fishing methods such as using explosives or poison to capture fish. As such, FADs have been employed to facilitate management of MPAs in the Komodo National Park in Indonesia and in the Western Indian Ocean.[19] Anchored FADs can be used to demarcate the boundaries between closed areas and fishing zones making it easier for fishers and enforcement officers to distinguish between the two. For example, anchored FADs have been used for demarcating marine zones in the Philippines, doubling as marker buoys and FADs.[20] However, since there are a number of options for assisting fishers who are affected by the presence of an MPA, a careful evaluation is required before deciding to spend resources on a FAD programme. In addition, an MPA itself is unlikely to have the resources/capacity/finance to install FADs directly and a better approach may be to work with the fisheries department and other organizations. Finally, if it is decided that FADs represent a good solution to some of the problems facing the MPA, expert advice should be sought at an early stage.[21] Fisheries managers, when considering FAD programmes should also take into consideration the Protected Area Management Categories of Marine Protected Areas by using the International Union for Conservation of Nature (IUCN) guidelines to ensure that there is no conflict with the integrity of the area under management.[22]

FADs provide benefits for livelihoods and food security, but this also comes with responsibilities for management towards long term societal and ecological profit.

Anchored FADs can also set the framework for cooperative management of fisheries between governments and coastal communities and villages including policy development, joint FAD programme planning, rules for FAD usage and FAD ownership, and

[16] Picquel and Blanc 2009
[17] Anon 2012
[18] Good sources of information on safety at sea for small-scale fishers can be found at www.safety-for-fishermen.org/en/ and in the author's opinion, Safety in Small Craft (Scanlon, 2002), a book written for New Zealand boaters, is also an excellent source of information on safety at sea for small boaters.
[19] Anon 2000
[20] Anon 2003
[21] Western Indian Ocean Marine Science Association - Managing Marine Protected Areas: A TOOLKIT for the Western Indian Ocean – No I4. Theme - Fish Aggregating Devices
[22] IUCN Guidelines for applying the Protected Area Management Categories for Marine Protected Areas. https://cmsdata.iucn.org/downloads/iucn_categoriesmpa_eng.pdf

rights based management. FADs can also be an entry point for the organization of fishing cooperatives. In the Galapagos Islands, for example, anchored FADs have been instrumental in the organization of fishing cooperatives and have provided fisheries managers with a way of safe-guarding the very important marine reserve by providing fishers with an alternative to bottom fishing and lobster fishing.[23] The Galapagos National Park FAD programme is an integral component of the fishing cooperatives that operate on the three most populated islands. There are four cooperatives that have shifted their efforts away from beche de mer or sea cucumber collection, bottom fishing, and lobster fishing to offshore anchored FAD fishing. The cooperatives help finance and maintain the FADs.[24]

3.1.5 Code of Conduct for Responsible Fisheries 1995

The FAO Code of Conduct for Responsible Fisheries states that: *"States should, within the framework of coastal area management plans, establish management systems for…fish aggregation devices. Such management systems should require approval for the construction and deployment of such…devices and should take into account the interests of fishers, including artisanal and subsistence fishers."* and *"States should ensure that the authorities responsible for maintaining cartographic records and charts for the purpose of navigation, as well as relevant environmental authorities, are informed prior to the placement or removal of…fish aggregation devices."*[25]

The FAO Technical Guidelines on the Implementation of the Code of Conduct – Fishing Operations[26] clearly states in Article 9.3 under Section 8.10 and 8.11 of the Code of Conduct for Responsible Fisheries that:

"Fish aggregating technology should be further developed to improve the performance of anchored and drifting devices.

The management systems concerning Fish Aggregating Devices (FADs) should set out the responsibility of the competent authority and the users for minimum design standards, operation and maintenance of FADs.

The competent authority should also establish a system of approval for the deployment of FADS and maintain a record of the owners. The record should contain, as a minimum requirement:

a) The mark assigned by the competent authority for the identification of ownership;

b) Name and address of the owner(s);

c) Type of FAD; and

d) Location of allocated geographical position.

The competent authority should ensure that the authorization to fish at FADs includes details of the fishing methods to be used as well as a requirement for reporting catches.

FADs whether drifting or anchored, should carry means to identify their position by day and by night.

The competent authority should also establish a system for the reporting of lost FADs and the retrieval of those considered to be a danger to navigation."

Anchored FAD programmes require clear strategies and planning based on consultative processes with fishers to raise awareness of the importance of data collection, research on the resources in the area, market analysis and participation of fishers in fisheries resource management.

Inadequate planning and preparation and poor research of FAD programmes will result in negative environmental impacts, social conflicts and economic and financial losses. These present real risks and threats to the sustainability and success of all FAD programmes.

[23] Diaz *et al.* 2005, and Chalen 2007
[24] Diaz *et al.* 2005, and Chalen 2007
[25] FAO 1995
[26] FAO 1996 FAO Technical Guidelines for the Implementation of the Code of Conduct for Responsible Fisheries- Fishing Operations – 1 http://www.fao.org/docrep/003/W3591E/W3591E00.HTM

3.2 Risks and threats for and by anchored FAD programmes

3.2.1 Environmental risks

Data and research requirements – There is a serious concern amongst fisheries biologists, fisheries managers and environmentalists that pelagic species that aggregate at FADs can be too easily over exploited. FADs do not increase the quantity of fish, they merely concentrate fish in one localized area, making them easier to catch by both fishers using industrial drifing FADs and by artisanal fishers using anchored FADs. Unfortunately because of the lack of data on the exploitation of fish resources fished around anchored FADs, the levels of exploitation cannot be verified. The Tahiti conference on FADs recognized that there is a need to define minimum requirements to obtain high quality data with an acceptable level of certainty that could be used to establish data and monitoring protocols.

Before embarking on a FAD programme, fisheries managers in charge of the programme should be guaranteed adequate human and financial resources to ensure data gathering and technical, socio-economic and environmental monitoring.

There is also an urgent need to undertake studies on the biology, production levels, and characteristics of FAD fisheries to help determine sustainable catch rates. To accomplish this, fishers need to be involved in the collection of catch and effort data so that fisheries scientists can determine the status of fish stocks and advise fisheries managers on maximum sustainable yields. However, since pelagic species are highly migratory, it would be necessary to integrate wider regional fisheries management and data collection protocols with data from locally anchored FAD systems and programmes.

In general, collection of data from artisanal fisheries presents many challenges, notably these include low literacy levels of fishers in sometimes very remote locations, lack of government resources (human and financial), lack of prioritization of the sub-sector and the sheer millions of fishers in the Southeast Asian region.

3.2.2 Concentration and species re-distribution

One outcome that emerged from the FAD conference in Tahiti in 2011 was that anchored FAD density is one of the most important FAD management issues, because FADs redistribute the fish which aggregate near them, rather than creating more fish. The general consensus was that there were not necessarily more benefits when FADs were anchored close to each other. Actually, high concentrations of FADs can lead to tangling and aggregation interaction or competition between neighbouring FADs. This can occur when the installation of anchored FADs is unplanned and/or unregulated. Over-concentration of FADs in an area is also costly and can lead to loss of overall productivity. The diversity of target species and gear types makes it difficult to determine the optimal number and density of FADs for any given area. In addition, very few studies have been done on redistribution of species around anchored FADs. Conversely, if FAD programmes are under-funded and/or poorly planned, this can result in an insufficient number of FADs. Individual FADs may act as separate units with no overall benefit from a combined aggregation that several FADs can have. The number and density of anchored FADs should be determined by carefully planned studies conducted in a cautionary and truly participatory manner with all stakeholders, and not just by regulation and top-down decision making.[27] One previous study concluded that "under the hypothesis that the local biomass of tuna in the area cannot be increased by immigration of new fishes, if too many FADs are moored in the same place they will enhance the dispersion of the fish and decrease the concentration on any single FAD. The optimal distance between FADs was estimated to be 10 nautical miles".[28] In addition, "if FADs are moored at greater distances from the coast, they might also attract tunas swimming offshore."[29]

FADs that are too close together compete with each other and make the fish more dispersed. Some tunas do not remain permanently around FADs and the number and species will vary according to migratory patterns, sea surface temperature and the proximity of other drifting debris which may attract tunas away from a FAD. Installing FADs too close increases the investment cost of the programme and gives diminishing returns.

[27] Taquet 2011
[28] Cayré 1991
[29] Marsac *et al.* 1996

3.2.3 Sanctuaries and protected areas

Anchored FADs may disturb delicate ecosystems if they are deployed in the wrong places. Obviously, FADs should not be deployed in sanctuaries or reserves and important ecosystems that are vital for endangered, threatened or protected species such as some species of whales and dugongs. However, there may be exceptions to this, for example, where rules governing a reserve may allow a certain number of FADs whose purpose is to divert fishing effort to more resilient species and away from sensitive parts of the reserve. Such is the case in the Galapagos Islands National Park Reserve. The marine reserve in the Galapagos Islands is defined as all waters extending 40 nautical miles from the shoreline of all islands. This encompasses most of the area where small-scale fishers are able to fish and so the reserve, in this case, does not implement a total ban on fishing. All of the anchored FADs in the Galapagos National Park FAD programme are within the reserve.[30] In all cases, all FAD programmes must be monitored and properly managed to ensure the sustainability of the fishery and that conservation principles and rules are respected.

Although anchored FADs for food security target mainly migratory species which are not resident in the protected area but migrate through or near to a protected area or sanctuary, conservation and livelihoods objectives should be carefully defined and considered when installing anchored FADs in or near to sanctuaries and protected areas.

3.2.4 Bycatch and discards

Fishing on artisanal anchored FADs using selective small-scale hook and line fishing methods produces minimal bycatch. Bycatch can best be mitigated by using only hook and line fishing methods and by training anchored FAD users in the proper way to handle and release bycatch species including sharks, turtles and birds if or when they are caught. Circle hooks are the best choice for most FAD fishing techniques with the exception of trolling, which usually uses a J shaped hook. Certain types of nets, poisons, explosives and other destructive practices should not be permitted or used around anchored FADs.

Bycatch management rules should be clearly defined with FAD user groups and applied in all FAD programmes and should be an integral part of the programme planning process.

3.2.5 Marine debris

Anchored FADs that break from their moorings and particularly those with plastic components are a form of marine debris that can pollute beaches and reefs and the open seas.

FADs should be inspected and maintained on a regular basis to avoid loss, ghost fishing and negative impacts on the marine ecology.

FADs have also been identified as one source of abandoned, lost or otherwise discarded fishing gear.[31] The negative impacts of this type of marine debris can be ghost fishing (including special interest species such as sea turtles), alteration of the benthic environment, creating a hazard to navigation, creation of beach litter, introduction of synthetic materials into the marine food web, transporting alien species, and additional clean-up costs.[32] Anchored FADs with global positioning system (GPS) homing devices, though more expensive, can be tracked and recovered if they break loose from their mooring. However, this has to be done in a timely manner before the transmitters stop functioning.

3.2.6 Navigation and shipping

Both anchored FADs and drifting FADs can be a hazard to shipping and boats, particularly at night. FADs should therefore have appropriate lights, radar reflectors, and day marks installed to ensure they can be seen at night and by day. Anchored FADs that have lost their mooring present a serious threat to navigation and can cause loss of life and injury by entangling in the propellers or collision with small vessels, especially at night, if unlit and or unmarked.

30 Diaz *et al.* 2005 and Chalen 2007
31 FAO 2009
32 Macfadyen *et al.* 2009

3.3 Negative economic impacts

Although FADs can bring positive financial and economic benefits, poorly planned programmes can lead to financial and economic losses both for the government and fishers. FADs that have short life spans imply financial losses for the programme and for fishers. Preparation and planning is needed before embarking on a FAD programme to ensure sufficient spare parts and human capacity development, as well as undertaking financial and economic feasibility studies. It is therefore important to undertake a risk assessment before embarking on a FAD programme.

3.3.1 Market access

One of the risks is market saturation – an over-supply of fish which can reduce prices and profitability, and discourage fishers.[33] For example, over a ten-year period after anchored FADs were introduced on Reunion Island tuna prices fell from USD6.50/kg to USD4.50/kg.[34] In areas where the market access is difficult or the local market has limited purchasing power, fishers should give due consideration to the cost of transport, ice, and fishing time to access more lucrative but distant markets. A FAD programme also requires sufficient and reliably available ice, storage and transport boxes or arrangements being made where buyers come to take the fish. If ice is unavailable or the supply is unreliable, then this automatically limits the financial and economic benefits of any FAD programme, regardless of how well the FAD aggregates fish or how skilled the fishers are.

Arrangements for preservation, marketing and processing are important aspects for the success of a FAD programme.

3.3.2 Financial costs

Anchored FAD programmes are expensive – the materials for an anchored spar buoy or Indian Ocean FAD, the running costs for a survey vessel and deployment vessel, and monitoring and maintenance costs – can range from USD2 000 to USD4 000 per FAD. Of course, a FAD made from natural materials, such as a bamboo *payao*, will be less expensive than a spar buoy or Indian Ocean FAD, but the difference may not be so significant because the most expensive component of an anchored FAD is the mooring line, not the raft. Therefore the deeper the water depth, the greater the anchored FAD cost. Other factors that can significantly affect costs are the type of buoy, type of rope or cable used in the mooring, and type and size of anchor.

To cover the costs of conducting FAD site surveys, purchasing FAD materials, and deploying and maintaining anchored FADs, a reliable funding source should be secured. This should be done before a FAD programme is started. Funding can come from governments, fisheries departments, RFMOs, IGOs, NGOs, fishing cooperatives, game fishing clubs, taxes on industrial fish landings, taxes on fishing gear sales, or license fees paid by anchored FAD users.

Continuity and guarantees for the maintenance of FADs are paramount for the sustainability of any FAD programme.

Other important considerations are the cost of purchasing materials to build the FADs and their installation and maintenance costs. If and when FADs are lost, arrangements and money will be needed to replace them. Decisions on who will pay for this have to be taken before implementing a FAD programme otherwise the programme will be unsustainable.

[33] Anderson and Gates 1996 and Sharp 2011
[34] Detolle *et al.* 1998

3.3.3 Conflict between users

In fishing communities, fishers compete for the same resources. Usually when setting up FAD programmes, government agencies consult with fishers on where to install FADs, and seek their participation in the construction, fabrication and maintenance of FADs. However, often not all fishers participate in the consultation. This results in a portion of the fishers actively participating in the process of identifying the best sites to place FADs, constructing and maintaining FADs, and thereby becoming de facto owners. Meanwhile, the non-participating fishers look on from the sidelines. Once FADs are in the water, the non-participating fishers that did not work on them now want to fish around the FADs. This is often a source of conflict. Rights and responsibilities when not clearly negotiated can lead to conflict.

Conflict between users creates anchored FAD losses and in the long term can undermine the benefits from establishing a FAD programme. Conflict can make anchored FAD programmes unsustainable.

Fishers using other methods and gears often see fishing opportunities around FADs and this can be another cause of conflict. Figure 6 shows the purse line of a purse seiner entangled around an anchored FAD.

Figure 6. Purse line of a purse seiner entangled around an anchored FAD.

3.3.4 Lack of legislation and regulations

FADs are installed in what many consider the commons or a public space. Lack of laws and regulations or special provisions in national laws concerning the use, rights and responsibilities of anchored FADs are some of the main reasons for conflicts between fishers. These conflicts exist for both artisanal and industrial anchored FADs. The main dispute is not usually over who owns the FAD, but who owns the aggregated fish. Often these conflicts can lead to violence and to vandalism resulting in the loss of the anchored FAD. There are also implications for who pays to maintain the FAD and to replace deteriorating parts.

Legislation or regulations set the baseline and the framework on which responsibilities and sanctions are based. These should be developed as soon as possible and put into force preferably before the programme is implemented.

Good governance and responsible management of fishery resources requires that policies and a legal framework are in place which address anchored FAD construction, their ownership, their deployment, and rights based use of FADs, as well as the rights and responsibilities for their maintenance and recovery. In addition, the legal framework should also include calculations for the numbers and density, allowable fishing gear and techniques including the use of scuba gear, sports fishing, marking and lights, and notices to mariners. Last but not least, there should be sanctions for not abiding by these regulations. Ideally this should be discussed and agreed with communities and fishers before installing anchored FADs. In cases where anchored FADs are already deployed, efforts should be made to have all replacement anchored FADs regulated in accordance with the stated policies and legislation.

3.3.5 Lack of guidelines

The Tahiti FAD conference recognized that conflicts and interactions between FAD user groups was a significant issue in some areas that needed mitigation by an outside, impartial organization. A wide range of access regulations were identified including preferential access, license or permit requirements, catch limits, territorial use rights, and restrictions on fishing gear types. It was recognized that access issues are complex and need to be addressed at the local level, and cannot be standardized. General guidelines should be developed, to support the development of voluntary domestic codes of conduct for responsible anchored FAD fishing using inputs from all user groups.[35]

When developing legislation and regulations related to FADs, stakeholder consultations should be organized in order to have equitable representation of the different views, including those of women involved in fishing, processing and marketing of fish and fish products originating from anchored FADs.

Prepare and agree rules for the use of anchored FADs in advance of deployment. Ideally these should be developed with the involvement of fishers, processors, vendors and buyers.

3.3.6 Women and gender issues

There is a risk that FAD programme organisers will overlook gender issues. Falsely thinking that, since the main users of anchored FADs are male fishers, the role of women in the production, processing and marketing of fish caught in the FAD fishery can be ignored. Women have great insight into the timing of access to the market and information about the logistics and costs to access the most lucrative opportunities and markets. They can also provide advice on what products and species are most in demand and the price structure of the market. When to catch what, who will buy and how much you can make on which species, is important information that women will bring to an anchored FAD fishery.

Include women in the planning and implementation of FAD programmes.

Figure 7. Woman fish vendor, Sri Lanka.

35 Taquet 2011

3.3.7 Technical risks – longevity

In the 1980s, the average lifespan of an anchored FAD was nine months.[36] Since then several initiatives have been conducted to promote cheaper and longer lasting FADs.[37] The average lifespan of FADs in the Western Indian Ocean had increased to two years by the 1990s, and from 2001 to 2008 anchored FADs were lasting four to eight years in Niue, but longevity is still a recurring problem for anchored FADs.[38,39]

Longevity of an anchored FAD is the secret to long term productivity. Quality should not be compromised because of funding. It is better to have fewer well constructed and longer lasting anchored FADs than many of low quality that may be quickly lost.

Premature loss of anchored FADs in the Maldives has been attributed to mooring rope failure caused by environmental forces, and design flaws like inadequate buoyancy of the FAD raft, inadequate anchor holding capacity, wear and tear or failure of the FAD hardware, accidental propeller entanglement with the mooring line or vandalism.[40] The average lifespan of 103 anchored FADs installed from 1993 to 2008 in the Maldives was approximately 2 years and 1 month (760 days).

The lifespan of an anchored FAD can be significantly increased by using proven designs made with recommended materials, and by carrying out regular monitoring and maintenance. One recommendation from the Tahiti FAD conference in 2011 was that reducing the number of components (shackles and swivels) in the mooring system was likely to increase anchored FAD longevity.[41]

Developing a public awareness programme and a code of conduct for responsible fishing practices around FADs will also likely increase anchored FAD longevity. For example, some FAD programmes do not allow boats to tie up to anchored FADs as this can result in dislodging of the anchor, and fishing may be restricted within a certain minimum radius adjacent to a FAD to avoid damage caused by fishing gear. FAD users should be made aware of such regulations. One solution to theft and vandalism is the sub-surface anchored FAD (see Figure 6) – the buoy of a sub-surface FAD usually lies 25–50 m below the water surface and so is out of reach.

3.3.8 Climate change

When planning anchored FAD programmes today, climate change impacts must be taken into consideration. A risk assessment should be undertaken as part of the planning process in order to assess the vulnerability of FADs to being lost because of extreme weather events triggered by the increased warming of the oceans. The exposure of the proposed area coupled with the extent to which the fishers and the anchored FADs will be exposed will have to be taken into account in the risk assessment. The mitigation for this analysis would be to decide on the strength and robustness of the anchored FAD construction and quality of the components. Some countries in Southeast Asia and elsewhere are more exposed than others to extreme weather events such as cyclones, floods, water spouts and severe storms. In any event, with increasing climate variability in the region, it will be necessary for all countries, even those that have not been hit by cyclones or severe weather events in the recent past, to include a climate risk analysis based on the most up-to-date scientific data and projections. Failure to do this could result in complete loss of installed FADs.

Integrate climate change into the risk assessment when planning anchored FAD programmes.

[36] Boy and Smith 1984
[37] Ben-Yami *et al.* 1989, Higashi 1994, Gates *et al.* 1996, Gates *et al.* 1998, de San and Pages 1998, Holland *et al.* 2000, and Chapman *et al.* 2005
[38] de San and Pages 1998
[39] Sharp 2011
[40] Shainee and Leira 2010
[41] Taquet 2011

4. Conclusions and recommendations

The following conclusions and recommendations of this study should be useful to all persons contemplating the implementation of anchored FAD programmes.

- Anchored FADs are an important tool for small-scale coastal fishing communities to assure their food security and small-scale fisheries livelihoods. Properly planned and implemented anchored FADs programmes which carry out due diligence in identifying risk, conducting adequate research, carrying out consultative stakeholder processes and involvement of fishers in catch and effort monitoring and the formulation of good policies and regulations can bring financial and economic benefits and support sustainable fisheries management.

- However, most FAD programmes are not approached in a holistic manner. If resource management, environmental, socio-economic and technical aspects are not properly taken into consideration then the FAD programme will likely be unsustainable and result in financial and economic losses and possible negative impacts on environmental and aquatic resources.

- Anchored FAD programmes have been insufficiently institutionalized within government fisheries departments with respect to priority, funding and human resources dedicated to the FAD programme. New efforts aimed at assisting small-scale tuna fishers should focus attention on institutionalization of anchored FAD programmes.[42] Other recommended management measures for anchored FAD programmes include: sustained long-term budget allocation, on-going maintenance and replacement, monitoring and evaluation of the technical, socio-economic and environmental impacts of the anchored FAD programme. This is important in order to obtain future funding for the continuation or scaling up of a sustainably managed anchored FAD programme.

- It is important to monitor catch and effort data, and ideally to involve fishers in the process, so as to determine the levels of exploitation around anchored FADs and the impact of anchored FADs on the overall fishery. This data should be analyzed and used for anchored FAD and fisheries management purposes. When there is any doubt over the health of the resources a precautionary approach should be taken and the anchored FAD programme re-analyzed to determine its impact on fishing mortality. Fishing at anchored FADs should therefore be subject to input or output controls. The management system may be rooted in community-based self-regulations, with facilitation support from NGOs and/or academia, or co-management approaches involving resource users and centralized or decentralized government institutions.

- The results of anchored FAD programmes should be documented and reported to regional fishery organizations and the information and knowledge shared between countries, so that there will be better understanding of the use and development of sustainable anchored FAD programmes in the future.

- Industrial and particularly drifting FADs used by purse seiners should not be confused with artisanal anchored FADs that are used primarily as a support to food security and to improve livelihoods. The levels of exploitation, investments and type of fishing gear used and therefore gear selectivity are different for these two types of FADs. With the present controversy related to high seas industrial drifting FADs using tracking devices and sonar, it is important to distinguish between the very different characteristics related to scale of operations, rationale, and justification for industrial drifting FADs and artisanal anchored FADs.

- Governments should prepare the legal framework governing the construction, deployment, use, ownership, rights and responsibilities, sanctions and fines for noncompliance related to different types of FADs in the waters under their jurisdiction.

[42] Gillett 2003

- Before embarking on any anchored FAD programme for artisanal fisheries, it is necessary to undertake a risk assessment of the programme. The risk assessment should take into consideration the technical aspects, climatic change, marketing conditions, possible conflict between users, cost–benefit analysis, technical, biological and socio-economic monitoring, replacement of anchored FADs, maintenance planning and implementation and funding over a continuous period. Public awareness campaigns and consultation are an integral part of the risk assessment process.

- During discussions with fishers and other key stakeholders about a potential anchored FAD programme, a prerequisite for government and/or other support should include agreement that fishers will provide catch and effort data that can be used by fishery managers to make better informed decisions. One important consideration should be to monitor fish sizes and the proportions of tuna/tuna-like species and demersal fish within the catch. This will highlight a) the percentage of immature fish which have been caught before they have had a chance to reproduce and therefore the potential damage to stock recruitment caused by the anchored FADs and b) if the anchored FAD is sited in too shallow water or too close to the coast and is aggregating semi-demersal or coastal fish which are already heavily exploited.

- Training in anchored FAD fishing techniques and in safety at sea should be provided to all anchored FAD users.

- Scuba divers are often required to perform routine anchored FAD maintenance tasks such as replacing or cleaning aggregators, and changing hardware such as shackles, thimbles, and ropes. All divers performing maintenance duties on anchored FADs should be certified with a nationally recognized authority. The scuba equipment used should also be tested and certified according to nationally accepted practice for the equipment type.

Figure 8. A bamboo anchored FAD, Panachais locally managed marine area, Papua New Guinea.

TECHNICAL GUIDANCE ON SITING, CONSTRUCTION, DEPLOYMENT AND MAINTENANCE OF ANCHORED FADS

This annex provides technical guidance on the siting, construction, deployment and maintenance of anchored FADs.

Construction

All anchored FAD designs have the same principal components: an upper mooring, a lower mooring, and a catenary curve in between the upper and lower moorings.

The main cost of an anchored FAD is in the mooring line. Therefore, the deeper the water at the FAD site, the greater the cost. Braided mooring rope is undoubtedly stronger than three-strand rope, and it does not have the propensity to twist like three-strand rope, but it can cost two to three times as much as three-strand rope of the same diameter.

Other factors that can significantly affect anchored FAD cost are the type of buoy and the type and size of anchor. Lights, radar reflectors, electronic devices such as solar panels, GPS homing transmitters, and echo sounders will add to the cost of an anchored FAD buoy.

Figure 9 shows different types of FAD Buoys.

Figure 9. Construction of various FAD types.

Concrete block anchors and rebar grapnel anchors can be expensive to fabricate especially in remote locations where steel and cement are not readily available or have to be transported over great distances or imported. However, abandoned heavy machinery can usually be found and their parts can be used as weights (e.g. forklift counterweights). Anchored FAD costs can be lowered by avoiding spar buoys, by using three-strand rope, and by using heavy abandoned machinery parts for anchors. When using machinery parts, it is necessary to ensure that all oils, fluids and toxic materials are removed and safely disposed of before deployment in the sea.

Mooring rope

When a FAD is anchored, the entire length of mooring or anchor line is usually calculated to be about 120 percent of the depth of water. For example, a FAD deployed in a depth of 1 000 m would have a mooring line of 1 200 m long, i.e. 1 000 m to reach the bottom and the additional 200 m length of mooring line known as scope. The scope is important because it allows the buoy to ride over the waves when there are currents and wave action and ensures that the anchored FAD buoy does not sink below the surface creating additional jerking forces on the mooring line and the connecting hardware. However, when there is no wind or current the additional scope will rise to the surface if the mooring was made entirely of buoyant rope, or would sink to the bottom if it was made entirely of non-buoyant rope. In either case there is a risk of losing the FAD because buoyant rope on the surface can easily be run over and cut by a passing boat, and it would also be easier for vandals or thieves to cut the mooring. Likewise, sinking rope on the bottom would be chaffed by the anchor or rocks and eventually the FAD would be lost. To avoid anchored FAD loss by having too much scope on the surface or on the bottom, the principle of the catenary is applied. Catenary curves for anchored FAD moorings were first tested successfully in Hawaii and were later recommended by the South Pacific Commission for Pacific Island anchored FAD programmes.[43] The catenary curve is shown in Figure 10.

The catenary may be prepared by either using a counterweight as shown in Figure 1 or by using a combination of sinking rope for the upper mooring and buoyant rope for the lower mooring. Counterweight moorings were tested in Hawaii, however, the counterweights tend to become entangled in the mooring rope causing anchored FAD loss.[44]

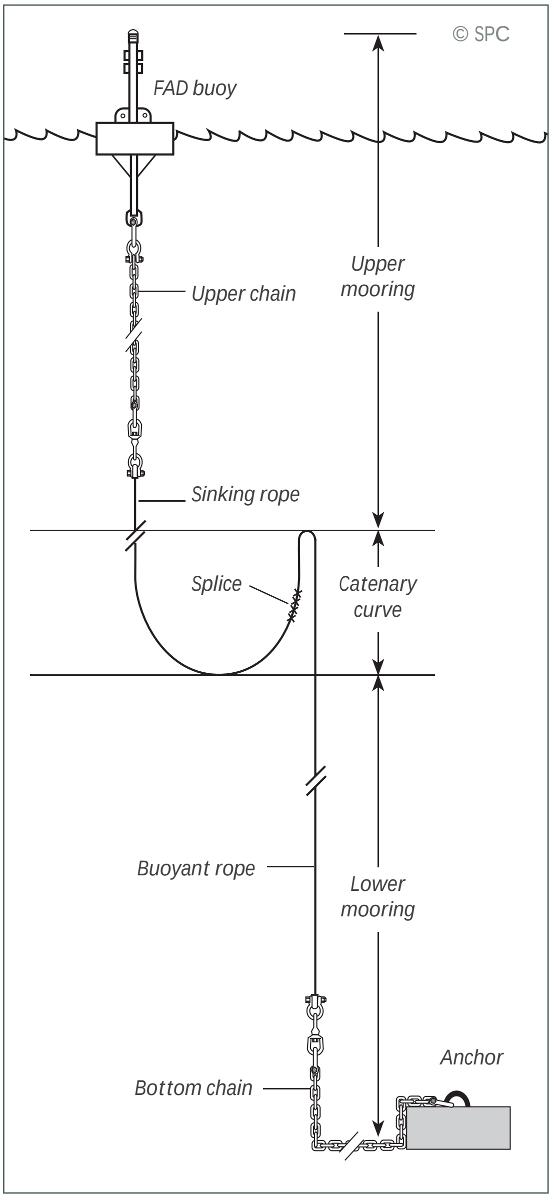

Figure 10. Catenary curve keeping the mooring ropes away from the surface and off the sea bed.

[43] Matsumoto *et al.* 1981, and Boy and Smith 1984
[44] Matsumoto *et al.* 1981, and Boy and Smith 1984

The ratio of sinking rope to buoyant rope in a catenary FAD mooring should generally be greater for shallow FADs than for deep FADs. Table 1 below shows calculated mooring lengths and sinking and buoyant rope lengths for depths from 100 to 1 500 m.

Table 1. Site depths and mooring line lengths for shallow (100 to 800 m) and deep (900 to 1 500 m) water FADs

Site depth (m)	Mooring length (m)	Sinking rope (m)	Buoyant rope (m)
100	120	36	84
200	240	72	168
300	360	108	252
400	480	144	336
500	600	120	420
600	720	216	504
700	840	252	588
800	960	288	672
900	1 080	216	864
1 000	1 200	240	960
1 100	1 320	264	1 056
1 200	1 440	288	1 152
1 300	1 560	312	1 248
1 400	1 680	336	1 344
1 500	1 800	360	1 440

For FAD site depths of less than 1 100 m the buoyant rope generally will not have enough floatation to lift the anchor chain off the bottom. In this case, additional (supplementary) floatation is needed. One or two high pressure buoys can be attached to the buoyant rope somewhere below the catenary to give the lower mooring ample floatation.[45]

Two alternate solutions to the problem of scope are to have a semi-taut mooring with almost no scope or a sub-surface FAD with no scope at all.[46]

In a semi-taut mooring the length of the mooring is slightly longer than the depth of the FAD site. There is scope, but only in the bottom chain. The mooring sits almost straight up and down and the dip of the chain takes the shock of swells and currents. Semi-taut and sub-surface moorings are recommended only for shallow FADs, less than 500 m depth.

Sub-surface FADs have been around for quite a while but have only fairly recently been looked at by artisanal FAD stake holders as an alternative to surface FADs. An American company manufactures what they call McIntosh Kites.[47] These are sub-surface FADs that use monofilament line for the mooring, a hard plastic buoy for lift, and a kite-like device that resembles a hang glider for an aggregator. They are popular with sports fishers and big game fishers. Sub-surface FADs have also been around in Okinawa, Japan for years, but like many Okinawan surface FADs these are big and expensive (Figure 11).[48]

Figure 11. Okinawan subsurface FAD buoy and aggregator.

45 Gates *et al.* 1996, Gates *et al.* 1998, and Chapman *et al.* 2005
46 Boy and Smith 1984, and Chapman *et al.* 2005
47 http://www.reefix.com/mcintoshP2.htm
48 Sokimi 2006

What has been tried more recently in the Pacific is something small and inexpensive, consisting of a string of buoys, a mooring, and an anchor (Figure 12).[49] Sub-surface FADs have some advantages and disadvantages. The biggest advantage is that, because they are well below the surface, they are almost immune to theft, vandalism, rough surface seas, and damage from passing boats and ships. The main disadvantage is that they are difficult to find, especially from a small boat that is not equipped with a GPS or an echo sounder. With a GPS and an echo sounder, however, a sub-surface FAD can usually be found, especially if it has aggregated lots of fish. The fish will show up on the echo sounder. Setting this type of FAD at the correct depth is also a challenge. GPS tracking and detailed sounding of the area is needed to ensure that the length of mooring is correct and that the FAD is not in extremely deep or too shallow water.

FAD buoys usually have some sort of flag, light, or radar reflector or a combination of all so they can be easily spotted by fishers and other mariners. Some are more sophisticated and have solar panels to charge batteries for the lights (Figure 13) and possibly echo sounders that can detect the presence of fish, and sensors to monitor sea surface temperature, and transmit this data to a vessel or land station. Anchored FADs can also be equipped with a locator beacon. In this way, they can be easily found by fishers and by FAD programme maintenance personal that have the corresponding receiver if the FAD breaks loose from its mooring.

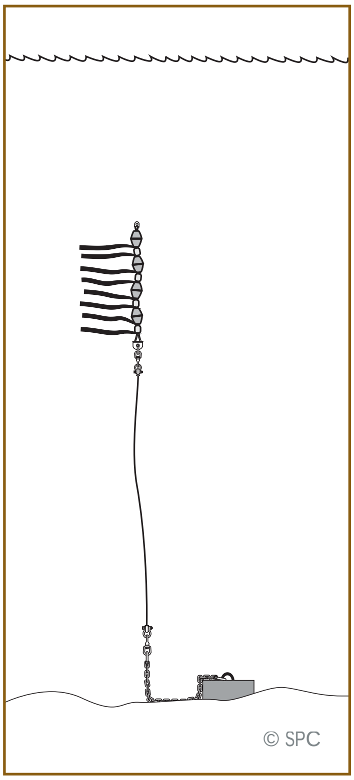

Figure 12. Diagram of an artisanal sub-surface FAD. (top)

Figure 13. Spar buoy with solar panel. (left)

49 Sokimi 2008

Anchor systems

FAD anchors can be concrete blocks (Figure 14), discarded machinery such as forklift counterweights (Figure 15), oil drums filled with steel tyre rims and concrete (Figure 16), or grapnel anchors made from steel pipe and rebar (Figure 17).

Figure 14. Concrete block FAD anchor. (top left)
Figure 15. Forklift counterweight FAD anchor. (top right)
Figure 16. FAD anchors made with concrete filled steel oil drums. (bottom right)
Figure 17. Grapnel FAD anchor being deployed. (bottom left)

Aggregators

FADs often have attachments called aggregators. These can be attached to the buoy or the upper mooring line. Aggregators are frequently made of old rope, discarded fishing net, plastic strapping, plastic mesh, mussel rope – almost any material that will help to aggregate fish by increasing the surface area for marine growth (Figure 18). However, bio-degradable material should be of preference. Using fishing net materials as attractors should be discontinued. When attractors using fishing nets are to be replaced, they should be replaced with ropes of canvas pieces which will avoid the entanglement of marine fauna. In a transition period, fishers may still use netting materials. Fish net materials as attractors should only be used if the mesh size is very small (less than 2.5 cm) and then the sheet of netting should be tightly rolled up and securely tied to form a rope or sausage. However, this measure would not eliminate risks of entanglement, especially if the netting-made rope or sausage becomes unravelled.

Figure 18. Indian Ocean FAD with plastic strapping aggregator.

Ideally natural and biodegradable materials should not be used for FAD construction. In reality, to date, there is no empirical scientific evidence that aggregators are effective.[50] In fact, aggregators may increase drag on a FAD and may decrease a FAD's longevity. One study found that, except for some baitfish species, there was no correlation between the size of the FAD structure and fish abundance.[51] This would seem to indicate that aggregators are not really necessary on an anchored FAD. Some anchored FAD programmes use separate aggregators that are attached to the FAD buoy as an appendage.[52]

Identification of Anchored FAD sites

An anchored FAD should be located at a distance from shore that is not too far for small boats to reach safely, but is also far enough away from the coast, reefs, reserves or whale sanctuaries so as not to interfere with natural fish aggregations. It has been recommended that anchored FADs should be located 4–5 nautical miles (nm) from the shore or reefs and should be positioned 10–12 nm apart, however, this is not always possible or practical.[53] An anchored FAD should be near a centre of fishing activity, where the bottom is not too steep, and the water depth is between 100 and 1 500 m. Marine charts should be consulted to obtain bathymetric and sea current information. Since currents are usually stronger near narrow passes and around points, these areas should be avoided.

Marine departments and shipping companies should be consulted so that shipping lanes, submarine communications cables, underwater pipelines, and any other submarine structures can be avoided. Once appropriate sites are chosen, then a permit to install the anchored FAD(s) should be obtained from the competent authorities and a detailed survey initiated.

Conducting an anchored FAD site survey

To conduct an anchored FAD site survey a suitable vessel equipped with a global positioning system and an echo sounder is necessary.[54] The echo sounder should be capable of sounding depths of at least 2 000 m. Electronic chart plotting of GPS positions integrated with depth are made and stored in the GPS and transferred to a computer and onto a nautical chart. A suitable anchored FAD site should be in a place where the bottom slope is gradual. Steep drop offs should be avoided as FAD anchors may shift into deeper water resulting in the FAD buoy being lost in the deep abyss. On a nautical chart if the isobath curves are close together, then the bottom slope is steep and these places should be avoided. When the isobaths curves are far apart the bottom slope is more gradual. These places make much better locations for anchored FADs.

50 Taquet 2011
51 Rountree 1989
52 Shainee and Leira 2010
53 Gates *et al.* 1998
54 Gates *et al.* 1998

Anchored FAD rigging

Once a FAD site has been chosen the anchored FAD mooring can be rigged. The length of the mooring should be 120 percent of the FAD site depth and the ratio of sinking to buoyant rope should be 30:70 for shallow (nearshore FADs) and 20:80 for deep (offshore FADs) (refer to Table 1). Mooring ropes should be connected using splices and never with knots since they weaken a rope more than splices do. All eye splices for accommodating shackles and swivels should be protected with rope connectors, thimbles, or protective tubing (Figure 19).

Figure 19. Combination rope eye splice with stainless steel thimble and whipping.

Once the mooring is rigged all of the materials can be loaded onto the deployment vessel (Figure 20). For safety it is best to connect the anchor to the mooring only just before deployment of the FAD into the water. The anchor should be tied down securely and separately at the stern of the vessel, so that if it were to come loose and drop overboard, it would not pull the rest of the mooring with it. If the anchor was connected to the mooring and it went overboard prematurely, it would create a very dangerous situation for anyone on deck as the mooring rope would follow the anchor down at great speed. The mooring rope should be flaked out with the anchor end at the bottom, but the bitter end should be accessible so that the anchor can be connected just before deployment. The top end of the mooring should be connected to the anchored FAD buoy. All shackles in the mooring should be safety wired with seizing wire and/or welded so that the shackle pins cannot work loose (Figure 21). Shackles and swivels should be made of low carbon galvanized or stainless steel. However, if the mooring is made with stainless steel cable, the shackles and swivels should also be stainless steel. Stainless steel and galvanized steel are dissimilar metals and should never come in contact with each other in a FAD mooring because electrolysis will take place, resulting in corrosion of the galvanized steel and premature loss of the FAD. Figure 22 shows all of the components of a typical catenary FAD.

Figure 20. Loading an Indian Ocean FAD onto the deployment vessel. (left)
Figure 21. Eye splice in rope connector, shackle, swivel, shackle, and anchor chain. Shackles are welded and secured with seizing wire. (right)

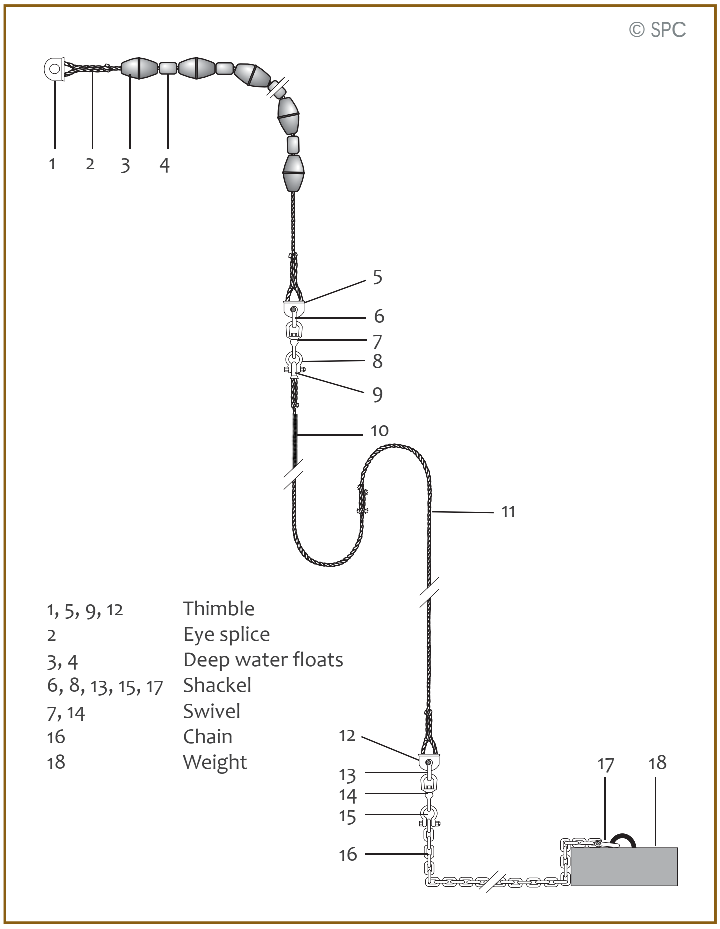

Figure 22. Diagram of a catenary FAD (Indian Ocean) showing all components except the flag.

FAD deployment

The safest way to deploy a FAD is the buoy first method.[55] There is however more than one way to do this. One method is to deploy the buoy at the site and then steam in a big circle, paying the mooring rope out carefully. The circumference of the circle should be equal to the length of the mooring. As the vessel returns to the original site all of the mooring rope should be in the water. Then the anchor is connected to the mooring and deployed.

Another method is the straight line method. The FAD buoy is deployed at a distance away from the actual anchored FAD site equal to ¾ of the length of the mooring. In other words, if the FAD mooring is 1 200 m long then the buoy will be deployed 900 m from the site. The vessel then steams toward the site (going against the current if possible), paying out the mooring rope. It passes over the site continuing to pay out the remaining 300 m of mooring rope. Then the anchor is connected to the mooring rope and deployed. The drag of the mooring and buoy should pull the anchor to the chosen anchored FAD site, much like a pendulum.

In all cases it is very important that crew members stay out of the bight when the mooring line is being deployed. It usually takes five to ten minutes for the anchor to reach the bottom, depending on water depth, and for the anchored FAD buoy to settle in position. The anchored FAD should be observed for at least 30 minutes after deployment to make sure is has settled, and the GPS position should be noted at that time.

Because of the scope of the mooring line, drag on the mooring line and buoy during deployment, and currents, the position the anchored FAD settles in, will rarely be exactly the chosen position. This is another reason to choose a site with a fairly flat bottom.

55 Ben-Yami *et al.* 1989, and Gates *et al.* 1998

If the exact position is missed the FAD won't be lost. After it settles, the buoy can describe a circle whose radius is equal to the short side of a right-angled triangle. This is called the watch circle. Because a FAD is not always in the same exact position it is important to have a flag or radar reflector on the buoy, so that it can be seen from a distance. FADs have often been reported missing but then turn up later, only because their position in the watch circle changed due to current fluctuations. The watch circle can be calculated by using Pythagorean Theorem.[56] In the example given below, solving the problem gives a radius of 663 m. Therefore the FAD buoy could be anywhere inside a 1.25 km² circle at any given time.

Mooring length squared (1 200 x 1 200)	1 440 000
Site depth squared (1 000 x 1 000)	1 000 000
Difference (1 440 000 – 1 000 000)	440 000
Square root of difference	663 m
Area of circle with 663 m radius	1.25 km²

Deployment of heavy weights presents a serious safety challenge for the crew of the deployment vessels and all precautions should be taken to ensure that crew do not get injured. Weather conditions should be monitored and FADs should not be deployed in deteriorating or heavy weather.

FAD maintenance

Monitoring and maintenance are an important component of any anchored FAD programme. Regular inspection trips should be carried out and repairs made when necessary. The lower mooring and anchor are usually out of reach, depending on the depth of the FAD, but the buoy and upper mooring can be reached from the surface. This is also where most damage and wear and tear occurs. The most vulnerable parts of a FAD are the steel components – shackles and swivels. A recent trend in many FAD programmes has been to reduce the number of steel components in a FAD as failure of shackles and swivels is one of the most common causes of premature anchored FAD loss.[57] These should be inspected regularly and changed if there are signs of wear. Divers can do a visual survey of the upper mooring (Figure 23) but to make any changes, the buoy and top end of the upper mooring should be hauled onto the boat. One other reason to have scope in a mooring is so that the upper part of the anchored FAD can be lifted onto the deck of a boat for inspection and repair. This can be done using lift bags or a deck winch. The buoy, flag, radar reflector, and any lights or electronic devices can also be serviced at this time. The rope stringing the buoys together on an Indian ocean FAD should also be inspected for signs of wear and chaffing. Anchored FAD users should be encouraged to report any maintenance problems. Anchored FAD programme budgets should include funds for maintenance and entire replacement of anchored FADs because, sooner or later, all anchored FADs will go missing, unless as should be the case, they are disposed of on land in an environmentally safe manner.

Figure 23. Divers inspecting an Indian Ocean FAD.

[56] Beverly and Cusack 1992
[57] Taquet 2011

Key points to remember when constructing/fabricating anchored FADs:

- Chain is recommended in the upper mooring for anchored spar buoy FADs. It will act as a counterweight to keep the spar upright and will also reduce theft and vandalism;
- Catenary moorings made with nylon and polypropylene are the best choice, but in areas where anchored FADs suffer from frequent theft and vandalism, combination rope (steel core polypropylene) or stainless steel cable can be used in the upper mooring;
- Braided rope is preferred over three strand rope as it does not twist and is stronger than three strand rope of the same diameter but it is more expensive;
- The mooring rope length should be 120 percent of the depth where the FAD is deployed;
- The ratio of sinking rope to buoyant rope should be 30:70 for shallow FADs (100–800 m) and 20:80 for deep FADs (800–1 500 m);
- Supplementary floatation (pressure buoys) should be added to the lower mooring on FADs where the FAD site depth is more than 1 100 m;
- If stainless steel cable is used then stainless steel swivels and shackles should be used too to avoid galvanic corrosion;
- All shackles should be secured with seizing wire and/or welded;
- Steel hardware should be kept to a minimum – one swivel connecting the buoy to the upper mooring and one swivel connecting the lower mooring to the anchor chain should be sufficient. One way to reduce the steel hardware is to splice the mooring lines directly onto the swivels, using PVC tubing to protect the line from chaffing;
- Aggregators are optional. If used they should be made ideally of light weight natural or biodegradable materials by preference – discarded nets and similar materials should be avoided;
- To reduce costs, scrap machinery should be used for anchors; anchors made with scrap machinery and/or grapnel anchors can be deployed from small vessels. This will also reduce costs;
- FADs should always be deployed using the buoy first method; and
- FADs made from natural materials are less durable than to those made from steel and plastics, however, their environmental impact is likely to be less. The choice of anchored FAD materials should be determined by the risk assessment and the technical guidelines provided in annexes 1, 2, 3 and 4 of this publication, rather than by the budget.

CASE STUDY I – NIUE

Sharp (2011) conducted a cost-benefit of Fish Aggregation Devices (FADs) in Niue for the Secretariat of the Pacific Community (SPC) as a tool to facilitate decision making and investment policy for the government and donors. Incremental increases in Catch per Unit of Effort (CPUE) as a result of fishing around FADs were compared against open water fishing. The incremental increase in CPUE was then used to quantify the net increase in the total value of production as a result of FAD fishing and determination of the Return on Investment (RoI) of FADs over time. The study also determined savings in fuel consumed when fishing near FADs against open water fishing. Fuel cost savings were then added to the increased value of production to determine the net economic benefit of FADs in Niue.

The study found that artisanal and commercial fishing targeted the domestic market and was therefore not subject to shocks of the global fish market. Fish was the main protein source in Niue and domestic demand for fresh fish was fairly steady. A total of 13 fishing methods were recorded for the period of 2001 to 2008, with trolling the most commonly practiced fishing method in open water, around offshore anchored FADs (depths greater than 600 m) and around inshore FADs (depths of less than 600 m), with open water trolling practiced on 80 percent of all trips, as fishers troll on the way to the fishing grounds.

Because CPUE differs greatly for different fishing methods, the cost-benefit study conducted by Sharp compared the CPUE of trolling in open water with that of trolling near FADs to ensure consistency in CPUE comparisons. The author highlighted that the value of production around FADs however would be understated because "Other" fishing methods conducted near FADs were omitted from the cost-benefit analysis.

Fourteen different species were recorded between 2001 and 2008. To determine the incremental increase in catch rate from anchored FAD fishing in terms of both number and size of fish, Sharp calculated CPUE by both fish number and weight, i.e. as CPUE (fish/hour) and CPUE (kg/hour) and compared CPUE for open water trolling against the combined CPUE of anchored FAD trolling i.e. offshore and inshore FADs together. With the exception of 2008, greater numbers of fish were caught per hour trolling near offshore than inshore anchored FADs, with both taking more fish per hour than open water trolling.

Average CPUE (kg/hour) for offshore FAD trolling (12.27 kg/hour) was more than 113 percent more than the average for open water trolling (5.74 kg/hour), while the average inshore FAD trolling CPUE was 27 percent higher (7.32 kg/hour) than the average for open water trolling. The combined CPUE (kg/hour) for inshore and offshore anchored FADs was 69 percent higher than for open water trolling.

Sharp used the average incremental increase in CPUE when fishing around anchored FADs to calculate the increased value of production as a result of FADs, at the 2003 effort levels, to compute the cost-benefit of FADs.

The study also pointed out that fishing around FADs reduced fuel consumption because of reduced cruising time, reduced "searching" for fish, and the increased CPUE (number and weight) meant less time was needed to take a target catch.

Sharp showed that the average catch per litre of fuel used fishing at offshore anchored FADs was higher than that when open water trolling, though surprisingly the catch per litre of fuel was lower for inshore FADs than for open water trolling. Relative fuel savings were considered when the cost-benefit of FADs was determined.

Using various assumptions Sharp used the impact of increased CPUE and reduced fuel consumption when fishing around FADs to determine the net financial gain per annum.

Assuming that fishing effort had remained steady at the 2003 level, a net annual increase in total catch and total revenue of 5 417 kg and NZD40 627 respectively was estimated as a result of increased average CPUE from fishing around FADs.[58] Of the total increase, NZD35 875 was attributed to offshore anchored FADs.

In addition, an estimated fuel saving of NZD18 305 per annum was made from fishing at around anchored FADs rather than open sea trolling, with the savings being entirely from the offshore anchored FADs as inshore anchored FADs contributed an estimated increased fuel cost of NZD3 666.

The combined increased CPUE and fuel cost differentia gave an estimated total combined (inshore plus offshore FADs) net gain of NZD58 906 per annum from FADs. These figures may not seem large, but in 2011 Niue only had a total of 1 398 inhabitants.

[58] All figures in the Sharp 2011 Niue FADs review were in New Zealand dollars.

Average total costs for annual inshore and offshore anchored FAD fabrication and deployment were NZD3 405 and NZD4 767 respectively with bi-annual maintenance costs of both FAD types estimated to be approximately NZD700. Assuming that anchored FADs were replaced every two years and that FAD maintenance was conducted once in every two years, the Niue anchored FAD program was financially and economically profitable, at a 5 percent discount rate. Overall government investment in anchored FADs in Niue was a positive investment which was bolstered by the strong returns from the offshore anchored FADs in particular. While inshore anchored FADs had positive financial returns the economic returns were negative, which should influence where the government decided to make investment in anchored FADs.

Sharp considered the estimate of the total financial and economic gains from the Niue anchored FAD programme to be extremely conservative and could perhaps have been doubled because:

i. The submitted fishing log sheets did not represent the entire fishing effort per annum;

ii. Trolling was the only fishing method examined in the study and yet 48 percent of the fish number and 13 percent of the catch weight were caught by other fishing methods, many of which were also conducted near FADs and which represented 20 percent of the time spent fishing; and

iii. anchored FADs provide other benefits e.g. increased fisher safety and reduced cost of fisher rescue as other fishers in the vicinity can rescue a fishing boat in trouble, rather than calling upon government resources.

Sharp gave the following anchored FAD policy recommendations for the Niuean fisheries sector:

i. Encourage the private sector to invest in anchored FAD fabrication, deployment and maintenance;

ii. The government should continue investment in anchored FAD replacement, fabrication, deployment and maintenance up to a maximum investment of NZD109 602 over a two year period;

iii. Continued government promotion and support should be provided for anchored FAD data collection; and

iv. Provide training for fishers on anchored FAD fabrication and deployment, and anchored FAD fishing techniques.

Reference

Sharp, M. (2011). The benefits of fish aggregating devices in the Pacific. In: Fisheries Newsletter Number 135, May–August 2011, p 28–36. Secretariat of the Pacific Community.

CASE STUDY II – SOUTHWEST INDIAN OCEAN[59]

Mauritius has a total land area of 2 200 km^2, and an EEZ of more than 1.6 million km^2 because of outlying islands, but only a limited area of continental shelf. The primary productivity of the surrounding sea is low for the Indian Ocean at only 0.15 g/m^2/day – (FAO/IOP, 1978).

In 1985 the annual fishery production of Mauritius was around 1 600 metric tons, with artisanal fishers fishing in either lagoons or in near-shore waters providing 75 percent of the total. The other 400 t were large pelagics taken by sport anglers, with the fish of choice being blue and black marlin (*Makaira mazara* and *M. indica*). Most of the artisanal catch was taken in the sea by seine and gill nets, while trolling lines and hand lines, basket traps, cast nets and harpoons were also used in the sea and the lagoon. From 1979 to 1987 the total annual catch dropped 17.9 percent from 1 945 to 1 597 t (Albion Fisheries Research Centre) due to overexploitation by over 2 000 fishers. The lagoon catch in particular declined by over 41 percent from 1 340 t to only 785 t over the same period and average catch per fisher per day was in decline. There was, however, a strong demand for fish because of a growing population and the steadily increasing number of tourists.

In 1985 the sea area accessible to fishers was already overfished, aquaculture had not commenced and there were few prospects for fisheries development as the large pelagic resources, including mainly tunas, mahi mahi (*Coryphaena hippurus*), marlins and sharks (*Carcharinus longimanus*) were insufficient for industrial operation, were too far off shore and were inaccessible by most artisanal fishers.

The FAO/UNDP Southwest Indian Ocean Project (SWIOP) (RAF/79/065) piloted the introduction and utilization of anchored fish aggregating devices to make large pelagics accessible to inshore artisanal fishers with the primary aim of diverting fishing effort away from the lagoon and from traditional demersal resources, and additionally to increase the supply of fish on the domestic market. Other secondary objectives were to optimize anchored FAD location, design, materials and deployment techniques, and to determine the most appropriate fishing techniques and catch rates in order to recommend appropriate investment levels, and to promote artisanal fishing around anchored FADs.

The first pioneering attempt to deploy an anchored FAD from a small boat was made in 1983 off the west coast of Mauritius. However, the first anchored FAD was lost during deployment and the second was quickly destroyed by fishers. Thereafter a variety of anchored FAD designs were tested during the project life including floating and anchored designs made with a variety of different materials, durability and cost.

Mauritian conditions include coastal water depths of 880–3 500 m, cyclones, trade winds, and strong tidal currents exceeding 3 knots which exert strong forces on anchors and mooring gear, and caused anchored FADs with insufficient buoyancy to submerge frequently leading to the collapse of floats at depths of greater than 150 m.

Over the project lifetime a total of 16 anchored FADs were deployed and despite losing some quickly at the start of the project, the average lifespan of the 16 anchored FADs deployed was 690 days (though some lasted considerably longer than this) compared to an average reported anchored FAD lifespan at the time of only 267 days. The following design improvements and management practices were identified:

- Indian Ocean style anchored FAD buoys were initially made with two rows of thirty 200 mm diameter pressure floats strung on 35 mm nylon rope with rubber discs between the floats to avoid abrasion. There were two strings of floats to avoid anchored FAD loss if one string broke loose;
- A flag was attached to one end of the buoy with a swivel. The flag was held upright by a chain counterweight that had net aggregators attached to it;
- The upper mooring consisted of 100–200 m of nylon rope. Plastic strapping was attached to the upper mooring to enhance aggregation;
- The lower mooring consisted of 18 mm polypropylene rope and 20 m of 16 mm chain;
- The ratio of site depth to mooring length was between 1:1.1 and 1:1.2;
- For deployment from small boats, scrap steel blocks were preferred to less dense materials like concrete, as this requires three times the weight in air to achieve the same immersed weight. This is particularly important because deploying FADs in rough seas from small boats is a critical and potentially dangerous operation;
- Anchors consisted of several pieces of scrap machinery linked together. Small boats could easily deploy this type of anchor;
- Use of different metallic parts for eye hooks, swivels, anchor chain, wire etc., caused electrolysis, weakening and wear and tear of the mooring gear, leading to premature FAD loss. The metal used for FAD mooring gear should ideally be the same for all fittings and should be galvanized; and,
- Wave movement causes ropes, hardware or floats that are in contact with each other to inevitably wear out. To mitigate against this, over-dimensioned materials and safety shackles should be used, loose steel parts should be welded closed and thimbles should be whipped. All anchored mooring gear should be checked regularly and serviced, and changed as needed.

[59] All figures in the Sharp 2011 Niue FADs review were in New Zealand dollars.

In Mauritius, because artisanal fishers were unaware of the advantages of anchored FAD fishing, the anchored FADs were deployed between 2.5 to 6.3 nm offshore which was where artisanal fishers normally operated. One anchored FAD was, however, later deployed 12 nm offshore. The distances between the anchored FADs varied from 3.9 to 9 nm.

Prey species began to appear in some cases within hours of deploying the anchored FAD and certainly within the first few days after setting a FAD. The number and variety of prey species increased over time, although the abundance fluctuated seasonally. The main identified species were mainly small pelagics including scad (*Decapterus macarellus*), coastal trevally (*Carangoides caeruleopinnatus*) and sardines (*Sardinella* sp.).

The high underwater visibility (26 m) strongly influenced the fishing gears used and how they were fished, as fish were able to see the gear. For the anchored FAD pilot the main gear used by the project boats, artisanal and sports fishers included trolling with artificial lures, dead baits, live baits at the surface and at depth with the best catch rates being obtained at dawn and declining after 09.00 hours, although some fish were caught throughout the day.

Other gear used included Japanese longlines which caught mainly sharks, tunas, mahi mahi, swordfish (*Xiphias gladius*), blue and black marlin, sailfish (*Istiophorus platypterus*) and barracuda (*Sphyraena barracuda*); monofilament longlines baited with fresh dead bait and live bait, with mahi mahi the main catch; hand-lines baited with live bait, which were mainly used by artisanal fishers; and drifting floats with single baited hooks suspended from floats.

All of the anchored FADs were set by government institutions and were considered to be common property. Catches from seven anchored FADs deployed along the west coast of Mauritius were examined over time. Four categories of boats and fishers fished around the seven pilot anchored FADs. These included:

- Two project boats (10 m in length, 120 HP outboard engines with a crew of 3);
- Artisanal boats (6.5–7.5 m in length, 8–15 HP outboard engines and sails and a crew of 2–3) using mainly hand-lining with live or dead baits, and trolling with dead or artificial baits;
- Sports (tourist) boats (10–12 m. with twin 120–135 HP diesel engines, with 2 crew plus paying tourists) which troll fished; and
- 16 part-time (mainly weekend and holiday) fishers who hand-lined.

The most abundant fish caught around the FADs were mahi mahi, yellowfin tuna (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*) and wahoo (*Acanthocybium solandri*). Other important species were sharks, marlins, sailfish, swordfish, albacore (*Thunnus alalunga*) and bigeye tuna (*Thunnus obesus*), barracuda and rainbow runner (*Elagatis bipinnulata*).

Catches increases from 5 kg to 56 kg/boat/day around anchored FADs were reported. Average catch per day for the project vessels, artisanal fishers[60], sports fishers[61] and part-time fishers[62] were estimated to be 35, 40, 35, and 25 kg per day respectively. Tuna accounted for 78 percent by weight (57.3 percent by number) of the artisanal catch, with tuna being caught year round.

The number of fishing trips to the pilot anchored FADs by both artisanal and sport fishers increased significantly between 1986 and 1987, until it stabilized in 1988. During the 647 project fishing boat trips up to 20 artisanal boats were observed regularly around the seven anchored FADs. The switch of artisanal fishers to the anchored FADs was reported to have reduced fishing effort in the lagoons and on the narrow continental shelf. Moreover, fishers were regularly catching fish species around the anchored FADs, which they previously rarely caught.

An estimated 35 sport fishing boats were regularly visiting the anchored FADs off the west coast, while a further 45 were fishing periodically. Additionally 16 part time fishing boats were reported to fish around the anchored FADs at the weekends and on holidays. The production around the seven anchored FADs on the west coast was estimated to be a minimum 333 t per year equivalent to 20 percent of the total national catch, with an average of production of 47.5 t per anchored FAD.

The artisanal fishers preferred fishing at the nearshore anchored FADs while the sport fishing boats preferred visiting the more distant anchored FADs. Big game fishers and sports fishers often caught baitfish at the FADs to be used to fish for marlin and tuna further from the anchored FADs.

Prior to the SWIOP the annual sport fishery landings were estimated at 400 t (MAFNR). During the SWIOP period the number of sport fishery boats increased from 40 to 75, though only 45 of those were considered to be fishing regularly. The authors estimated that as a result of the anchored FADs the total sport fishery landings were 480 t, i.e. an increase of 20 percent.

From the cost of anchored FAD construction and maintenance (USD2 466 and USD221 respectively at the time), the average anchored FAD lifespan and the assumption that anchored FADs were fished every day of the year, the authors estimated that the cost of each anchored FAD represented only 4 percent of the net annual production value of the fish caught by artisanal, sport, and part-time fishers.

Other than the above, however, no other detailed socio-economic analysis of the impact of anchored anchored FADs was conducted. One of the reasons for this was because despite guaranteed confidentiality, fishers systematically refused to provide any detailed catch data, even anonymously.

60 Only 4 skippers submitted logbooks for analysis.
61 Data from 21 sport fishing boat log books.
62 Data from 3 part-time fishers.

CASE STUDY III – COMOROS

This case study summarizes the findings of a study undertaken by Rey-Valettea *et al.* in 2000.

In 2000, a study on anchored FADs was undertaken by Hélène el al in Comoros, La Reunion, and Vanuatu.[63] *"The study used a methodology to assess the diversity and complexity of changes caused by anchored FADs on the one hand and the sustainability of this innovation process on the other. Sustainability includes both ecological and socio-economic".* The study proposed a multi-disciplinary approach at different scales due to the complex issues at play within the anchored FAD fishery. Social, biological, environmental, economic, marketing and technical design aspects were investigated.

The study formulated 23 indicators in order to analyze the evolution of fishing around the anchored FADs. These indicators were grouped around four components, a) Physical and ecological (numbers of anchored FADs, longevity, length of time fish are around the anchored FAD, depth of fishing); b) Catching system; c) Harvesting system and value chain; and d) Management system (resource and conflicts, access, maintenance, participation of fishers).

The study found that the benefits of anchored FADs only became of consequence when they remained in the water without being lost for a sufficient amount of time. In Vanuatu the anchored FADs lasted from 1–33 months, 4–12 months in Martinique, and an average of 14 months for the first generation design to 65 months for the second generations anchored FADs in La Reunion. It is important to note here, that the authors cited La Reunion as being successful because of the scale of engagement of the institutional and organizational arrangements. Anchored FAD loss was a function of the location, material and frequency of use and maintenance.

Aggregation was relatively close to the structure with 77 percent of the catches being within 200 meters of the anchored FAD and 20 percent between 200 and 500 m. The diversity of different species around the anchored FADs also impacted on the overall revenue depending on the market. The effective use of anchored FADs was manifested by the interest of the fishers that fished around the anchored FADs as they probably went there due to the higher likelihood of catching fish. However, this varied according to the presence or number of boats already fishing near the anchored FAD or in some cases climatic conditions.

The increased productivity around anchored FADs caused modifications and changes in fishing techniques which, in the case of La Reunion, increased pelagic fish catches by 340 percent over an eight year period and in Comoros where total production went from 6 000 to 12 000 t during the same period. However, the study reported that seasonality also had impacts and there were reduced catches or increased catches causing flooding of the market with fish and a consequent decrease in fish prices.

With the introduction of anchored FADs there were changes in the fishing operation which in turn affected the marketing system. The operational changes included different fishing times, time spent fishing and the number of trips. As anchored FADs offered greater security, the number of trips also increased. In La Reunion the number of monthly trips doubled. Although there were more trips, the average fuel costs per trip were reduced resulting in financial savings. At the same time, fishing hours decreased as fishers tried to return early to take advantage of better market prices. However, this also varied as some fishers tried to fish several anchored FADs in one day, increasing their range of activities. In some cases increased revenues also led to increased investments and changes in fishing strategies.

The study also noted that market conditions changed rapidly related to the absorption capacity of the market. In La Reunion, the lack of absorption capacity led to decreased prices and eventual disinterest in the anchored FADs by some fishers.

Finally, the study found that technological or fishing success was necessary but not sufficient for long term success of a anchored FAD programme. On the contrary it was the level of adaptation of the fishers and the management systems that were the most critical. From the time that physical, biological, technical and fishery impacts were notable, the management systems became an indispensable condition to relieve institutional constraints, resolve user conflicts, and for the adaptation of traditional laws and access rights. Institutional reliability and commitment was also found to be a key factor for long term success. However, the increase in fishing effort introduced also increased the risk of over fishing, so the integration of new fishing innovations such as anchored FADs requires changes in the structure of the fishery concerned and the sustainable management of such resources. While the study team admitted that more observations would have been better, the study gave an overview of the complexity of the sustainability of anchored FAD programmes.

[63] Rey-Valettea *et al.* 2000

ANCHORED FAD BEST FISHING PRACTICES

Target species – Artisanal fishing on anchored FADs targets tuna and other pelagic fish species including:

- Bigeye tuna (*Thunnus obesus*);
- Yellowfin tuna (*T. albacares*);
- Albacore tuna (*T. alalunga*);
- Skipjack tuna (*Katsuwonus pelamis*);
- Blue marlin (*Makaira mazara*);
- Black marlin (*M. indica*);
- Striped marlin (*Kajikia audax*);
- Sailfish (*Istiophorus platypterus*);
- Wahoo (*Acanthocybium solandri*);
- Mahi mahi (*Coryphaena hippurus*); and
- Rainbow runner (*Elagatis bipinnulata*).

Figure 24. Maintaining the cold chain by using ice slurry.

Fishing methods – The best methods for artisanal and small-scale commercial fishing around FADs are hook and line techniques that target pelagic fish and that require minimum investment in gear and equipment. These include:

- **Trolling** – dragging lures or dead or live fresh baitfish behind a boat – catch is billfish, mahi mahi, wahoo, and small tunas;
- **Vertical longline** – a mainline with several baited branch lines is suspended from fishing buoys and allowed to drift past the FAD – catch is larger, deep dwelling tunas and billfish;
- **Drop stone** – uses a stone and a leaf to sink one baited hook and chum to a desired depth – catch is deep dwelling tunas;
- *Palu ahi* – Hawaiian method similar to drop stone but uses a cloth and a lead weight. *Palu* is chum, *ahi* is tuna;
- *Ika shibi* – a Japanese-Hawaiian method that first catches squid (*ika*) on a handline and then uses the squid to catch tuna (*shibi*) on a handline;
- **Jigging** – a handline with a lure or a baited hook is bobbed up and down near the FAD at various depths, sometimes on a jigging spreader – catch is wahoo and tuna; and
- **Drifting bottle** – a short line with one baited hook is attached to a small buoy or plastic bottle that is then allowed to drift past the FAD – catch is mahi mahi, rainbow runner, and small tuna.[64]

[64] Desurmont 1996, and Preston *et al.* 1998

Fish handling – Whatever the fishing method, it is important to produce fish that are safe to eat and marketable.[65] This can best be done by keeping the fish chilled and the boat and all equipment clean. Fish should be cooled to as near to 0ºC as soon as possible after they are caught. From the boat to home or market, the cold chain should be uninterrupted. The cold chain implies that the core temperature of fresh fish is maintained at about 0ºC from the fish hold, to offloading, to transporting, to home, or to market. The best way to cool fish quickly is to immerse them in a slurry of 2 parts ice and 1 part clean seawater in an insulated fish box. Fish can then be either left in the slurry or packed in flake ice. Keeping fish at +4 to 0ºC will avoid problems such as *histamine* (mainly in tuna), and will make the fish more valuable if they are destined for the market. Fresh fish should be firm to the touch and not have gaff marks or scale loss; eyes should be clear; and gills should be red and have a seaweed smell. Tuna that are going to be sold as sashimi grade fish should be spiked, bled, and gilled and gutted before they are chilled.[66]

Sanitation – All surfaces and tools that come in contact with fish should be rinsed clean of blood and slime with sea water during fishing operations. At the completion of all fishing trips all tools and surfaces should be cleaned with soapy water and sanitized with a mixture of one part household bleach to 20 parts water and then rinsed thoroughly. Regular cleaning and sanitizing will avoid problems such as *salmonella*. Contaminants such as fuel and oil should never be allowed to come into contact with fish.[67]

Figure 25. ***Palu ahi*** **fishing method.**

[67] Beverly 2011
[65] Beverly 2011
[66] Blanc *et al.* 2005

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