The use of anchored FADs in the area served by the Secretariat of the Pacific Community (SPC): regional synthesis

Aymeric Désurmont, Lindsay Chapman
Secretariat of the Pacific Community, BP D5, 98848 Noumea Cedex, New Caledonia
AymericD@spc.int

Abstract

In the area served by the Secretariat of the Pacific Community (SPC), which includes 22 Pacific Island countries and territories, anchored FADs have been used since the late 1970s. First introduced from the Philippines, *via* Hawaii, they were quickly adopted by both industrial and artisanal fisheries sectors: in 1984 more than 600 anchored FADs had been deployed in the region. Since these early days, the development of the technique by the industrial and the artisanal sectors have followed parallel paths with little interaction. In the industrial private sector, companies are funding, deploying and monitoring their own FADs. For some purse seining companies from the Solomon Islands or Papua New Guinea, these FADs have become a necessity. FAD programmes for small-scale fisheries have been almost exclusively run by the public sector, with technical support from regional and international development agencies and financial assistance from overseas funding agencies. These programmes have had mixed successes: becoming an on-going and essential tool in some places like French Polynesia or Guam; or being momentarily suspended, like in Vanuatu or Nauru, because of the lack of funds, partly due to the lack of proven economic return to the fishing communities. This document is an attempt to synthesize the current information on these very diverse situations, including technical, economical and social considerations.

Introduction

The authors of this regional synthesis have endeavoured to pull together as much of the available information on anchored FADs and their use in the Pacific region. This has been a large task as there are 22 Pacific Island countries and territories in the region, and trying to summarise the current status has been difficult due to the great variation in approaches and the availability of documented information. In some cases, anecdotal information has been collected, or the hands-on experiences of the authors and other SPC staff have been drawn upon to present the most up-to-date "picture" of the Pacific situation.

Context and original conditions

The geographical zone concerned

This document is related to the geographical zone served by the Secretariat of the Pacific Community (SPC, formerly the South Pacific Commission) as shown in figure 1. It extends between 23°N and 32°S in latitude and 130°E and 120°W in longitude.

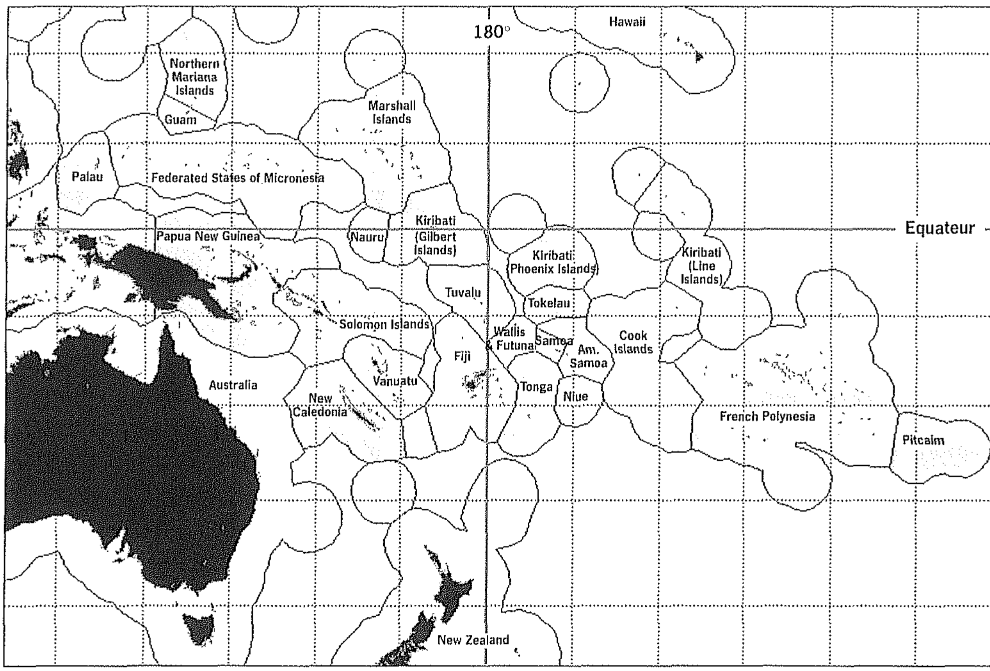


Figure 1
Countries and territories served by SPC (grey areas represent the approximate Exclusive Economic Zones).

It includes 22 States and Territories (tab. 1) spread over more than 30 million square kilometres, of which two per cent only are emerged land. It comprises more than 7,500 islands, but only 500 of them are inhabited. This isolation complicates administration, communication and the provision of basic services. The Pacific Islands are separated into the three sub-regions of Melanesia (west), Polynesia (south-east) and Micronesia (north), based on their ethnic, linguistic and cultural differences. The islands themselves feature great geographical diversity. Papua New Guinea accounts for 83 per cent of the land area, while Nauru, Pitcairn, Tokelau and Tuvalu are each smaller than 30 square kilometres. Some countries or territories, such as Nauru and Niue, are compact and consist of only one island; others, such as French Polynesia and Federated States of Micronesia, include more than a hundred islands, which are distributed over enormous distances. In terms of physical geography and natural resources, the Melanesian countries tend to be large, mountainous and volcanic (with rich soils and exploitable mineral deposits), while the Polynesian and Micronesian islands are smaller: Kiribati, Marshall Islands, Tokelau and Tuvalu consist of low-lying atolls, only one or two metres above sea level. The smaller volcanic islands such as the Cook Islands, parts of the Federated States of Micronesia and French Polynesia, Tonga and Samoa, have some fertile land, but both living and non-living natural resources are mainly confined to the ocean.

Table 1 - Countries and territories served by SPC (population estimate prepared by SPC Demography–Population Programme).

Country/territory	Population estimate (mid-1999)	Land area (km^2)	Pop. density (people/km^2)	EEZ area (km^2)
Melanesia	6 317 102	539 712	12	8 170 000
Fiji	801 543	18 333	44	1 290 000
New Caledonia	212 807	18 576	11	1 740 000
Papua New Guinea	4 692 437	462 243	10	3 120 000
Solomon Islands	421 011	28 370	15	1 340 000
Vanuatu	189 304	12 190	16	680 000
Micronesia	521 158	3 214	162	10 405 000
Federated States of Micronesia	116 414	701	166	2 780 000
Guam	149 643	541	277	218 000
Kiribati	88 558	811	109	3 550 000
Marshall Islands	63 226	181	349	2 131 000
Nauru	11 346	21	540	320 000
Northern Mariana Islands	72 776	471	155	777 000
Palau	19 195	488	39	629 000
Polynesia	604 121	8 133	74	10 750 000
American Samoa	63 329	200	317	390 000
Cook Islands	16 769	237	71	1 830 000
French Polynesia	228 786	3 521	65	5 030 000
Niue	2 040	259	8	390 000
Pitcairn Islands	40	39	1	800 000
Samoa	167 988	2 935	57	120 000
Tokelau	1 500	12	125	290 000
Tonga	99 657	649	154	700 000
Tuvalu	9 637	26	371	900 000
Wallis and Futuna	14 375	255	56	300 000
All Pacific Islands	7 442 381	551 059	14	29 325 000

Development status of fisheries and constraints

Fishing activities in the region cover the whole range from very low-technology coastal subsistence activities to the high-technology oceanic fisheries such as offshore purse seining for tunas. They can be split in three main categories (Adams, 1996):

Oceanic fisheries: fisheries for tropical tuna, which are carried out mainly by distant-water fishing vessels of non-Pacific Island nations, within the Economic Exclusive Zones (EEZs) and of high seas adjacent to Pacific Island nations;

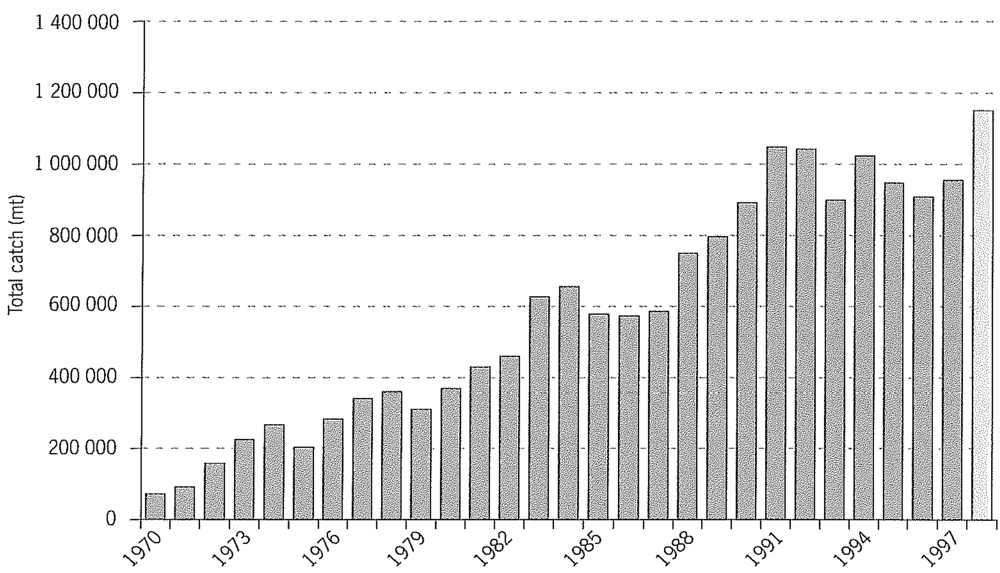
Coastal fisheries for domestic consumption: multi-species, mainly reef and lagoon, fisheries carried out mainly by Pacific Island nationals in the small-scale commercial and artisanal sectors, using hook-and-line, net, spear, traditional trap or weir and hand-collection;

Coastal fisheries for export: a more limited range of species, generally those which are not consumed locally and/or which obtain a high price overseas, are exported, mainly to Chinese-speaking areas of the world.

Oceanic fisheries

Within the SPC area (see fig. 1), this fishery currently catches around one million tons per year whole weight of skipjack tuna *(Katsuwonus pelamis)*, yellowfin tuna *(Thunnus albacares)*, bigeye tuna *(Thunnus obesus)* and albacore tuna *(Thunnus alalunga)* (see fig. 2 for tuna catch trends since 1970) worth around US$ 1.5 billion landed value. Apart from bigeye tuna, for which recent studies have raised some concerns (Hampton *et al.*, 1998; Bigelow *et al.*, 1999), this level of tropical tuna fishing appears to be sustainable. However, Pacific Island vessels are only landing a small portion of this fish (12% in 1997, source: Regional Tuna Fisheries Database maintained by SPC), and these vessels are mainly owned by Governments or foreign investors.

Figure 2
Tuna catch trend in the Pacific Islands region (data source: SPC Oceanic Fisheries Programme; 1998 value is provisional).



Since the early nineties, several Pacific Island countries and territories, (Fiji, Federated States of Micronesia, French Polynesia, New Caledonia, Tonga and Papua New Guinea), have developed domestic fleets of small longliners (16 to 25 m), mostly targeting the fresh sashimi market. One country, Samoa, has developed an incredible fleet of over 250 small longliners (8.5-12 m alia catamarans, fig. 9) targeting albacore tunas for their local market and nearby American Samoa canneries (Mulipola & Fa'asili, 1999). These fleets appear as an intermediate level of development between artisanal and industrial fisheries in the region.

Coastal fisheries for domestic consumption

These fisheries take around 100,000 tons per year, of several hundred species of fish and invertebrates, within the territorial waters of SPC Island member countries and territories (Dalzell et *al.*, 1996). It is very difficult to separate domestic fishery production into commercial and subsistence components, since most Pacific Island fishing communities both consume and sell part of their catch. However, it is estimated that eighty per cent of all coastal fisheries production is used for subsistence (tab. 2). It is important to note that, unlike oceanic fisheries in the region, all of the coastal fisheries production is by Pacific Islanders (Adams *et al.*, 1996) and mainly by poor people. It is thus coastal fisheries that provide the majority of the current benefit derived by Pacific Islanders from fisheries. Most importantly, this benefit is obtained particularly in the smaller islands and rural areas. Fishing is a traditional activity, and is something that is still carried out by the great majority of Pacific Islanders. Unlike people in most developed countries, the majority of Pacific Islanders have a direct stake in coastal fisheries.

Table 2 - Rough estimate of total Pacific Islands coastal annual production (non-tuna) (from Dalzell *et al.*, 1996).

	Subsistence	Commercial	Total
Catch (mt)	80 048	24 610	104 658
Value (US$)	160 323 927	83 353 790*	243 677 346*

* Nominal values.

Coastal fisheries for export

Pacific Island nations do not export many fishery products from their coastal zones, probably less than 10,000 tonnes per year exported weight, within the territorial waters of SPC Island member countries and territories (Dalzell & Adams, 1996). Those that are exported are primarily commodities aimed at specific niche markets. In volume, the most important exports are those of dried sea-cucumbers, (still known as "beche-de-mer" in Melanesia and "*trepang*" in Micronesia) which are mainly consumed by Chinese-speaking people, and of top and mother-of-pearl-shells (*Trochus niloticus, Pinctada margaritifera, Turbo marmoratus,* in decreasing order of volume) used for buttons.

Since the mid-1990s, a live reef fish fishery for food, mostly exporting to the Hong Kong market, has developed in the region (Johannes & Lam, 1999; Sommerville & Pendle, 1999; Yeeting, 1999). However, considering the very high prices offered for live reef food fish and the fragility of the resource, this fishery combines most of the elements leading to overexploitation and will need to be very tightly managed to be sustainable.

The export-oriented deep reef-slope commercial fishery for eteline snappers that started in several countries during the 1980s has given way, in most cases, to small-scale tuna longlining, not because of stock depletion but because of better economic returns.

Although more related to aquaculture than to fishing, black pearls from the blacklip pearl-shell *Pinctada margaritifera*, resulting from the cultivation of primarily wild stocks, are another valuable export product. French Polynesia and the Cook Islands, where dense populations of wild broodstock can be found, have established a very successful black pearl industry (value of black pearl exports from French Polynesia exceeded US$ 140 millions in 1996, see *SPC Pearl Oyster Bulletin*, 12, p. 11), and several other countries in the region are in the process of developing their own.

Where FADs originated: the first types

Anchored FADs were first recorded in Malta, Mediterranean Sea, during the 17th century (de San & Pages, 1998). In Indonesia and the Philippines, fishermen started to use FADs in the early 1900s (Anderson & Gates, 1996). In the Pacific region, anchored FADs have been used since the late 1970s by both industrial and artisanal sectors. Despite a probable common origin, the development of the technique within the two sectors has followed parallel but different paths, with little interaction. Because of this evolution, the information provided in this synthesis will in many cases be presented under the headings of **Industrial sector** and **Artisanal sector**, to show the differences that have occurred over the years.

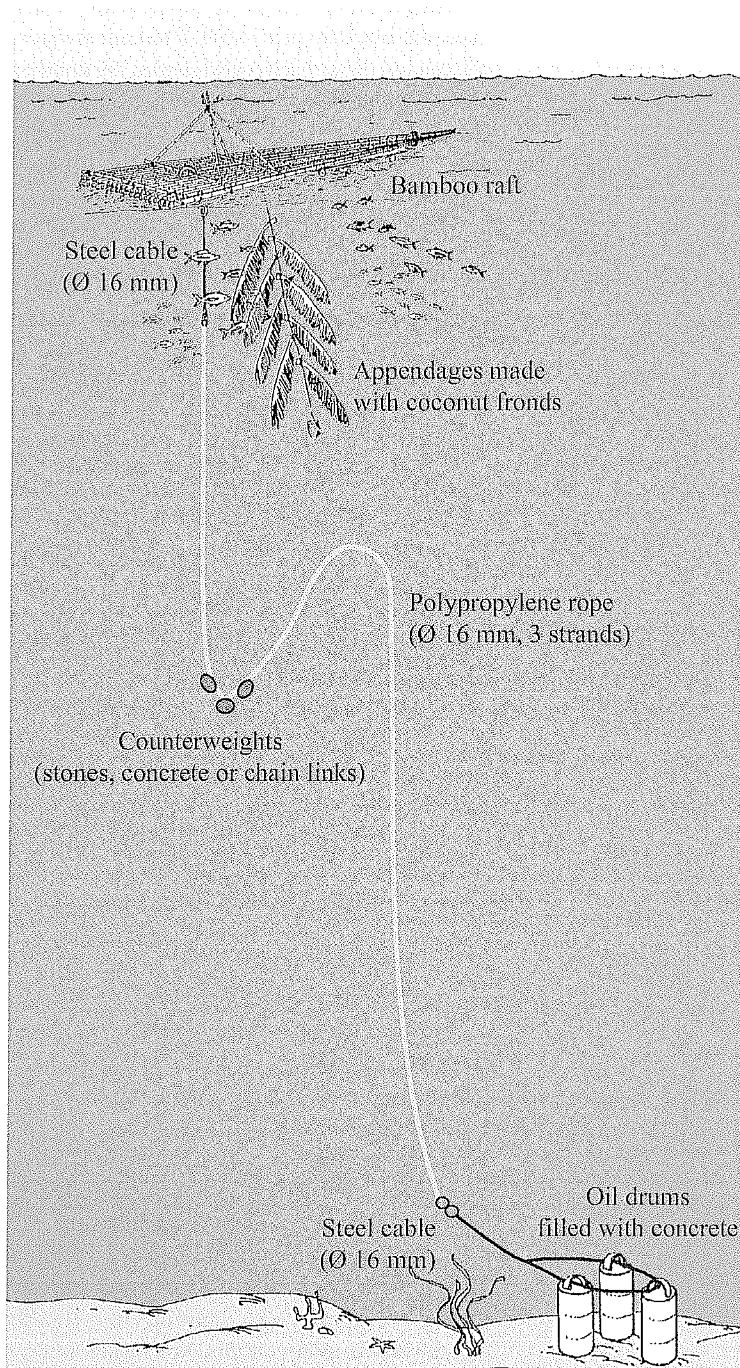
Industrial sector

Anchored FADs used by industrial tuna fishing fleets in the Western Pacific originated from the payao model (fig. 3) used in the mid-1970s by purse seiners in the Philippines (Chikuni, 1978). It consists of a single or double-layered bamboo raft, 2.5 m at one end, tapered at the other and 12 m or more in length, linked to the bottom by a 16 mm, 3 strands, polypropylene rope. Anchors were made of 200 l drums filled with cement and linked to the mooring line by a 16 mm wire cable. To keep the floating polypropylene rope from coming to the surface, counterweights made of cement, chain links or stones were added along the mooring line.

Artisanal sector

Most Pacific Islands countries and territories first heard about FADs during the 1979 SPC Regional Technical Meeting on Fisheries (RTMF), with the presentation of experiments carried out in Hawaii between 1977 and 1979 (Matsumoto *et al.*, 1979). Encouraging results obtained in Hawaii convinced many SPC member countries and territories to start their own experiments. They all used the Hawaiian model (fig. 4) to develop their own systems. Four years later, more than 600 FADs had been deployed in the region, of which 150 were used by the artisanal sector (Boy & Smith, 1984).

Figure 3
The FAD model (payao) introduced from the Philippines in the mid-seventies.



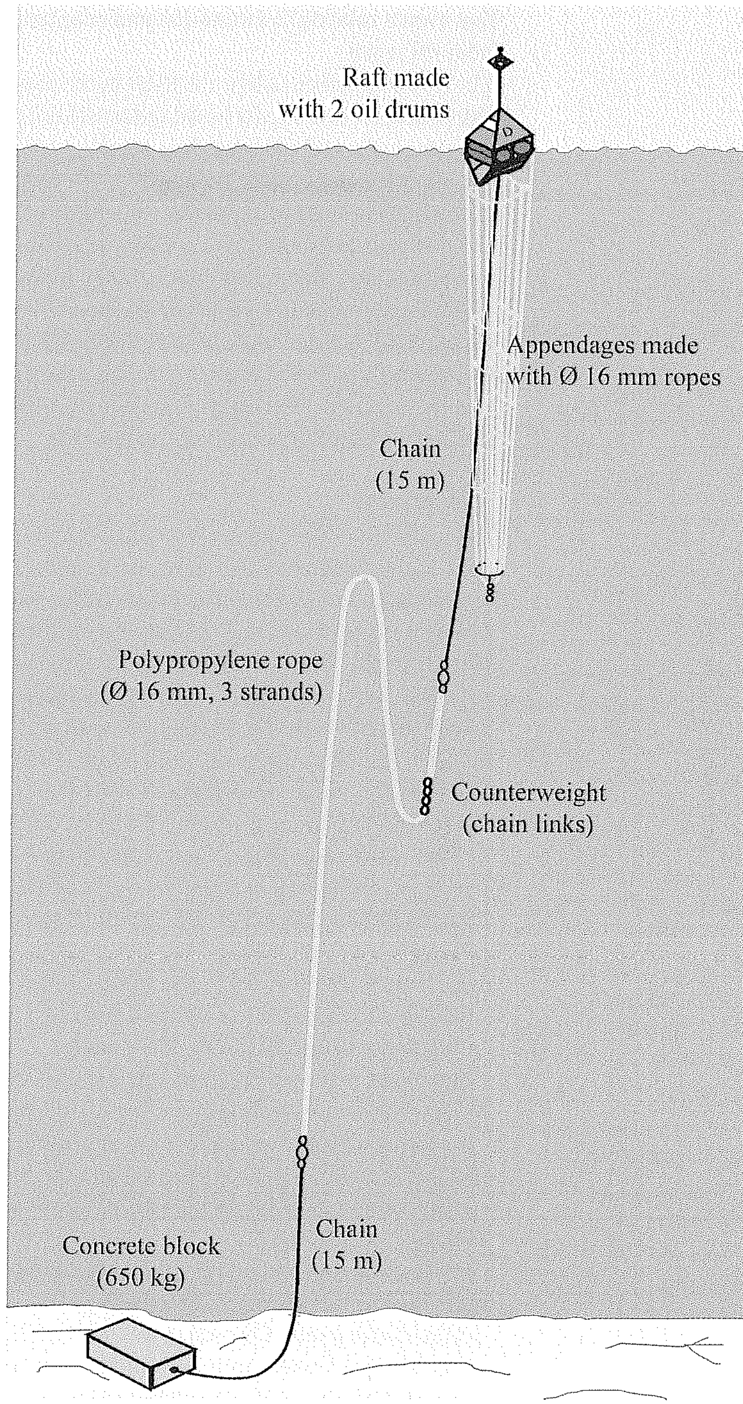


Figure 4
The FAD model developed in Hawaii (from Matsumoto *et al.*, 1979).

Key events relating to innovation and adaptation in the zone

Industrial sector

The first countries to adopt the FADs in the region were Fiji and the Solomon Islands where locally based industrial fishing companies, with fleets of purse seine and pole-and-line vessels, were operating. A few minor changes were made by each company to the original model imported from the Philippines according to the availability of materials (Solomon Taiyo Ltd, in Solomon Islands, is now using stainless-steel cable to link the raft to the mooring line (Sibisopere, 2000). In Papua New Guinea (PNG), where three companies are managing around 700 anchored FADs (Kumoru, in prep.), rafts are made of steel to which bamboos and coconut fronds are attached. In recent years, to prevent other fishing boats from cutting the line, a 100-m steel cable, protected by a PVC tube filled with grease, has been inserted at the top of the mooring.

Artisanal sector

From 1979 to 1984, most SPC countries and territories developed their own systems based on the Hawaiian system. According to availability of materials and engineering possibilities within each country, many different types of rafts and anchors were built with very variable success (Boy & Smith, 1984). However, all used the same type of mooring line, i.e. 13-20 mm polypropylene rope with a counterweight to keep it underwater. In mid-1983 the average lifespan of FAD systems was only six months, and concerns were raised on their costs versus benefits.

In 1983, this situation prompted SPC to undertake a region-wide FAD research and development project which culminated in the publication, in 1984, of the handbook: *Design improvements to Fish Aggregating Devices (FADs) mooring systems in general use in Pacific Island countries*. The authors, Richard Boy and Barney Smith, reviewed the systems used in the region and made recommendations on ways to improve them. The FAD model (fig. 5) they recommended was based on three design criteria:

- working-life expectancy of more than two years;
- unit cost within US$ 3000-4000 range;
- capable of deployment from small vessels (9-18 m).

Main improvements recommended included the use of:

- a catenary-curve mooring line (using sinking Nylon rope in the upper part and floating polypropylene rope in the lower part) to get rid of the counterweight which was a probable cause of line tangling (Preston, 1982);
- non-torque ropes (8 or 12-strand plaited ropes) to avoid kinks when ropes are submitted to extreme loads;
- all hardware made of hot-dip galvanized mild-steel to avoid electrolysis;
- special rope connectors made of plastic (Samson Nylite™) instead of the wire rope thimbles considered to be unsuitable for synthetic ropes.

The new design was progressively adopted throughout the region and by 1989, most countries and territories were reporting longer FAD life expectancy. However, the two-year average lifespan goal was still not achieved and costs in some countries had increased well beyond the limits set.

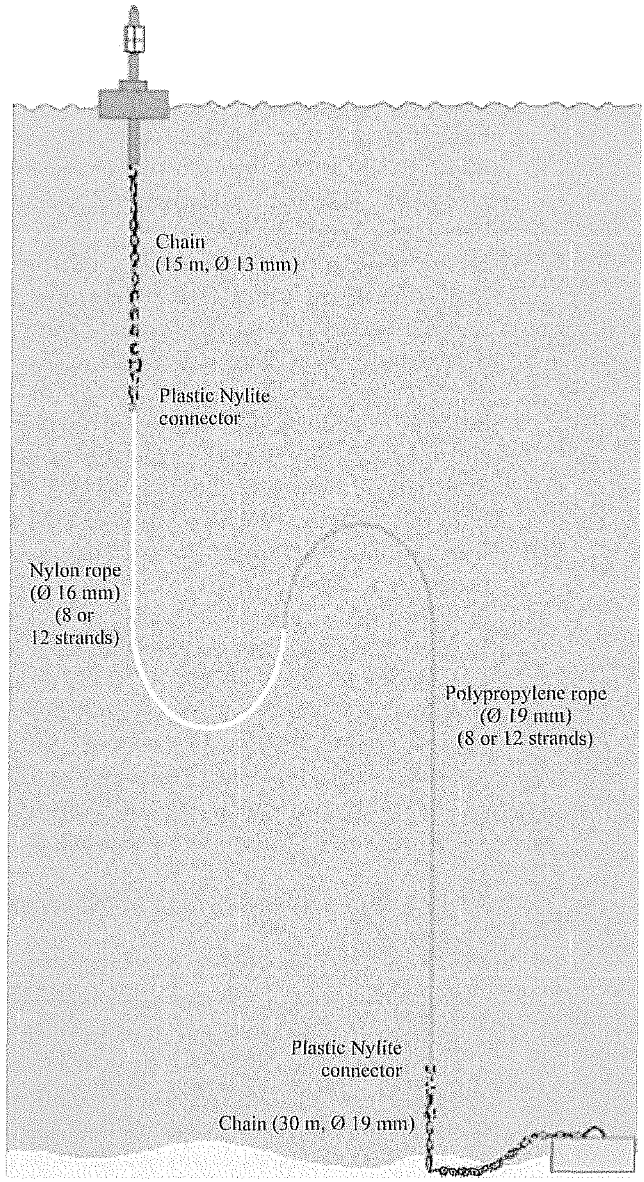


Figure 5
The FAD model developed for SPC by Boy & Smith (1984).

These events led to another phase of FAD development for SPC, which started in 1990. It was aimed at: further improving FAD technology through practical research; establishing standard procedures for all aspects of FAD programmes, from the preliminary planning to the maintenance; and training regional FAD technicians. The programme was finalized between 1996 and 1998 with the publication of the three volumes of the *SPC FAD Manual (Planning FAD programmes* (Anderson & Gates, 1996), *Rigging deep-water FAD moorings* (Gates *et al.*, 1996), and *Deploying and maintaining FAD systems* (Gates *et al.*, 1998).

Dynamics of deployments

Original and revised objectives

Three objectives are common to all FAD programmes, regardless of whether they are for the industrial or the artisanal sector: 1) increase production, 2) reduce operational costs and 3) achieve more consistency in the landings over time.

For the artisanal sector, some of the other objectives set by Fisheries Departments when they develop FAD programmes include: reducing pressure on reef resources, increasing safety at sea and supporting or developing sports fishing activities[1].

Meeting these objectives also implies that the costs of FAD programmes do not exceed the benefits they bring. Therefore, extending life expectancy and limiting costs of FADs can also be considered as two important objectives when setting FAD programmes. However, these objectives have very different values for the industrial and artisanal sectors. For industrial fishing operations, the availability of FAD materials is not a problem and replacing lost FADs is done easily by the companies' boats. Therefore inexpensive FADs which last a single season are acceptable. In contrast, for the artisanal sector, FADs are almost always paid for, built and deployed by the public sector. Every action has to be planned well in advance: budgets, if any, have limited flexibility, materials may be hard to obtain, boats used to set and maintain FADs are not always available, so FAD lifespan is the paramount objective. As stated earlier, an average lifespan of more than two years is an objective that has been set by most Pacific Island FAD programmes.

Achievements, adaptations, constraints and difficulties

Industrial sector

The use of anchored FADs in the industrial sector is limited to the two countries that have active home-based industrial fishing companies: Papua New Guinea (~700 FADs) and Solomon Islands (~200 FADs). Little data is available to assess the exact benefits brought by anchored FADs to these fishing companies, but all are recognized to be heavily dependant on these FADs to survive. Solomon Taiyo Ltd, a private company based in the Solomon Islands, estimates that 90% of its purse seiners' catch and 60 to 70% of its pole-and-liners' catch come from fishing around anchored FADs (Sibisopere, 2000).

The companies place anchored FADs in relative proximity to their base. In Solomon Islands, FADs can be placed in territorial waters (within 12 miles of land), in Papua New Guinea, they must be anchored outside of the 12-mile zone, but within archipelagic waters. Until now, the number of FADs set and the distance between FADs are more related to economic

1. The "political" objective is another important one when studying reasons for FAD deployments in the Pacific. Setting a FAD close to a village is a good way to show that something is done for the village. It would probably be interesting to analyse the number of FADs put in place in relation to the proximity of elections; however, it would be hard to put an exact figure on the benefits obtained.

constraints than government regulations, even if there are plans, both in PNG and the Solomon Islands, to put such regulations in place. Distance between FADs varies from 4 to 20 miles. When FADs are placed close together, boats have less distance to travel and are able to check more FADs in one day. But, schools from different FADs can easily mix, which could be a problem if undersized fish from one FAD mix with bigger-sized fish from another FAD. On the other hand, some purse seiners are now associated with several light-boats that gather fish from different selected FADs with appropriate sized fish, to create one school big enough for a set. This is only possible when FADs are not too far apart.

In PNG, three other criteria are used to choose FAD locations: "shallow" depths (to minimize the cost of the mooring line), little current (strong currents put strain on the FAD, are believed to decrease its fish retention rate and make it difficult to set the net) and "low" (<30°C) sea surface temperature, (which means shallow thermocline and easier catches; Kumoru, in prep.).

Another constraint comes from other fishing boats cutting the FAD mooring lines or setting around the FADs with no care, since they are not the owners of the FADs. Some companies in PNG are now using 100 m of cable at the top of the mooring line as prevention.

Artisanal sector

FADs have been deployed in all Pacific Island countries and territories served by SPC, except Pitcairn. If increasing production is the only benchmark used to measure success, it can be considered that all FAD programmes have been successful, as there is no report of a place where FADs "did not work". However, three categories can be set to evaluate, in more detail, achievements in the region:

- places where FADs have contributed significantly and consistently to fish landings from the artisanal sector (e.g. French Polynesia, Guam, Cook Islands or Niue);
- places where FADs have contributed intermittently to fish landings (e.g. Samoa, Nauru or Vanuatu).
- places where the contribution of FADs to fish landings has been minimal (e.g. New Caledonia, Solomon Islands, Papua New Guinea, Kiribati or the Marshall Islands).

Some constraints and difficulties are common to all FAD programmes in the Pacific. The main one, that has hampered FAD programmes since the beginning despite progress made in design and construction, is the premature loss of FADs due to: adverse weather (cyclones), human intervention (deep fishing lines tangling and severing the mooring, vandalism), fishbite, line break by vessels, etc. Considerable efforts have been deployed to address these problems, but the two-year lifespan set as an objective by most FAD programmes in the region has never been reached. It is interesting to note here that, until very recently, FAD programmes in the region have used exclusively "heavy" FADs (with mooring lines in the 16-24 mm range), following the rather expensive path

set by SPC: "make it strong so it will last". The other path, followed in part by the industrial sector, "make it cheap, because it won't last", has almost never been followed in the artisanal sector.
Some examples of achievements, constraints and difficulties encountered in each of the three categories are given below.

Places where FADs have contributed significantly and consistently to fish landings

These are limited to four places in the Pacific, French Polynesia (mainly in the Society Islands), Guam, Cook Islands (mainly in Rarotonga) and Niue, where coastal resources are limited and artisanal fishermen have to rely on oceanic resources.
In French Polynesia, 236 FADs have been set between 1981 and 1997, but most of the programme (70% of FADs set) has been concentrated on the Leeward and Windward Islands where 20 FADs are now permanently kept on station (Leproux, 1998). Interestingly, the main difficulty encountered by this FAD programme is somehow related to its success, since the number of premature FAD losses has been directly correlated with the number of fishermen visiting the FADs. The main fishing technique used around FADs is the midwater drop-stone technique and damage by fishing lines has been reported as the main cause of premature FAD losses. To try to solve this problem, costly protective sheeting has been added to the top 200 m of the FAD mooring line but the effectiveness of this measure is still questioned. This problem is common to all places where midwater fishing techniques have been developed.
In Guam, after experimental trials in the early 1980s, the FAD programme really started in the early 1990s. Following the Coast Guards regulating the authorized number of FAD locations, it has grown from maintaining 4 to 16 FADs on station (DAWR, 1998). Apart from this limitation on the number of FADs that can be maintained on station, the programme has also been constrained to use expensive steel buoys able to carry a radar-reflector and a flashing light for safety of navigation purposes.
On the island of Rarotonga, Cook Islands, the Ministry of Marine Resources has maintained almost permanently a minimum of two FADs on station despite the difficulties encountered in securing overseas aid funds for its FAD programme.
On the tiny island of Niue, there is no lagoon and the fringing reef is extremely narrow. During the last ten years, four to eight "inshore" FADs (± 300 m from shore) have been kept on station for canoe fishermen. The fish caught around these FADs (mostly baitfish but also tuna and "mahi-mahi") is used for home-consumption. One "offshore" FAD (± 2 miles from shore) is also set for a few professional fishermen and the two game fishing operators.

Places where FADS have contributed intermittently to fish landings

Several other places in the Pacific also rely on oceanic resources to complement relatively limited coastal resources. But several constraints, including availability of funds and limited markets, have affected their FAD programmes. When the local economies are not strong enough to support a FAD programme, funding has to be found overseas through aid agencies or bilateral agreements. This type of funding is almost always associated with projects well defined in time (usually 3-5 year projects) and many FAD projects have been interrupted while new funds were looked for.

In Samoa, for example, FAD programmes have been funded through overseas aid funds and were interrupted several times. Nevertheless, FADs have contributed to the development of an important artisanal fishery. Using small, outboard-powered aluminium catamarans ("alias"), Samoan fishermen have gone from deep-bottom fishing for snapper, to FAD fishing for skipjack and small yellowfin tuna, and finally to tuna horizontal longlining, using manually powered longline drums. In 1998, a fleet of 250 of these small-scale longliners have landed more than 7,000 t of tuna (Mulipola & Fa'asili, 1999). Since 1995, the FAD programme has stopped, mainly because of the lack of funds, but also because the fishermen using horizontal tuna longlines did not need FADs anymore. In 1999, the Samoan Fisheries Department has started a new FAD programme aimed at smaller-scale fishermen who are not able to make the initial investment needed to enter the longline fishery.

In Port-Vila, Vanuatu, small-scale fishing operations, using trolling techniques, rely on the FADs set by the Fisheries Department. When the programme was interrupted in 1997, partly because of the lack of funds, most operations stopped, but one was kept active by its manager who decided to finance and set his own FADs (a light model developed from the Martinique-type FAD; Chapman, 1997, René Laurent, pers. comm.). In addition, the charter and sport fishing operators in Port-Vila are now also assisting with financing FADs for their fishing operations.

In the small island of Nauru, FADs, when in place, have contributed significantly to fish landings; prices of fish climb when no FADs are on station. However, FAD programmes, partly because of inconstant funding, have not really contributed to the development of the artisanal sector. When no FADs are on station, artisanal fishermen switch to other techniques.

Places where the contribution of FADS to fish landings has been minimal

In some places like New Caledonia, Papua New Guinea or Solomon Islands, coastal resources are still plentiful. Fishing in coastal waters is easier and usually requires less initial investment than fishing around FADs. Therefore, the need for FADs is marginal and FAD programmes have been run, when funds were available, more on an experimental basis. However, close to urban centres where too many fishermen may be competing for the same coastal resources, FADs have sometimes contributed to the development of small fisheries. In the early 1990s, a FAD was set to the west of Port Moresby, Papua New Guinea, specifically to assist the fishermen of Daugo Island (Fisherman's Island; Beverly &

Cusack, 1993). At this location, around 50 small boats and canoes fished the lagoon, reef and offshore waters. The setting of this FAD greatly assisted the fishermen of this island to increase their catches, with much of the catch landed at Port Moresby's Koki Market for sale.

Appraisal of operations

Use, ecological impact, fishing operation and species composition

The Pacific experience with the effectiveness of FADs has been very positive. All countries and territories in the region have reported that the FADs they have deployed attract fish, although the level of use changes from location to location.

Industrial sector

As has already been stated, the two industrial fishing methods used in the Pacific around FADs are purse seining and pole-and-line. Both methods target surface schools of skipjack tuna and mainly juvenile yellowfin tuna, which often swim together in mixed schools. Some juvenile bigeye tuna are also mixed in the schools at times, plus a range of other by-catch species.

When purse seining a tuna school associated with a moored FAD, a light-dinghy (small vessel with underwater light and generator) is attached to the FAD raft during the late afternoon or night. Before dawn, the raft is detached from the FAD mooring so that the raft and light-dinghy drift away from the mooring, taking the attracted fish with them. Before day-break, the purse seine net is set around the raft and light dinghy encircling the tuna school. As soon as the net is set and the purse seiner has retrieved the first end of the net, the purse line is hauled to close off the bottom of the net, thus closing off any escape for the encircled tuna school.

Many purse seine skippers believe that the baitfish that have congregated around the FAD raft assist in the attraction of tunas, so they make an effort to release as many of these species as possible. In many cases, when pursing is complete and before the net hauling commences, the main boom is lowered on the net side, so that a gap forms between the vessel and the end of the net through which the FAD raft can be slowly towed, allowing the bait, at least in part, to escape (Bailey *et al.*, 1996). The FAD raft is then slowly towed back to the mooring where it is re-attached.

This method takes all fish that have been attracted under the FAD and encircled in the net, including larger yellowfin tuna and a range of by-catch species, including sharks (several species), marlins (several species), rainbow runner *(Elagatis bipinnulata)*, "mahi-mahi" *(Coryphaena hippurus)*, wahoo *(Acanthocybium solandri)*, mackerel scad *(Decapterus macarellus)*, and oceanic triggerfish *(Canthidermis maculatus)*.

There is limited data available for the complete species composition list or the numbers and weights of each species taken from moored FAD sets by purse seining. Therefore the following information is provided from

Lawson (1997) as a guide or indication of what could be expected from moored FADs sets, based on purse seine log sets (drifting FADs) in the Western and Central Pacific (WCP) tuna fishery. Overall the by-catch, as identified by observer data, is estimated at 3.0 to 7.3 per cent of the total catch by weight for log sets. A summary of the preliminary estimates of annual catch taken by the American, Japanese, Korean and Taiwanese purse seine fleets is provided in table 3.

Table 3 - Preliminary estimates of annual catches (metric tons) by the American, Japanese, Korean and Taiwanese purse seine fleets in the SPC statistical area for log sets (adapted from Lawson, 1997).

Species	Catch (mt)	Percentage of catch
Skipjack tuna (*Katsuwonus pelamis*)	228 048	64,32
Yellowfin tuna (*Thunnus albacares*)	103 472	29,19
Bigeye tuna (*Thunnus obesus*)	19 800	5,58
Rainbow runner (*Elagatis bipinnulata*)	1 118	0,32
Sharks (mainly *Carcharhinus* species)	548	0,15
Mackerel scad (*Decapterus* spp.)	325	0,09
Oceanic triggerfish (*Canthidermis maculatus*)	296	0,08
Other mackerels (unidentified, possibly *Decapterus* spp.)	284	0,08
Mahi-mahi (*Coryphaena hippurus*)	183	0,05
Black marlin (*Makaira indica*)	145	0,04
Blue marlin (*Makaira mazara*)	99	0,03
Bullet tuna (*Auxis rochei*)	72	0,02
Barracudas (*Sphyraena* spp.)	50	0,01
Wahoo (*Acanthocybium solandri*)	25	0,01
Pacific rudderfish (*Psenopsis anomala*)	17	0,00
Fish (unidentified species)	15	0,00
Whale shark (*Rhincodon typus*)	9	0,00
Manta rays (*Mobula japonica, Manta* spp.)	5	0,00
Ocean sunfish (*Mola mola*)	4	0,00
Frigate tuna (*Auxis thazard*)	2	0,00
Sailfish (*Istiophorus platypterus*)	2	0,00
Broadbill swordfish (*Xiphias gladius*)	2	0,00
Trevallies (unidentified *Caranx* spp.)	2	0,00
Pelagic stingray (*Dasyatis* sp.)	1	0,00
Total	354 524	99,97

Bailey *et al.* (1996) indicate that there is a slightly higher by-catch rate for purse seining catches from moored FADs compared to log sets. This is attributed to the fact that moored FADs are located close to islands and land masses, where by-catch species may be more abundant. In addition, moored FADs are not fished as consistently as logs, thus allowing a possible build-up of by-catch species.

There is strong evidence of stratification of the baitfish and tunas, with the baitfish staying in the upper water column closely associated to the

FAD and the tunas aggregated below. Skipjack tuna tend to aggregate in the upper 20-40 m, with yellowfin tuna further below and bigeye below 110 m (Bailey *et al.*, 1996).

For pole-and-line fishing around moored FADs, the target species are the same as for purse seining (skipjack tuna, juvenile yellowfin tuna with small numbers of bigeye tuna). The fishing operation is simple, the pole vessel approaches the FAD and throws small live baitfish to attract the surface-schooling tunas to the boat. Water is sprayed from the side of the vessel into the water to break the visual outline of the vessel and to simulate baitfish on the surface. Fishermen then use a pole with a short line (less than the length of the pole) and a barbless lure to attract and catch the fish, swinging or "poling" them on board.

By-catch from poling is restricted to larger fish (>1.0 kg) and not bait species, that can be caught on the barbless lures used in this fishing operation. Poling is also a very selective method so that if unwanted by-catch species are caught, they can be released alive or the fishing operation can be ceased to restrict the numbers caught. In the Solomon Islands for instance, only rainbow runner and island bonito *(Auxis thazard)* are retained as by-catch by the pole-fleet for local sale.

Artisanal sector

The artisanal fishery around moored FADs is very different to the industrial fishery. Artisanal fishing methods include trolling, handlining, midwater handlining, vertical longlines and single-hook drift lines. These fishing techniques are employed from a range of vessel types, from traditional canoes to outboard-powered dinghies and catamarans to diesel-powered dories and skiffs. The main species targeted by these methods are skipjack tuna, yellowfin tuna and "mahi-mahi", although other species like rainbow runner and albacore tuna *(Thunnus alalunga)* are also taken.

The placement of FADs for artisanal fishing influences the species that are attracted. For example, inshore FADs may be set to attract mainly bait species (mackerel scad and bigeye scad, *Selar crumenophthalmus*) that can be caught for eating or for use as bait for other fishing methods. Inshore FADs are generally located within 500 m of the coast or reef, which is the case in Niue where these FADs are specifically set for canoe fishermen (around 300 m offshore), so they can paddle out and fish relatively close to the island. Canoe fishing around these inshore FADs is mainly done with light handlines near the surface, heavier handlines in midwater, with some surface trolling. Similarly in Nauru, the large ocean mooring buoys for the phosphate vessels act as FADs close to shore with many fishermen working around them for bait species as well as tunas in midwater (Chapman *et al.*, 1998).

The more offshore FADs tend to concentrate some baitfish, although the main aggregations are tunas and other larger pelagics ("mahi-mahi", wahoo, rainbow runner, etc.). Trolling the surface schools of tunas is the most common fishing method employed throughout the Pacific, especially at first and last light (believed to be the main feeding and aggregating time around the FADs). The size of the tunas caught is generally less than 10 kilogrammes. Traditional trolling or Polynesian pole-trolling use pearl-shell lures attached to a long bamboo pole *via* a length on line. This has given way to the more modern rod-and-reel or rigid trolling lines using monofilament Nylon, synthetic or vynal lures and metal hooks. A description of different trolling techniques used in the Pacific, including FAD trolling, can be found in Preston *et al.* (1987).

Midwater fishing techniques as described in Moarii & Leproux (1996), Preston *et al.* (1998), or Chapman (2000) are mainly used in the Polynesian countries in the region (French Polynesia, Cook Islands, Tuvalu, Kiribati, Niue and Tokelau). These methods target the larger tunas (over 10 kg) that aggregate at depth around many moored FADs and traditional "tuna holes". The traditional drop-stone method uses a monofilament handline and baited hook. The baited hook and some chum are bound to a flat stone with the monofilament handline and secured with a slipknot. The stone is then dropped over and allowed to sink to the desired depth where the line is held and jerked to release the slipknot. The stone then unwraps from the line and sinks to the bottom, leaving the baited hook and chum at the desired fishing depth. A Hawaiian version of this method called "palu-ahi" is also used. This method replaces the stone with a lead weight and cloth which remains attached to the line, with the gear used in a similar manner to the drop-stone method (Chapman, 2000).

Vertical longlining is also used around moored FADs to fish for the larger tunas in the water column by presenting baited hooks at a range of depths (usually 10-20 m apart) from the surface to depths of over 400 metres. Using this and other midwater techniques does not result in large numbers of fish being caught, although the weight per fish usually makes up for the lower numbers taken. Again, these methods are very selective and apart from sharks, all fish taken can be sold or eaten locally.

These fishing methods, especially trolling, are also used by recreational fishermen, sport fishermen and charter fishing operations around moored FADs. These sectors are growing as more people have money to purchase vessels for fishing, and FADs provide a logical place to go to maximize the chance of catching fish.

Boat type, fleet size, technology impact, and vessel operation

Industrial sector

The purse seine fleet that operated in the statistical area of the SPC in 1998 consisted of 152 distant water vessels from five countries (America, Taiwan, Japan, Korea and the Philippines), with an additional 30 vessels locally-based from five (Papua New Guinea, Federated States of Micronesia, Vanuatu, Solomon Islands and Kiribati) of the 16 member countries of the Forum Fisheries Agency (FFA). It is estimated that the total purse seine catch of tuna landed from the WCP was 886,500 mt in 1998 (Cartwright, 1999). From the purse seine catch in 1998, provisional estimate show that 363,390 t came from log sets, 120,051 t from drifting FAD sets, and 33,259 t came from moored FAD sets. Figure 6 presents the estimated annual purse seine catch in the WCP for log, drifting FAD, and moored FAD sets (source: SPC database).

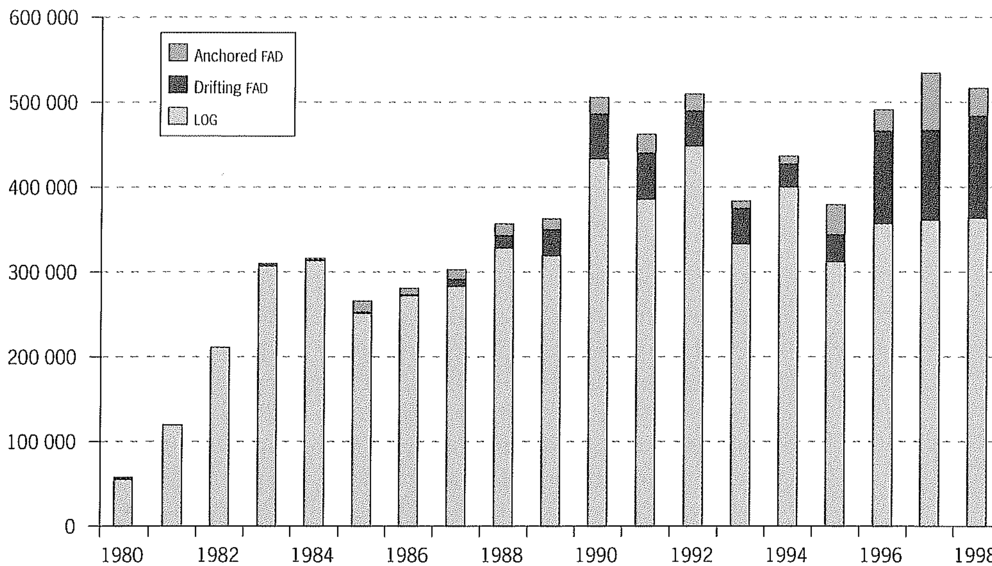


Figure 6
Estimated annual purse seine catch for log, drifting FAD, and moored FAD sets in the WCP (1980-1998; source: SPC Oceanic Fisheries Programme; 1998 values are provisional).

The purse seine fleet is mainly made up of vessels in the 60-70 m range with a gross registered tonnage (GRT) of 1,000-1,550 t (carrying capacity of 800-1,200 t of frozen tuna). Only a couple of vessels are over 70 m in length, while the smallest purse seiner on the FFA regional register in 1998 was 36 m with a GRT of 443 tons. These vessels usually stay at sea until the fish hold is full and then they may travel to a cannery to unload, tranship through shore facilities to a cannery of their choice or tranship to a carrier vessel in the region they are fishing. In many cases, the purse seiners will stay at sea for months at a time, fishing and transhipping the catch as they follow the fish across the WCP. Many of the larger purse seiners have helicopters to assist in locating free-swimming schools of tunas, and to a lesser extent, logs and FADs. Table 4 summarises the percentage of sets by set type for the purse seine fleet in the WCP. This table shows that the fishing practice has changed dramatically in 1999 for the US purse seine fleet (the largest users of helicopters) as this fleet has moved away from fishing free-swimming schools (46.9% in 1998 down to 5.8% in 1999) and concentrated more of drifting FAD sets (23.2% in 1998 up to 86.1% in 1999). The changes in fishing practice for other fleets do not appear to be as marked, although the Japanese fleet has changed in a similar fashion to the US fleet (source: SPC database).

When fishing drifting FADs, a purse seiner will usually drift by it in the afternoon and use both echo-sounder and sonar to locate the aggregated fish to assess the size of the aggregation (tonnage). If the aggregation is small, the vessel may move to another FAD. If the aggregation is considered large enough, then the vessel makes ready as described in the previous section for a pre-dawn set.

Table 4 - Percentage of sets by set type for purse seine operations in the WCP (source: SPC database). "Others" comprises purse seiners from Korea, Taiwan and Pacific Island countries.

	Japan				USA				Others			
Year	Free swim.	Log	Drift. FAD	Anch. FAD	Free swim.	Log	Drift. FAD	Anch. FAD	Free swim.	Log	Drift. FAD	Anch. FAD
1988	35,3	59,6	0,3	0,0	78,1	21,0	0,4	0,0	14,9	52,3	12,5	11,5
1989	41,4	54,2	0,8	0,0	79,2	20,1	0,1	0,0	20,9	54,4	12,5	9,3
1990	38,9	54,2	0,4	0,0	81,4	18,1	0,1	0,0	13,9	62,4	13,3	9,0
1991	53,7	37,1	0,8	0,0	91,7	7,7	0,0	0,0	18,3	57,9	13,3	7,7
1992	48,8	42,2	2,5	0,0	76,8	22,5	0,1	0,0	33,5	51,4	6,7	6,3
1993	54,5	38,1	0,5	0,0	71,5	27,9	0,0	0,0	49,2	40,8	5,0	2,3
1994	42,8	50,7	0,8	0,0	84,5	14,6	0,0	0,0	45,2	48,6	2,9	1,4
1995	50,7	40,6	1,6	0,0	77,9	21,1	0,5	0,0	54,5	37,4	3,3	3,6
1996	43,6	47,8	1,4	0,0	55,7	12,9	30,4	0,0	51,0	39,0	5,9	3,6
1997	36,7	53,5	4,6	0,0	43,6	27,1	29,2	0,0	47,4	34,3	7,8	9,6
1998	42,1	40,4	9,1	0,0	46,9	29,5	23,2	0,0	57,8	24,1	9,4	8,0
1999	28,4	30,7	34,1	0,0	5,8	7,9	86,1	0,0	46,7	25,4	18,0	9,2

Very little of the purse seine catch in the WCP comes from moored FADs (tab. 4). Only two countries in the Pacific region have purse seining operations using moored FADs at present, Papua New Guinea (joint venture between PNG and Filipino companies, with Filipino vessels) and the Solomon Islands. In these two countries, the government has left FAD development and deployment to the industrial sector. These fishing operations rely almost entirely on the moored FADs to aggregate and hold fish close to the bases where the catch will be unloaded, rather than having the catching vessels to follow the tunas as they move across the WCP. *In addition, during the mid-1980s, two New Zealand purse seiners* fished in the EEZ of Fiji almost exclusively setting on a large network of anchored FADs (Bailey *et al.*, 1996). In each of these cases, the fish has been landed in-country to local tuna canneries for processing.

Pole-and-line fishing operations have reduced over the last two decades as a result of high operating cost compared to the value of the landed catch. Japan in 1998 had a total of 44 pole-and-line vessels on the FFA regional register as vessels working in the WCP. These vessels ranged from 25-66 m in length (76-721 GRT), with most vessels in the 50-55 m range (350-499 GRT). In 1997, the Japanese poling catch of tuna from the WCP was around 40,000 t (Cartwright, 1999).

The Solomon Islands are the only Pacific country with a significant pole-and-line fleet. There are 27 pole-vessels, owned and operated by two companies. The vessels range from 21-29 m length (50-80 GRT) with two vessels around 36 metres. The pole fishery relies heavily on the moored FADs set by the two companies for their catch. In 1998, around 22,200 t of tuna were taken by this pole fleet (Cartwright, 1999) and it is estimated that 60-70 per cent of this catch came from moored FADs (Sibisopere, 2000), with the rest coming from free-swimming schools and schools associated with drifting logs.

Pole-and-line operations are very intensive labour and require daily access to baiting grounds (baiting done at night using light attraction and a "bouke-ami" net) to catch the live bait needed for the fishing operation. Fishing operations commence before dawn, when the pole vessels head from the baiting ground to the FADs. Good navigational equipment is required for locating the more offshore FADs, especially in the morning twilight. When not fishing FADs, some pole vessels are fitted with "bird radar" to locate small patches of seabirds that may be associated with feeding tuna schools.

Artisanal sector

It is difficult to place a value on vessel numbers and vessel types when looking at the artisanal fisheries in the region that work around moored FADs, due to their diversity by location. The main common factor is that trolling activities are undertaken mainly at daybreak and late afternoon. The vessels normally return to port midmorning or in the evening to unload the catch for sale. Alternatively, midwater fishing activities can be undertaken at any time during daylight hours, with some trolling vessels conducting midwater fishing activities around the FADs before they return to port. Vessels involved in this fishery are generally low-technology vessels, equipped with a compass, possibly a GPS, and a radio. This also holds true for many recreational fishermen, sport fishermen and charter operators.

It is difficult to come up with any specific vessel designs and numbers for the region as a whole. Therefore, a few examples of specific vessels and possible locations are provided as a sample of the large variety of craft used.

In Tahiti, French Polynesia, Leproux (1998) estimated that in 1996 there were around 900 small-scale vessels that worked the 21 moored FADs for varying amounts of time. The 900 vessels were split into three groups with 200 commercial "poti-marara" (5-7 m outboard-powered

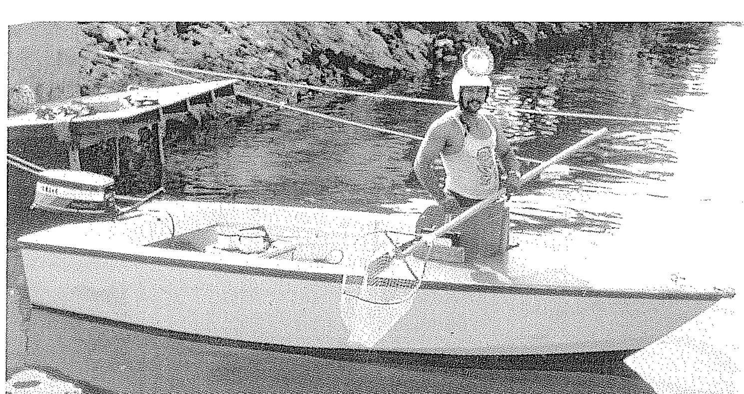
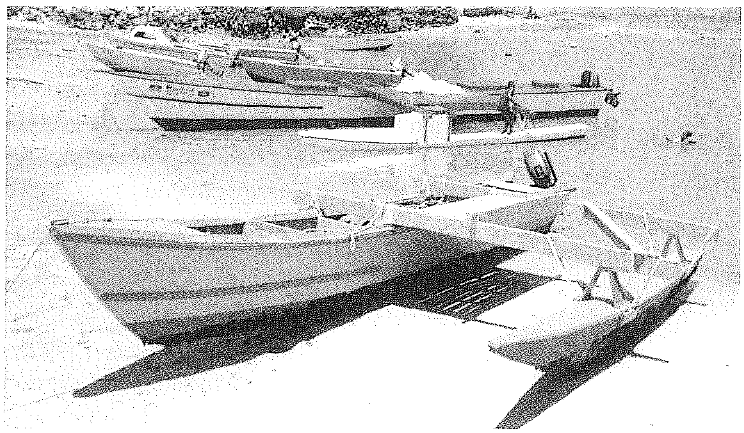


Figure 7
"Poti-marara": type of vessel used in French Polynesia and the Cook Islands.

boats built locally; fig. 7), 200 recreational and semi-commercial "poti-marara", and 500 recreational vessels of varying construction. The Cook Islands also use the "poti-marara"-style vessel, although the numbers are much less than in French Polynesia.

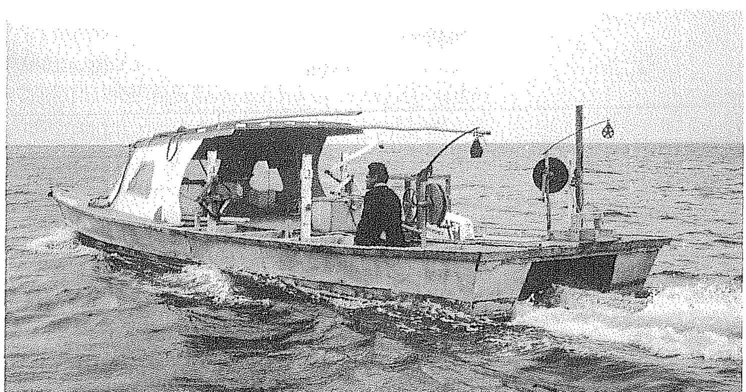
Traditional and modified canoes are used in many locations (Niue, Nauru, Kiribati, Tuvalu, Tokelau) for tuna fishing around FADs. These canoe designs vary considerably from country to country, although most incorporate an outrigger for stability. Some of these canoes now have small outboard engines fitted, so that the fisherman does not have to paddle (fig. 8). These canoes range from 4 to 9.5 m length, with many made from sawn timber and plywood.

Figure 8
Canoe from Kiribati fitted with a small outboard.



A range of 4 to 8.5 m fibreglass, aluminium and timber (including plywood) skiffs, dinghies and dories are also used throughout the region in varying numbers by location. In some locations, larger fibreglass vessels (8.5-14 m) are found, mainly associated with sport fishing and charter fishing operations. The "alia" catamaran developed in Samoa (fig. 9) has also been used for FAD fishing in several countries in the region, although most of its work has been in Samoa and American Samoa.

Figure 9
Samoan "alia" catamaran used for trolling around FADs.



Impact in terms of catches, markets and supply

The vast majority of the tuna catch in the WCP region is taken by the industrial sector, mainly purse seining, with very little of this catch coming from moored FADs. Therefore, the overall picture of tuna catches in the region is presented here, with more specific information on catches from moored FADs presented where available.

Industrial sector

The catch from the industrial purse seine and pole-and-line fisheries is primarily frozen on board the catching vessels, with the vast majority of it sold to canneries around the world. The price paid is a "world price" and it fluctuates greatly based on supply and demand. For instance, good fishing in the WCP, Indian and Atlantic Oceans at the end of 1998 pushed prices down from a nine-month average of around US$ 1,050/t to around US$ 550/t (Cartwright, 1999). Such fluctuations place the burden back on the fishermen who have to make ends meet. This has also attributed to the ageing of the purse seine fleets in the Pacific as people or companies are reluctant to increase investments in a fishery that may cost them if prices are low. In the case of pole-and-line vessels, fluctuating purchase price for tuna greatly contributed to the reduction in vessel numbers and the ageing of the fleet that remains.

Many canneries have a minimum size for tunas of around 1.8 kg (4.0 lb), as fish below this size increase the cost per kilogramme in the canning process. As a disincentive to fishermen, the canneries usually pay a much lower price for fish below this size, which in some cases leads to sorting and discarding of these fish at sea by the operators.

By-catch taken in purse seine fishing operations is usually discarded at sea with some retained by the crew for their own consumption, as many canneries do not want to purchase many of the by-catch species and the purchase price is generally low as a disincentive. Additionally, in many countries where industrial vessels unload their catch, either to canneries or for transhipment, local regulations forbid the sale of fish by these vessels on the local market (as protection for local operators in many cases).

At the tuna cannery in the Solomon Islands, the annual throughput of raw material is around 20,000 t, with 60 or 70 per cent of this fish coming from FAD fishing. Of this, 75 per cent are used in canning whilst the other 25 per cent are cooked and hot-smoked to make arabushi (heavily smoked tuna loins) for export to Japan. Mainly pole-caught tuna are used to make arabushi in the Solomon Islands, with other pole-caught tuna shipped frozen to Japan for processing to arabushi and then katsubushi. The market for arabushi seems to be stable although any large increase in production may affect this.

Artisanal sector

Just about all tunas caught by artisanal fishermen from moored FADs are sold locally on domestic markets as fresh fish. In most cases, the fish is sold directly to the public by the fisherman or family members. Supply is generally seasonal and therefore supply and demand during the main fishing season may force the price down. Most fishermen will drop their price to sell the catch when there is a lot of fish for sale, or it is the end of the day, as they do not have the facilities to freeze and store excess catch for marketing at other times of the year.

In more specific situations, like in Rarotonga in the Cook Islands, the demand for fish far exceeds the supply, even during the main tuna season. This means that the price of fish is high compared to other imported protein sources. In Niue, a different situation exists as most people catch their own fish and there is only a small local market for fish sales.

Economic impact

Industrial sector

In the industrial sector, the cost of FADs has been included in the overall cost of fishing operations. Anecdotal information indicates that the value of the catch from only one good set on a FAD by a purse seiner (after operating and marketing costs are deducted), is enough to cover the cost of the FAD. Therefore, additional sets on the same FAD over time should increase the profitability of the operation, or may cover the cost of FADs, which are lost before being fished. For pole-and-line operations, the main cost savings are in the lower operating costs (do not have to search for fish, just go from one FAD to another), and the greater chance of locating and catching fish (and good catches). The bottom line in the industrial sector is that if the use of FADs was not cost effective they would stop using them.

Artisanal sector

There is plenty of anecdotal information around to support the benefits of FADs to artisanal fishing operations. However, it is difficult to measure the economic impact of FADs in the artisanal sector in real terms, as limited hard data has been collected.

In the Cook Islands, Sims (1988) conducted a one-year creel census of the artisanal offshore fishery off Rarotonga, in an effort to investigate the cost-benefit of FADs. Catches were recorded with volume and value of landings for different categories of fishing including FAD fishing. Trolling around FADs was found to be US$ 0.48 per line-hour more productive than trolling elsewhere, with increased landing valued at US$ 5,460. Landings from midwater fishing around FADs were worth US$ 13,780. The three FADs off Rarotonga were only in operation for 46 per cent of the survey year, yet still produced a 312 per cent return on expenditure (Sims, 1988).

Research in American Samoa in the early 1980s produced a slightly different result to that of the Cook Islands. In this case, trolling catches from FADs were compared to catches from open water and to catches from offshore banks. Buckley *et al.* (1988) reported that the best catches were achieved from the offshore banks at 31.0 kg per hour, followed by FADs with a catch rate of 21.0 kg per hour, with trolling in open water producing a catch rate of 5.8 kg per hour. It was also noted in Buckley *et al.* (1988) that the size of the yellowfin tuna and skipjack tuna caught around FADs was smaller than in the other locations.

Data was collected from the Daugo Island fishermen off Port Moresby, following the deployment of a FAD in August 1992, approximately 5.5 nautical miles off the island. For the period January to March 1993, the average fishing time per day around the FAD was 6.4 hours, resulting in an average catch of 56 fish for a weight of 119 kg (Beverly & Cusack, 1993). This catch had a value of US$ 184.00 with the fuel usage of 40 litres (estimated cost of US$ 17.00). The total catch in this three-month period was 2,622 kg, with a value of US$ 6,610 (Beverly & Cusack, 1993). The handful of fishermen involved in this fishery were reporting a good profit from their FAD fishing activities.

In French Polynesia, Depoutot (1987) looked at the domestic surface pole-and-line "bonitier" fishery and the catch difference between FAD and non-FAD fishing activities. The results indicated that FAD fishing provided a 33 per cent increase in catch. Another study conducted in French Polynesia by Josse (1992), compared catch rates from "poti-marara" vessels when FAD and non-FAD fishing activities were under-taken. The results showed that for non-FAD fishing, the catch rates were 5.0 kg/hour for surface fishing (65% "mahi-mahi", 25% tunas, 10% others) and 2.7 kg/hour for drop-stone fishing (midwater hand-lining) in tuna holes (98% albacore and yellowfin tuna). FAD fishing produced a catch rate of 9.2 kg/hour (95% albacore and yellowfin tuna), much higher that the non-FAD fishing catch rates.

Some analysis of fishing around two FADs off Suva in Fiji has been reported in Anderson & Gates (1996). Prior to the deployment of the two FADs in late 1991, the average annual catch of tunas was 154 t from 1983 to 1991. In 1992 and 1993, this catch increased to 240 and 260 t respectively. Good catches of larger tunas, up to 80 kg, were also reported from these FADs by five small-scale vessels. After changes in handling practices and the use of ice, the value of these large fish to the fishermen increased from US$ 2.00/kg to US$ 5.00/kg as they were exported. In the Suva fish market, the FAD fishery contributed a significant quantity of fish to the overall total, especially early in the week when there were more FAD-caught fish for sale than reef fish (Anderson & Gates, 1996).

A study by Cillauren (1990) was conducted off Efate, Vanuatu, on the economic viability of fishing around FADs. The results indicated a troll fishery around the FADs was not viable due mainly to the high running costs through travel time to and from the FADs (two hours in each direction), with only a very small profit made per trip. If parameters like a reduction in fuel cost or an increase in efficiency of fishing effort were to occur, then this would change the economics of fishing operations, and profits increased.

More recently, SPC assisted the Nauru Fisheries and Marine Resources Authority (NFMRA) to deploy several FADs in 2,600 m of water (around 3.5 nautical miles off the coast). NFMRA as part of their programme implements a data collection system and during the first three months of data collection, over 24,500 kg of tuna was taken from the three FADs, with most of the catch from one FAD (Capture Section, 1997). If the fish were sold for an average price of US$ 2.60/kg, then the landed value of the catch would be just under US$ 65,000. Just prior to the FAD deployments there was a fish shortage on Nauru, which was alleviated by deployment of the FADs. Unfortunately, the most productive FAD was lost after four months and the landings greatly reduced.

Review of capacities and activities

Catch monitoring

Monitoring of the industrial catch of tunas by purse seine and pole-and-line is mainly done through log books, which vessel skippers are required to complete under different fishing agreements or government regulations. This data is collected by the member countries and territories of the SPC, with SPC itself being the repository for this data. SPC has all of this data keyed into a database and uses the data in regional stock assessments for skipjack, yellowfin and bigeye tunas.

In addition to the log book data, both regional and national (some countries) observer programmes have been established to validate the log book data, provide information on changing fishing practices and collect other additional data and biological samples as needed. Also, a vessel monitoring system (VMS) is currently being implemented in the region to better validate the actual fishing location of vessels.

Wherever possible, fishermen from the industrial sector are being encouraged to divide their fishing operation into fishing locations. That means for purse seine sets, whether the set was on a log, drifting FAD, moored FAD, free-swimming school, etc. Observer data is already split in this fashion, however, this is only a small fraction of the actual data for the tuna fishery in the Pacific at present. It is hoped that fishermen will soon supply more specific data to assist in dividing the catch by situation.

Unfortunately, monitoring of the catch from artisanal fishermen fishing around FADs has been minimal to non-existent throughout the region. In New Caledonia, a log book system is in place; however, the information is not specific enough. In Vanuatu, a catch return system was introduced to qualify fishermen for duty-free fuel. In this case, there was no validation of the data and it was felt that people were completing catch returns with erroneous data just to get the duty-free fuel. In the Cook Islands a different approach is used, with anecdotal information collected from fishermen on Friday afternoons in a social situation. In most other countries and territories in the region, no formal recording of data is required.

FAD maintenance

The industrial sector tends to use basic low-cost materials wherever possible in the construction of their moored FADs. This approach allows the companies to recoup costs quickly (one set by a purse seiner), which makes the FADs an "expendable" item. The one part that is maintained or changed from time to time is the FAD raft and its appendages (if used). This is usually a very low-cost component that is attached to the FAD mooring buoy.
Artisanal sector FADs are generally set by the Fisheries Department in the country, as in most cases they are considered as a "community" item. Some countries do regularly maintain the FAD buoy, appendages if used, and upper hardware (Guam, French Polynesia, Niue, Cook Islands, New Caledonia), although the time between maintenance visits fluctuates (2 weeks to 2 months). FADs are usually inspected visually, through diving. Quite often weather and sea conditions greatly influence when maintenance trips are undertaken.

Institutional integration, regulations and arrangements, fishery policy, monitoring of access and dispute management

The setting of FADs by the industrial sector only occurs in two countries in the region at present, Papua New Guinea and the Solomon Islands. In both cases, new government requirements are being implemented to better manage where FADs are set and the procedures. In Papua New Guinea, the government has moved towards managing the numbers of FADs being set, with additional requirements covering identification markings, the use of radar-reflectors and the provision of positions to the Fisheries Department. There is concern over the possible interaction of FADs on the expanding domestic tuna longline fleet's operation, although it is unclear at present how this will be addressed.
Under the new Solomon Islands National Tuna Management and Development Plan (the Plan; Solomon Islands Government, 1999), a register is being established to record all FAD deployments (moored and drifting) and losses. Operators need to let the Fisheries Division and Marine Division know of intent to deploy FADs, and once deployed, the number and position of each device. The Marine Division then publishes the position of all FADs for maritime safety. Companies are required to report every three months with an updated list of FADs and their positions plus any FAD losses.
In the case of the Solomon Islands, moored FADs need to be clearly marked with the owner's identification and be fitted with a radar-reflector or reflecting tape. The Plan covers who can set FADs and any restrictions that apply based on the fishing licenses being held by a company. The Plan also looks at the possibility of future restrictions on the number of FADs to be set and the distance between FADs, although no restrictions apply at present. In addition, the Plan specifies an exclusion zone of five nautical miles around inshore FADs, where only

the company who deployed the FAD can operate. It is unclear if this exclusion zone applies to artisanal operators. Areas that the Plan does not address include the monitoring of access around FADs and a mechanism to resolve disputes.

The requirements for setting FADs for the artisanal sector, and the Government Departments involved, change from country to country. The Fisheries Department in most cases takes the primary role, although it may choose, or be required, to consult with local fishermen or other departments. In countries like Guam and American Samoa, the Fisheries Department works with the Coast Guards to select suitable sites and these are generally restricted in number. In other locations, the Fisheries Department may consult with the Marine Department to ensure that FADs are located outside shipping lanes, or with local fishermen to gain advice on areas where tuna tend to congregate.

Some countries have regulations in place to prevent fishermen from tying fishing gear or their vessel to FADs. Other countries have "gentlemen's agreements" between the fishermen regarding the fishing operations around FADs. In some locations like the Cook Islands, troll fishermen feel that mid-water fishing takes the fish away from the surface, which they believe affects their trolling catch. Vandalism has also been a problem in some countries in the past, and regulations are in place to cover this. The problem here is that there is no monitoring or policing, which makes it almost impossible to detect and prosecute offenders. Likewise, there is no mechanism in place to resolve disputes should they arise.

FADs, cost recovery and fostering ownership

In the industrial sector, all costs for the FADs are covered by the sector, although it is unclear about actual ownership or exclusive fishing rights. As stated in the previous section, the Solomon Islands have implemented a five-nautical-mile exclusion zone around company FADs. However, how is this to be monitored and enforced and does this apply to just the industrial sector or does it include the artisanal sector?

Fisheries Departments around the region have looked at cost recovery from the users of FADs as a way to assist in the funding of ongoing FAD programmes for the artisanal sector. In two countries, Vanuatu and the Cook Islands, this approach has been taken on board informally, with a portion of the cost of FADs being borne by the users. In Vanuatu, one commercial operator and the charter fishing operators have contributed financially to the cost of several FADs, plus they have assisted with the construction and deployment. In the Cook Islands, the Fisheries Department is recovering around 15 per cent of the cost of FADs from the commercial fishermen in the first instance.

In all cases, the FADs deployed by Fisheries Department for the artisanal sector remain community property, that is, there is no ownership and all people have equal rights to fish around them. The question here is whether or not vessels from the industrial sector can fish around FADs deployed for the artisanal sector, which was the case in Fiji for pole-and-line fishing operations in the 1980s. Apart from the Solomon Islands where it is not clear, no private citizen can set their own moored FADs. Some countries have considered allowing fishermen to deploy FADs to cut costs for the government, although in these considerations it has been clear that they would not have exclusive fishing rights, they would have to allow everyone access to the FAD.

Overall there is an ongoing debate regarding the allocation of exclusive fishing rights based on having a FAD. If applied in the case of the Solomon Islands, a company could set a large number of FADs spacing them 10 nautical miles apart and effectively annex off a large section of fishing area for there exclusive use. From the industrial sector's point of view, this is probably preferable as it keeps other companies out. However, from an artisanal fisherman's point of view, such an approach could be devastating to small-scale fishing operations.

Conclusion

There are many conclusions that can be drawn from this synthesis. The most important of these is that FADs do work in regard to attracting tuna and other species, both in the industrial and artisanal sectors. However, much of the information regarding the artisanal sector, in support of FADs and their success, is anecdotal. There is a real shortage of accurate, documented evidence or data, not just on catches, but also on the economic benefits of FADs.

Success of anchored FADs in the artisanal sector is also very hard to determine due to the diverse nature of the programmes run in the region by different countries. In some countries where there would appear to be a real need for moored FADs, programmes are intermittent due to funding constraints, while in other countries the opposite may apply.

In the industrial sector, data is much more available and it is being refined all the time to break down catches by area and type of fishing operation. In regard to the success of FADs in this sector, companies would not continue using them unless they were economically viable. One important fact for the operations in Papua New Guinea and the Solomon Islands is that the use of FADs has allowed the companies to fish year-round in specific locations close to their fishing base (or marketing base) so that vessels do not have to follow tunas as they move around the WCP. This has greatly reduced operating costs for the vessels, especially pole-and-line fishing operations, thus adding to the viability of this fishing style in the Solomon Islands. It also assists the shore facilities to have a steady supply of raw materials year-round.

Some of the issues that are yet to be resolved include: increasing the lifespan of FADs whilst keeping costs to a minimum; ownership of FADs and who can fish around them; ongoing funding for artisanal

FAD programmes including cost recovery from the users (or the user pays principle); dispute resolution; how to monitor fishing activity; and how to collect better catch data and data for cost-benefit analysis. Addressing these issues will allow a better understanding of the true value of these devices to fishing operations, both industrial and artisanal.

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