Fisheries Newsletter

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Fish aggregating devices (FADs) are a promising tool for coastal fishers, or could mean destruction of tuna stocks, depending on who you are speaking with. Both perceptions may be right, but they relate to two very different types of FADs: artisanal (small-scale) and industrial.

Artisanal FADs are anchored close to shore to help local fishers gain access to oceanic resources such as tuna, mahi mahi, wahoo and rainbow runner. In doing so, they provide another source of food for families and help fishers move away from declining reef resources.

Industrial FADs are drifting rafts set by purse-seine vessels to concentrate schools of skipjack and mixed tuna species, and to make their operations commercially viable. But, this also means huge catches of unwanted species such as silky sharks and juvenile bigeye tuna, which are already over-exploited (see article on p. 2). Artisanal fishers, who use hooks and lines around nearshore FADs, are able to limit their catch to targeted species.

The FAD issue continues to be of interest to many people, and in fact, attracted 150 participants to a conference in Tahiti in November 2011. On page 35, a wide panel of experts report on their discussions, their findings, and list research and management needs in this area.

In one of the other feature articles (p. 27), Mark Sinner and his colleagues report on their study of ciguatera poisoning occurrences in the Pacific Islands region. You will probably be as surprised as I was to learn that up to half a million people may have been affected by ciguatera over the last 35 years. The authors suggest that this figure should drive decision-makers to pay much more attention to this issue.

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Triggerfish aggregation under a drifting FAD (Image: Marc Taquet, FADIO/IRD-Ifremer)

Secretariat of the Pacific Community

Prepared by the Information Unit, Division of Fisheries, Aquaculture and Marine Ecosystems

The western and central Pacific tuna fishery: 2010 overview and status of stocks

The western and central Pacific tuna fishery, encompassed by the Convention Area of the Western and Central Pacific Fisheries Commission, is the world's biggest tuna fishery.

Fishing ranges from small-scale, artisanal operations in the coastal waters of Pacific states, to large-scale industrial purse-seine, pole-and-line and longline operations in the exclusive economic zones of Pacific states as well as in international waters (high seas).

Using detailed fisheries and biological data, some going back to the 1950s, SPC's Oceanic Fisheries Programme scientists have assessed the trends and current stocks of the four tuna species mainly targeted by fishers:

- skipjack tuna (*Katsuwonus pelamis*)
- yellowfin tuna (*Thunnus albacares*)
- bigeye tuna (*T. obesus*)
- south Pacific albacore tuna (*T. alalunga*)

Data identified as 'provisional' will be revised once we have received and processed all data for 2010.

Key messages and recommendations

The western and central Pacific tuna fishery is in the best shape of all the tuna fisheries in the world. On a scale of 1–10, it is estimated as 6–7, a green traffic light that is in the process of turning yellow.

Overfishing of bigeye tuna continues, i.e. fishing effort is too high. The bigeye spawning population is also the most heavily impacted of the four tuna species. Though the species is not at risk of extinction, and is never likely to be, fishing effort needs to be reduced.

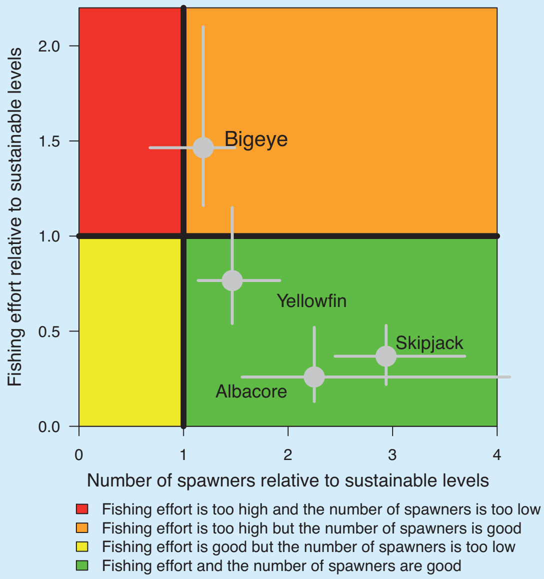
Yellowfin, skipjack and south Pacific albacore stocks are being fished at moderate levels, and stocks are reasonably healthy. This does not mean that there is potential for higher catches. Responsible management is needed to maintain profitable fisheries and food security. Now is the time to think about limiting catches (or fishing effort) at around the current levels.

Recommendations

✓ Reduce **bigeye** fishing effort by at least 32% from the average levels for 2006–2009 to ensure long-term sustainability.

✓ Limit **yellowfin** fishing effort in the western equatorial Pacific to around current levels.

✓ Consider developing limits on **skipjack** fishing to keep this critically important stock at healthy levels, to get the best economic returns from the fishery, and to provide food security to Pacific Island communities.

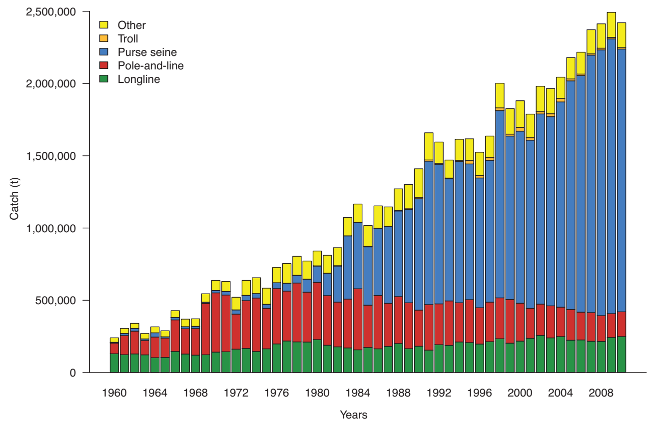


Tuna catch – 2010 second highest on record

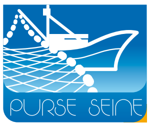
The provisional total tuna catch for 2010 is:

- 2,421,113 tonnes (t)
- the second highest annual catch recorded
- 71,673 t lower than the 2009 record (2,492,786 t)
- 83% of the total Pacific Ocean catch (2,911,918 t)
- 60% of the global tuna catch (4,017,600 t, provisional)

Over the history of the fishery, there has been an upward trend in total tuna catch, mainly due to increases in purse-seine fishery catches since the 1980s.



Catch by gear

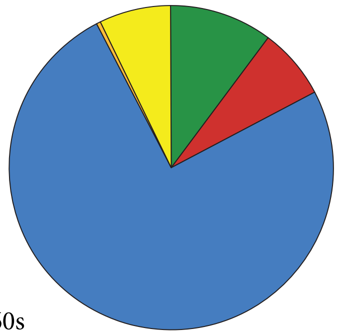


Third highest catch for purse-seine behind 2009 and 2008

Second highest catch in the past 10 years;
8% lower than the 2002 record (256,582 t)

Slightly higher than 2009;
second lowest annual catch for pole-and-line since the mid-1960s

TOTAL: second highest on record



2010 catch by gear

Longline	248,589 t (10%)
Pole-and-line	171,597 t (7%)
Purse-seine	1,818,255 t (75%)
Troll, Other	182,672 t (8%)

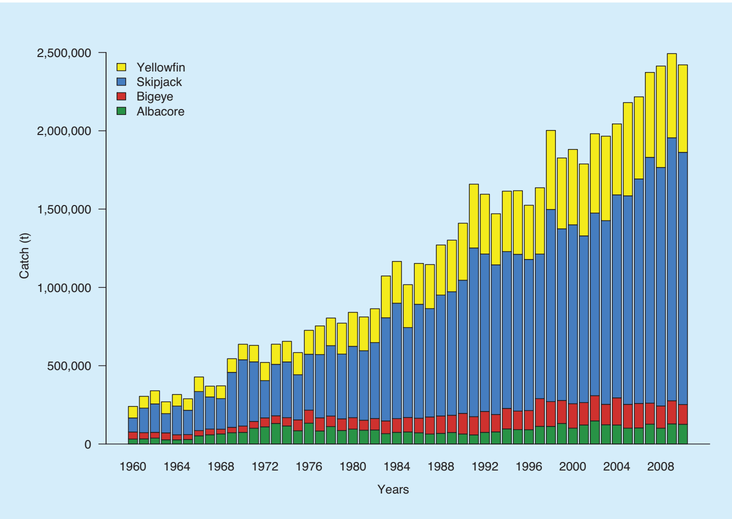
2010 longline catch by species

Tuna species	Catch (t)	% of total longline catch	Observation
 Skipjack			insignificant catch
 Yellowfin	82,485 t	33%	highest since 1988, but includes catches by Vietnam (9,513 t) for the first time
 Albacore	100,846 t	40%	highest on record; 9% higher than the previous high in 2009; 25% higher than the 2000–2009 average; driven by dramatic increases in southern Pacific catches
 Bigeye	64,117 t (provisional)	26%	lowest since 1996, despite including catches by Vietnam (2,441 t) for the first time
TOTAL	**248,589 t**		second highest catch for longline in the past ten years; 8% lower than the 2002 record (256,582 t)

2010 purse-seine catch by species

Tuna species	Catch	% of total purse-seine catch	Observation
 Skipjack	1,381,070 t	76%	second highest on record after 2009
 Yellowfin	382,521 t	21%	third highest on record after the record 2008 catch (499,133 t)
 Albacore			insignificant catch
 Bigeye	54,356 t (provisional)	3%	lower than the recent five-year average; 27% smaller than the 2009 catch
TOTAL	**1,818,255 t**		third highest catch for purse-seine after 2009 and 2008

Catch by tuna species



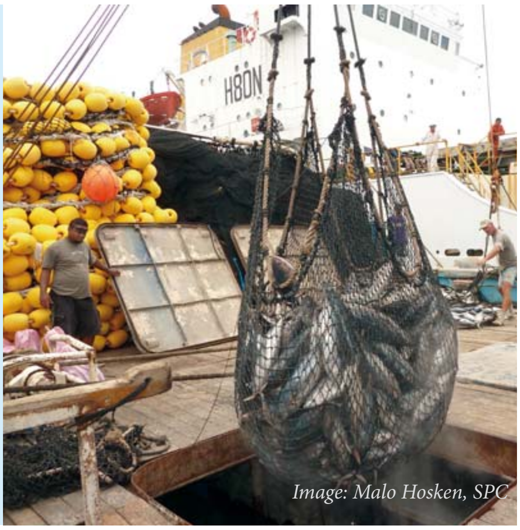


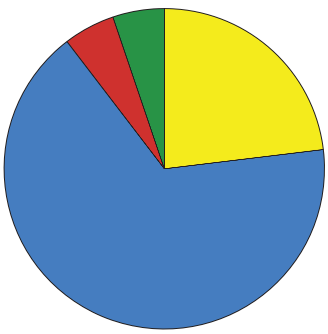
Image: Malo Hosken, SPC

Yellowfin: third highest on record

Skipjack: second highest on record after 2009

Bigeye: lowest since 1996

Albacore: fifth highest on record; highest ever catches on the southern Pacific stock (81,217 t)



2010 catch by species

Yellowfin	558,761 t	(23%)
Skipjack	1,610,578 t	(67%)
Bigeye	125,757 t	(5%)
Albacore	126,017 t	(5%)

Skipjack

Skipjack fishing effort is within sustainable levels. The stock (by weight) is now down to about 60% of what it would be if there had been no fishing. The number of spawners is also within sustainable levels, but for this short-lived species, this situation can change quickly.

Because the stock is declining, if current catch levels continue we can expect individual daily catches and profitability to eventually decline.

Recommendation

Consider developing limits on fishing to keep this critically important stock at healthy levels, to get the best economic returns from the fishery, and to provide food security to Pacific Island communities.

Albacore

Overall, fishing effort is within sustainable levels. The stock (by weight) has declined gradually over the duration of the fishery, but the abundance of spawners in the southern Pacific Ocean is still within sustainable levels.

Nevertheless, catches have increased in recent years and the longline fisheries in many Pacific Island countries are particularly vulnerable to further depletion of the stock and could see declines in individual vessel daily catches and profitability.

Yellowfin

Overall, yellowfin fishing effort is within sustainable levels. The stock (by weight) has declined gradually over the duration of the fishery, but the number of spawners is still within sustainable levels. While this is good news overall, the western equatorial Pacific, from which around 81% of the overall yellowfin catch is taken, is at least fully exploited, with no potential for increased catches.

Recommendation

Limit the number of yellowfin being caught in the western equatorial Pacific to around current levels.

Bigeye

Fishing effort on bigeye tuna has been too high for several years and the number of spawners may already be below sustainable levels. The number of spawners is now only 23% of the level that would be expected if no fishing had occurred.

Recommendation

Reduce bigeye fishing effort by at least 32% from the average levels for 2006–2009 to ensure long-term sustainability.

For more information

Read the full report

Statistics presented in this article are complete to the end of 2010. They are presented and analysed in more detail in the full report, "The western and central Pacific tuna fishery: 2010 overview and status of stocks", which is available online in both English and French.
Visit: www.spc.int/oceanfish/

Contact us

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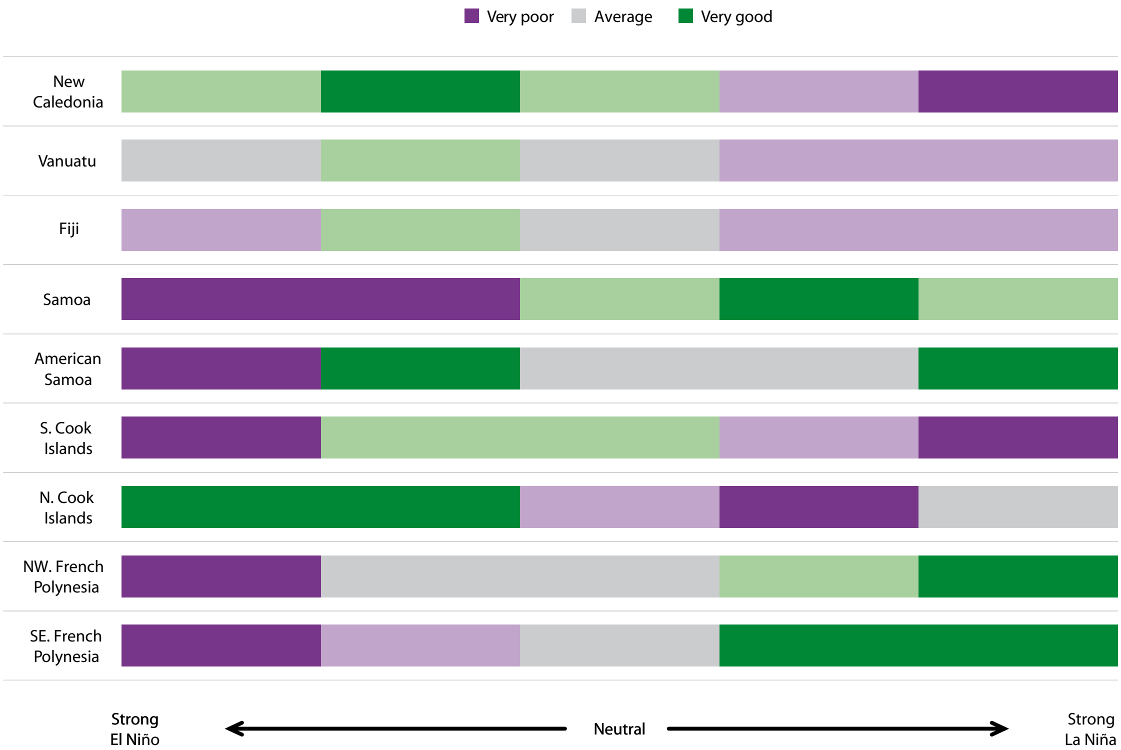
SPC's Oceanic Fisheries Programme studies the effects of El Niño-Southern Oscillation on South Pacific albacore catches

SPC's Oceanic Fisheries Programme (OFP) is currently completing analyses on environmental impacts on South Pacific albacore catches. The work is being led by Graham Pilling, Karine Briand, Shelton Harley and Simon Nicol from OFP, in collaboration with a team of physical oceanographers from the French Institute of Research for Development (IRD). One of the focus areas for this work is to better understand the impact of the El Niño-Southern Oscillation (ENSO) phenomenon on albacore fisheries in the South Pacific Ocean.

This analysis is being undertaken in several parts. The first step has been to standardize historical catch data to minimize the impact that different vessels have on albacore catch rates. These standardized data were then used to construct an index of abundance, which has, in turn, been modelled against ENSO to determine its influence on catch rates and recruitment.

An example of the analyses is provided in the figure below. Using the Southern Oscillation Index (SOI) as a measure of ENSO, the influence of SOI state on catch rates by exclusive economic zone (EEZ) area is shown. In western EEZs, an El Niño state has a positive influence on albacore catch rates (shown in green). In contrast, in eastern EEZs, a La Niña state has a positive influence on catch rates. For more centrally located regions, the impact is less consistent. This pattern of higher catch rates in the western and eastern regions of the South Pacific Ocean, in association with different phases of ENSO, is partially explained by the oceanographic conditions that each ENSO phase generates in each area. During an El Niño state, the depth of the 20°C thermocline deepens in the east and shallows in the west. During La Niña conditions the reverse patterns is observed: the thermocline is deeper in the west and a shallower in the east. It is likely that the decreased depth of the thermocline constricts the preferred habitat for albacore and consequently improves the catchability of longline equipment, whereas when the thermocline deepens, the reverse occurs with the volume of preferred habitat for albacore increasing and catchability subsequently decreasing.

Outputs from these analyses are expected to be completed in 2012 and will be provided to SPC member countries as part of the new Specific National Reports produced by OFP.



South Pacific albacore catches in relation to the El Nino Southern Oscillation (ENSO) phenomenon

When economy meets with tuna

The SciCOFish[1] project has recently added two new staff members, Aaron Berger and Roseti Imo, who are introducing economic perspectives to the biological scientific work that is already being done by SPC on oceanic fisheries. Their main task is to estimate the economic impacts of various fisheries management options proposed to Pacific Island countries.

Providing economic advice on fisheries management

Aaron is based at SPC in Noumea and Roseti at the Pacific Islands Forum Fisheries Agency (FFA) in Honiara, and together they work closely on reinforcing the way in which SPC and FFA collaborate to provide scientific advice to member countries.

It has effectively been a demand from the Pacific Island countries that the usual national or regional tuna fisheries status reports as well as the national briefs provided regularly by SPC in response to specific national requests should relate to economic impacts.

As an example, some countries are interested to know the number and type of vessels they can authorize in their exclusive economic zone, according to the potential catch but also taking into account the impacts of different fishing effort levels on costs and benefits of the fishery.

Bioeconomic indicators included in the fishery performance evaluation

The idea is to constitute a modelling platform that predicts changes in the spatial and seasonal distribution of fishing effort in response to tuna stock conditions and management controls. Incorporating fishing cost and market price by size and/or grade information to current stock projections would provide useful metrics for comparing the economic performance of the fishery under alternative management scenarios, such as the extent and duration of fish aggregating device closures and high seas restrictions.

Some useful economic measures include price elasticity, net present value, economic impacts of bycatch, and ways to estimate the performance of the fleet under varying fuel costs. The aim is to automate such calculations for future regional reports and meetings, knowing that the work load will vary considerably from country to country as a result of fleet size and available data.

Data: The key to the process

An inventory of fishing cost information available for input into the regional models has been completed. However, this information is dated, with cost estimates determined from patchy data available from some of the fleets in the South Pacific region.

Aaron and Roseti are now developing a new economic survey form for purse-seine vessels, being tested for later distribution to countries in the region that have domestic-based, purse-seine fleets and to distant-water fishing fleets. An additional approach to acquiring the necessary data for analyses, such as the fuel used when fishing each set type, will be to use the existing vessel monitoring xystem database to estimate distance travelled between sets.

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[1] SciCOFish = Scientific support for the management of Coastal and Oceanic Fisheries in the Pacific Islands region. For more details, see: http://www.spc.int/fame/en/projects/scicofish/about-scicofish

Transshipping tuna is an important variable cost incurred by many purse seine fleets (Image: Aaron Berger)

Improving the management of deepwater snapper resources in Pacific Island countries

Deepwater snappers are an important fisheries resource in several Pacific Island countries and territories (PICTs). Caught on the outer reef slope and around seamounts, they are out of the range of many small-scale inshore fishers and have largely escaped the overfishing that characterises the more valuable inshore resources. Snappers are good-eating, and because of their deepwater habitat they are not subject to ciguatera poisoning, which makes large reef fish a risky choice.

Deepwater snapper constitutes an export fishery (notably in Tonga), supplying a market in Hawaii. In countries with tourim industries deepwater snapper are sought after by hotels and restaurants, and can command relatively high prices. In New Caledonia, for example, deepwater snappers account for less than 50% of the volume but 70% of the value of coastal finfish landings.

While there are several species with different characteristics, deepwater snapper are generally large but slow-growing by tropical standards. In many cases, fisheries have developed on a previously unfished resource, yielding impressive catches at first, but which soon declined. There is a lack of management plans in most PICTs except the US territories and Tonga, and a lack of information on the status of stocks thath could be used to develop plans. A recent review (McCoy 2010) of snapper fisheries management measures in the Pacific identified requirements that are not being met in most PICTs. These include the application of financial and human resources to ensure that the collection of high quality data is of sufficient coverage to meet the needs of management, and the lack of scientific and technical expertise familiar with the resources, their assessment and management.

In July 2011 a meeting was held at SPC to develop a work plan for deepwater snapper management in the region and to identify priority information and training needs.

2012–2014 PICTs Deepwater Snapper Work Plan

Objective

To improve stock assessments for deepwater snapper in PICTs to allow sustainable development of the fishery, while developing national capacity to undertake this kind of work.

Priority PICTs

The work plan will initially focus on the Marshall Islands, Samoa, Tonga and Vanuatu in line with priorities identified in SPC Joint Country Strategies. Other PICTs are encouraged to contact SPC for assistance on a needs basis.

Fisheries data collection systems

Recent experiences to assess the status of tuna and shallow inshore coastal species clearly demonstrate substantial benefits of adopting a standardised approach to fisheries data collection across the Pacific region. These include: 1) facilitating the development and maintenance of a common database system in each PICT, which minimises development and maintenance costs; 2) providing consistency in how and which data are collected and analysed; 3) facilitating comparisons of fisheries among PICTs; and 4) allowing data fields to be categorised and prioritised depending on their intended use.

Activities

- Develop deepwater snapper fisheries data forms that allow multiple levels of data to be recorded depending on individual PICT capabilities and capacities, while maintaining the integrity of the data reported. Use existing data forms where feasible (e.g. artisanal data form, Tonga's deepwater snapper data collections system) to maintain familiarity in data reporting and to maximise the likelihood of accurate data being reported.
- Develop a new data management system for deepwater snapper (SNAPMAN), with similar user interfaces to the system used for tuna.
- Build in-country capacity to sustain these data collection systems.

Biological knowledge

Estimates of demographic parameters, such as growth and mortality rates, are fundamental to understanding a species' population dynamics and for predicting responses of populations to exploitation. Surprisingly little knowledge exists for these parameters in the Pacific Islands region.

Activities

- Collect data on growth rates of major target species, allowing for future comparisons between PICTs.
- Conduct at least one catch depletion experiment on an unexploited population of snappers to estimate mortality parameters.

- Collect data on the reproductive biology of major target species, allowing for future comparisons between PICTs.
- Collect data on stock structure to identify management units for deepwater snapper in each PICT.

Stock assessment systems

The lack of available data for deepwater fish species in many PICTs has prevented the use of traditional stock assessments. Management procedures offer an alternative paradigm to fisheries management decision making (Bentley and Stokes 2009), and are formal specifications of the management actions that will be taken in response to data collected from the fishery (e.g. exploitation reference points based on the ratio of fishing mortality to natural mortality). A key advantage of management procedures is that, due to their ability to be simulated, the performance of alternative forms of management can be evaluated against a range of management objectives.

Activities

- Characterise the deepwater snapper fishery in each PICT to identify trends and critical data limitations.
- Develop species distribution models and provide maps of potential habitat for major target species.
- Develop biological and fishery reference points suitable for application within the management procedures framework.
- Develop plausible management actions that can be implemented within each PICT in response to reference points.

Capacity building

- Where appropriate, Pacific Island fisheries officers should participate in longer term attachments to SPC to focus on developing data collection and stock assessment systems for application in their home country.
- Provide opportunities for Pacific Island fisheries graduates to complete post-graduate studies to enhance capacity for deepwater snapper management and assessment in their home country.

References

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McCoy M.A. 2010. Overview of deepwater bottomfish fisheries and current management activities in Pacific Island countries and territories.

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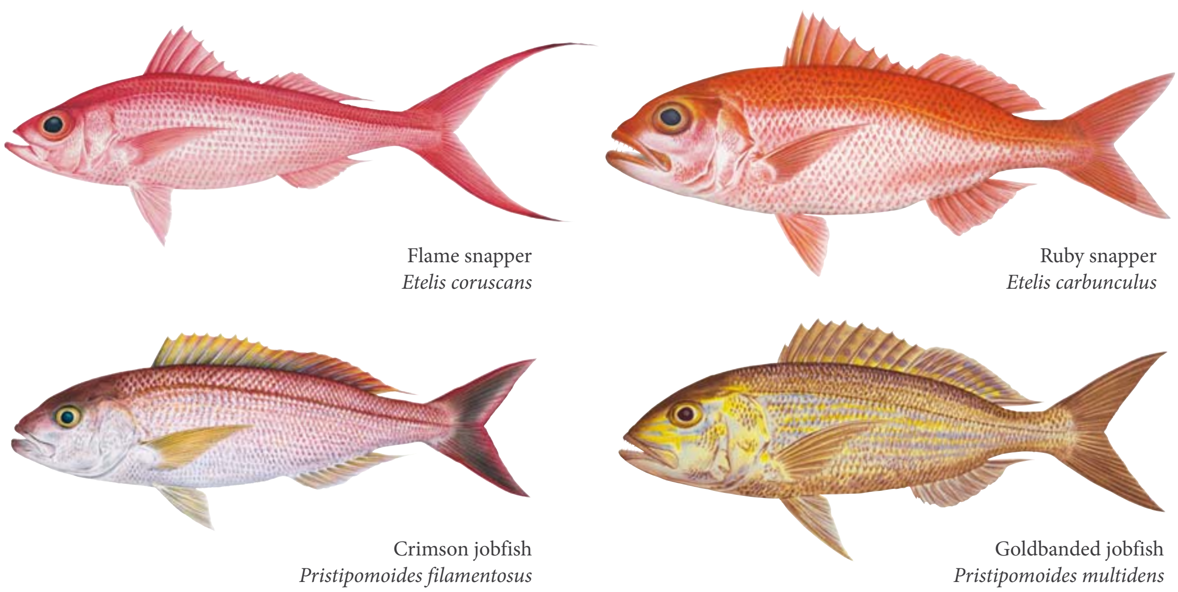

Four of the main species targeted by deepwater snapper fisheries of the Pacific Islands region (Illustrations: Les Hata)

Sustainable development and strategic planning for New Caledonia's aquarium fishery

A targeted fishery for the aquarium trade has been operational in New Caledonia for the past 15 years. However, to date, this fishery has focused mostly on a few species that command high market prices. Following the recent establishment of a new company (AquariumFish NewCaledonia), whose aim is to diversify the existing aquarium trade fishery, local authorities have raised a number of questions.

These questions include:

- What is the best way to ensure that development and diversification of the fishery is conducted in an environmentally, socially and economically sustainable fashion?
- What should best practices for collection, holding and packing of targeted species be in order to ensure maximum survival rates at collection and holding facilities, and while travelling, and upon arrival?
- What management measures are needed to optimise the sustainable exploitation of the resource in New Caledonia?

Following a request by the aquaculture and fisheries department of the Southern Province Development Agency (Département de l'aquaculture et des pêches, Direction du Dévelopement Rural Province Sud – DDR) to the Secretariat of the Pacific Community (SPC) for assistance in the matter, SPC's Coastal Fisheries Programme held a two-day workshop (23–24 November) to address the above questions.

Specifically, the workshop's objectives were to:

- capitalise on SPC's network, particularly Tony Nahacky, a very experienced and knowledgeable collector and industry operator in the region;
- present experiences, lessons learned and challenges encountered in the aquarium trade business at the scale of New Caledonia;
- draft recommendations, in collaboration with all workshop participants, of "next steps" for the aquarium industry in New Caledonia.

To open the workshop, Antoine Teitelbaum, owner of AquariumFish NewCaledonia, gave participants the unique opportunity of a guided tour of his holding facility, and answered questions they had. The remainder of the workshop was held at SPC. Tony Nahacky presented the history of two successful, yet very different, examples of the industry — one from Hawaii, where the trade is industrialised and contributes significantly to the economic returns of the Big Island; and the other from Fiji, where although contributing to the livelihoods of a large number of community members, the trade operates at a much more basic level. Other workshop presentations included a summary of aquarium fisheries development throughout the Pacific Islands region over the last 10 years (Being Yeeting); an overview of New Caledonia's aquarium fishery (Bernard Fao); the economics of the marine ornamental trade in the Pacific (Michael Sharp); a review of SPC's current and planned aquarium trade programme activities (Colette Wabnitz); and an overview of SPC's ornamentals permit and export database (Frank Magron). A number of short films demonstrating best collection practices and the short documentary feature "The dollar-fish island" by Eric Clua were also shown.

One of the key outputs of the workshop was that local authorities walked away with a better understanding of how the trade operates and some of the challenges faced by the industry in the region. The workshop also highlighted the special context in which the trade operates in New Caledonia. Local authorities indicated that currently, no further funding would be provided to individuals expressing an interest in establishing themselves as aquarium trade operators and that a list of conditions would, in all likelihood, be appended to ornamental fishing licenses, reflecting a number of the recommendations coming out of the workshop. These would need to be discussed in consultation with the relevant authorities before being implemented, but could include for example, limits on the total length and mesh size of nets used; specific catch reporting requirements; the prohibition on damaging habitat while collecting marine ornamentals; and the recommendation to encourage rotation of collection areas and to avoid collection within a certain distance from dive locations.

Local authorities also expressed great interest in obtaining copies of the best practice fact sheets for the marine ornamental industry that are currently being drafted by SPC for the region. Once translated, these fact sheets will also be adapted to fit the needs and specificities of New Caledonia.

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Pacific fisheries: Winners and losers identified in new climate change book[1]

By Toss Gascoigne

Image: Andre Seale

Pacific Island nations are under significant pressure to sustain their fish resources and maintain a vital source of food. Now, climate change poses a fresh challenge. A new book, "Vulnerability of tropical Pacific fisheries and aquaculture to climate change", claims there will be winners and losers from climate change, and the way Pacific governments react and adapt is vital to determining the end result.

The book, published by SPC,[2] was launched at the Conference of the Pacific Community in Noumea in November 2011 by James Batley, Deputy Director-General of the Australian Agency for International Development.

At 900 pages long, the book incorporates the contributions of 88 scientists from 36 institutions and is, according to Dr Jimmie Rodgers, SPC's Director-General, "the most comprehensive and up-to-date analysis yet on the likely impacts of climate change on Pacific fisheries and aquaculture and the ecosystems that underpin these activities".

Lead editor Dr Johann Bell, a Principal Fisheries Scientist at SPC, said that the book contains an analysis of the effects of projected changes to surface climate and the ocean on fish habitats, fish stocks and aquaculture.

The book also has a chapter on the implications for economic development, government revenue, food security and livelihoods, and another chapter on adaptations and policies to reduce the threats and capitalize on opportunities.

Dr Bell said the writing team has prepared a summary for each Pacific Island country and territory that sets out the ways that fishing communities and enterprises are expected to be affected, and lists the most appropriate local adaptations and supporting policies.

The effects on fisheries fall into five main areas.

Changes in the distribution and abundance of tuna

Alterations in ocean temperatures and currents, and the nutrients at the base of food webs in the open ocean (made up of plankton, small fish, squid, and other organisms), are expected to affect the distribution and abundance of tuna species.

Skipjack, yellowfin and bigeye tunas are likely to move farther east. This has implications for how much fish is caught around each Pacific Island nation, and the supply of fish to canneries in Papua New Guinea, Solomon Islands and Fiji.

It will also affect the amount of government revenue that some smaller nations receive from access fees paid by distant-water fishing nations. Countries such as Kiribati, Nauru and Tuvalu, whose governments already depend heavily on these fees, are expected to benefit. More tuna in their exclusive economic zones (EEZs) is likely to result in more licence fees.

[1] This article appeared in the December 2011 issue of *Islands Business*.
[2] Available from SPC website at: http://www.spc.int/climate-change/fisheries/assessment/

Decline in coastal fisheries and coral reefs

Because many species of coastal fish in the tropical Pacific are already living very close to their upper temperature limits, they will have to move to cooler waters as sea surface temperatures rise.

Even where coastal fish species can tolerate rises in sea temperature, many of them will struggle because the coral reefs they depend on will be degraded by ocean acidification and increased bleaching due to higher water temperatures.Overall, the production of reef-associated fish in the tropical Pacific could decline by 20% by 2050 and by up to 50% by 2100 if high emissions of carbon dioxide continue.

According to Dr Bell, "The losers include people who continue to depend on coastal fisheries. They will have to find additional sources of food. Higher sea surface temperatures, ocean acidification, and loss of important habitats like coral reefs, seagrass beds, mangroves and intertidal flats are expected to have a dramatic impact on the fish and shellfish that support many coastal communities."

Increases in freshwater fisheries production

Higher projected rainfall in the tropics will increase the area of fish habitat on the floodplains of large rivers in Papua New Guinea. Increased air temperatures are also expected to have positive effects on the growth rates of many freshwater fish.

Effects on aquaculture

The long-term effects of climate change on aquaculture are likely to be mixed.

Higher water temperatures, sea level rise, ocean acidification, reduced salinity and increased disease risk could eventually affect growth and survival of shrimp, pearl oysters, seaweed and ornamental species cultured for the aquarium trade.

On the other hand, increased rainfall and higher air temperatures should increase the number of places where freshwater fish can be grown in ponds, and the growth rates of these fish.

Increased operating costs

The possibility that cyclones could be stronger increases the risk of damage to shore-based facilities (wharfs, jetties), domestic tuna fishing fleets and processing plants. Fleets operating within the cyclone belt may need to be upgraded. Rising sea level may eventually make many existing wharfs and shore-based facilities unusable.

Louisiade Archipelago, Papua New Guinea
(Image: Christophe Launay)

Dr Brian Dawson, SPC's Senior Climate Change Adviser, said scientists have a reasonably good idea about where climate change is heading, and what the potential impacts will be, but the changes may not turn out exactly as expected, so we need to adjust to circumstances.

"There's a range of adaptations that can substantially reduce the risks and costs, but they need to be tailored to the circumstances. Adaptation is a flexible, not a static concept." He said planning for change is vital, because fish is the single biggest source of animal protein in Pacific Islanders' diet. Smaller atoll countries are particularly dependent on fish to meet their daily protein requirements. Exports of fish products, particularly tuna, also provide a large income flow. Anything that reduces those export incomes is going to undermine the ability of Pacific Island countries and territories to meet their development aspirations.

"The important thing is that there are opportunities for reducing the risks and our vulnerability. Some of these are: managing the coastal zone to protect fish habitats, looking at how to include a greater proportion of tuna into Pacific diets to fill the gap between the fish required for good nutrition and the catches available from coral reefs, and developing freshwater pond aquaculture," he said.

The average annual consumption of fish by rural coastal populations in the tropical Pacific ranges from 30 kg to more than 100 kg per person. Even in urban centres, fish consumption usually greatly exceeds the global average of 16–18 kg per person per year.

Dr Bell said that scientists are seriously concerned about the capacity of coastal fisheries to supply the fish needed for food security.

"Another 115,000 tonnes of fish will be needed to help provide good nutrition for the expanding population of the region by 2030. That's an increase of 47%," he said.

And Dr Jimmie Rodgers added, "The reality is that there will be countries in the Pacific with bigger populations and fewer fish to eat. We ignore the book at our peril because it comes up with sound scientific analyses, hard-hitting key messages and policy options. It gives Pacific leaders the opportunity to look 20 years ahead and plan for the future," he said.

"Vulnerability of tropical Pacific fisheries and aquaculture to climate change" contains a comprehensive list of win-win adaptations to address the pressures facing fisheries now, and the threats and opportunities associated with climate change. These recommended adaptations fall into three broad areas. The following examples indicate the sort of actions required.

1. *Adaptations for economic development and government revenue*

- Fully implement the vessel day scheme, which allows fleets to follow the tuna into the EEZs of Pacific Island countries as climatic conditions change.
- Diversify sources of tuna to supply canneries in Papua New Guinea, Solomon Islands and Fiji when fish are not so abundant in the EEZs of these countries.
- Conduct energy audits to improve the efficiency of vessels and reduce the carbon footprint of fishing operations.

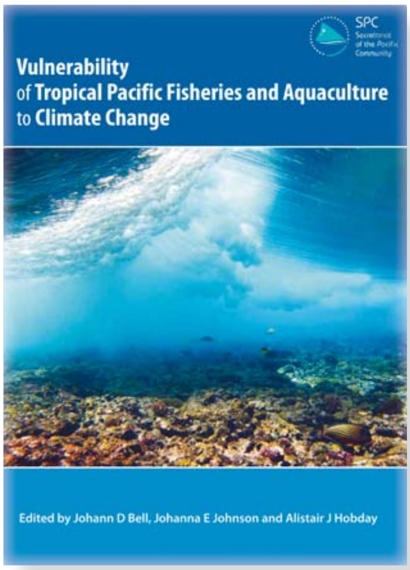
2. *Adaptations for maintaining the contribution of fish to food security*

- Restore vegetation in river catchments to prevent sediments and nutrients from entering coastal waters and putting coastal fish habitats (coral reefs, mangroves, seagrasses) under stress.
- Install fish aggregating devices to attract tuna closer to shore and make them easier for coastal fishing communities to catch.
- Develop freshwater pond aquaculture for the large inland populations of Papua New Guinea.

3. *Adaptations for maximizing sustainable livelihoods*

- Improve technical and business skills of Pacific Island communities through training in fishing and farming techniques, and provide access to micro-credit.
- Rebuild stocks of high-value export commodities (sea cucumbers and trochus).
- Develop coral reef ecotourism ventures as an alternative to deriving income from catching and selling fish.

Dr Jimmie Rodgers said that Pacific Island countries and territories can work on putting legislative and legal measures in place to help protect future generations. "I think those are some of the tangible things that we can work towards," he said. "The challenge is not to plan only for today's generations, but to use the information that we have at hand and then ask the question: What kind of Pacific do we want to see in 20 years?"



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Bagan fishing in Majuro, Marshall Islands

A* bagan *is a bait-fishing platform commonly found in Indonesia and neighbouring Asian countries. This fishing method targets small pelagic species that are sold fresh, sundried for secondary edible products or used as live bait for pole-and-line fisheries.

In August 2009, the Pacific Islands Forum Fisheries Agency (FFA) took active steps to explore the concept of implementing small-scale, pole-and-line fishing in the Pacific Islands region. The fishing method itself was previously carried out on pole-and-line boats in some Pacific Island countries but the economics of running these large-scale operations was not viable due to several logistical factors, particularly baiting ground access.

Many experts have attributed the failure of industrial pole-and-line fishing in the Pacific Islands region to a combination of reasons; but one of the factors that contributed to the restriction of baiting ground access was the exclusion of rural fishing communities and baiting ground owners from the actual ownership of pole-and-line fishing boats and seclusion to only receiving royalties for bait taken from their baiting grounds.

Now, one of the motives for encouraging small-scale, pole-and-line development is to involve stakeholders in the actual fishing operations, and encourage them to take ownership of providing bait for small-scale, pole-and-line boats. However, the bouke-ami baiting method used in large-scale, pole-and-line fishing could only be effectively used from fishing vessels of 18 m or more in length, and required many hands to perform the operation. Potential baiting alternatives were sought to complement small-scale, pole-and-line fishing.

In September 2009, FFA's Fisheries Development Adviser, Robert Stone, undertook a trip to Indonesia to observe the *bagan* bait-catching units, and this initiated the used of this method in the Pacific Islands region, noting the adverse social and environmental issues that accompany any type of fishing method implemented without a proper management plan. The first step is to trial the method to determine its effectiveness in different locations and collect data on the type of bait species, seasonal abundance, and social and environmental implications. Since then, FFA and SPC have liaised on implementing *bagan* trials in the Solomon Islands and the Republic of the Marshall Islands (RMI). FFA engaged the renowned fishing boat designer, Oyvind Gulbrandsen, to work on a suitable *bagan* design that can be used in the region and several small-scale, pole-and-line boat designs.

SPC organised the *bagan* project in Majuro in cooperation with the Marshall Islands Marine Resources Authority (MIMRA). FFA's approach is to encourage *bagan* operations to supply bait for small-scale, pole-and-line boats while SPC looks more toward addressing food security issues. Some of the species caught with *bagan*s are important food fish that can be sustainably exploited to alleviate food security concerns, or can provide an income to artisanal fishers when sold as fresh food fish, bait fish or processed food products (e.g. dried, salted, marinated).

The RMI *bagan* was built in Kiribati by the KiriCraft Central boat building company and shipped, in kit form, to Majuro at the end of October 2011. SPC's Fisheries Development Officer, William Sokimi, was assigned to work with MIMRA staff in November 2011 to assemble the *bagan* together in preparation for the second phase of the project. In February 2012, fishing trials will be

The bagan, built in Kiribati, ready to be disassembled and shipped, in kit form, to Majuro (Image: William Sokimi)

The *bagan* fishing technique

The *bagan* is a big raft anchored in bays close to shore, and equipped with a large net and a several portable bright lights or kerosene lanterns. The lights are used at night to attract small pelagic baitfish species such as anchovies, sprats, sardines, herrings, silversides, mackerels, scads and cardinals. When there is sufficient baitfish aggregated under the lights, the net is lowered to around 15-m depth and the lights dimmed to concentrate the fish closer to the *bagan*. Lights are then turned off one by one until only a single light is left on. This light is centralised above the middle of the submerged net and dimmed further to draw the baitfish to the centre. When the bait has settled directly under the light, the net is hauled with a winch fixed on the *bagan* deck, winding up ropes that are evenly spaced on the four sides of the net.

Pole-and-line fleets use a similar technique called *bouke-ami*. However, the *bouke-ami* method, which is conducted directly off pole-and-line boats, requires large boats and many hands to carry out the operation. The *bagan* method requires only three to six persons and a net that is 8 m x 8 m, while the *bouke-ami* method requires nets that are 18 m x 18 m or more.

carried out with MIMRA staff and local fishers who will eventually adopt the *bagan* and continue with fishing and marketing operations. A comprehensive data collection system will also be introduced by SPC Fisheries Development Officer, Michael Sharp, to determine the socioeconomic and food security impacts of *bagan* fishing in RMI. Arrangements are underway to recruit two Indonesian *bagan* experts to join the SPC and MIMRA team during the fishing trials. The assembled *bagan* is sitting on the dock outside MIMRA, waiting for launching. The net, lights and other accessories are already in place for the project's second phase, which be reported in detail in the next issue of the *Fisheries Newsletter.*

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The bagan *net was made of two nettings of different mesh size (Image: William Sokimi)*

Eat more anchovies

Eat lower on the marine food web and tap into a bountiful supply of protein

by Martín Hall

Image: Jill Matsumaya, FlickR Creative Commons License

Source: *Conservation Magazine*, July–September 2007 (vol. 8, no. 3)

How many people do you know who make lions, tigers, or wolves a mainstay of their diet? On land, no one looks to the top of the food chain for protein, yet that is exactly the faulty logic we apply to the sea. Our growing demand for tuna, shark, swordfish, and other top marine predators drives their prices up and encourages fishers to catch more — in many cases threatening the longevity of the stocks. The good news is that we don't have to stop eating fish to preserve these gastronomic delights for the future — but we do have to change our eating habits.

The statement that we are overexploiting the oceans, although true in terms of many of the species we now select, is actually false in terms of protein production. Consider an oversimplified example: it takes close to 60 million tonnes of potentially edible fish per year to feed the three million metric tons of the three major tropical tuna species we harvest annually. If we could replace some of our tuna sandwiches with the anchovies, sardines, squids, and other species the tuna eat, we would open up a substantial supply of protein that could feed millions more.

We can still savor seared *ahi* and grilled swordfish steaks — they have the best meat and few bones, after all — but we must reserve them as a luxury product. As long as we let the current tastes of the richest nations dictate our ocean harvests, it will be extremely difficult to reverse the overexploitation of many species. We must redistribute our harvests in an ecologically sensible way, not by adding new species to the current harvest but rather by substituting catches of depleted stocks with fishes lower on the food web.

People who are determined to eat top predators regardless of the conservation cost should consider another fact. In our amazing lack of common sense, we already catch thousands of tons of anchovies each year; but instead of consuming them directly, we grind them up and ship them to farms halfway around the world to feed chickens, pigs, and farmed fish. This practice thrives in part because fishmeal is often as cheap as plant-derived animal feeds, yet it wastes a huge source of available protein — not to mention the fuel consumed for transportation.

In some parts of the world, the message is getting through. In Peru, which has contributed up to half the world's fishmeal since the 1950s, the anchovy is beginning to be embraced as fine food. Now fresh anchovies are available in many of Lima's markets, and the government is supplying anchovies as part of its food security program.[1]

It won't be easy. But we should follow the lead of people who fish to feed their families and teach their kids not to be fussy about what is on their plates.

[1] Note from the Editor: Anchovies are among the most ecologically sound fish choices available to New Zealand residents according to the Royal Forest and Bird Protection Society, a conservation organisation that publishes a biennial "Best Fish Guide".
Source: http://fiesta.bren.ucsb.edu/~costello/research/CatchShares/photos.html

The 2011 harvest of trochus in Aitutaki, Cook Islands

by Teuru Tiraa-Passfield,[1] Richard Story,[2] and Kelvin Passfield[3]

Background on Aitutaki trochus

There have been various secondhand reports on the original introduction of trochus — *Tectus* (formerly *Trochus*) *niloticus* — to Aitutaki. Some of these have indicated that there was a single shipment of 300 shells from Fiji in 1957, although at least one report stated there were only 40 shells in that original shipment. However, an old copy of the original typewritten report written by Ron Powell, the Fisheries Officer in the Cook Islands at the time of the introduction, has surfaced. Powell, along with Loba Marsters, was a key figure in the introduction of trochus, and his report reveals some interesting facts.

In December 1956, 300 trochus were brought to Aitutaki by air transport. Mortality was high, and it was estimated that only about 100 of these survived (Powell 1957). There would most certainly have been additional mortality after the trochus were placed on the reef due to stress related to the trip. Because of the poor survival rate of this initial shipment, Powell and Marsters, who were overseeing the shipments, conducted some research and found that transporting the shells in damp bags rather than in water actually increased the survival rate markedly. Another 300 trochus were introduced in March 1957; this time with about 220 surviving (Powell 1957).

A survey was conducted in 1965 by scientists from the Smithsonian Institute, and a number of live trochus of various sizes were observed, indicating that trochus had survived and successfully reproduced. A follow-up survey was conducted by Tom Wichman and Tom Marsters (now Deputy Prime Minister) in 1974 (Wichman and Marsters 1974), and they counted more than 14,000 trochus shells, although an estimate of total stock could not be found. The report recommended a commercial harvest at that time.

Harvest history

Despite the recommendation for a harvest in the Wichman and Masters 1974 report, the first commercial harvest in Aitutaki did not occur until 1981, when an estimated 200 tonnes (t) were taken over a period of 15 months. The last harvest in Aitutaki was in 2001, when approximately 37 t were taken. Overall, approximately 600 t, with a value of approximately NZD 2 million, have been harvested during 14 separate harvests since trochus were first introduced. The total harvest history for Aitutaki is shown in the table below.

2011 harvest

The world price of trochus dropped after 2001, and in order to try and obtain the best return for the resource, the Island Council did not authorise another harvest for several years, as they were waiting for prices to improve. However, prices have remained comparatively low. In addition, a number of harvest surveys have indicated that the trochus population has not increased much, although the reason why is not clear. The lack of population increase may suggest that there is some density-dependent effect that is limiting the total shell population. It was, therefore, decided that a harvest should be undertaken in 2011, in the hope that it may stimulate some revitalisation of stocks, and also provide some additional income to the people of the island, especially around the Christmas season.

A pre-harvest survey by the Ministry of Marine Resources (MMR) (Turua et al. 2011) indicated that 18 t of shells, equivalent to one full 20-foot shipping container, could be harvested without over depleting the stock. After tendering the pre-harvested shells to select

A local family harvesting trochus (Image: Kelvin Passfield)

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a buyer, the fishery was opened by a declaration from the Island Council on 28 November. Approximately 2,000 individual, 9-kilogram (kg) quotas were issued for every man, woman, child and infant resident on the island. Each 9-kg quota attracted a "licence" fee of NZD 2. Not everyone chose to take up their allocated quota, and so much of the individual 9-kg quotas were given to other community members to use. In the end, 79 families were involved in the 2011 harvest, which is estimated to be around 17% of all households. While typically only two to four family members are involved in the actual harvest, all able-bodied family members are involved in the boiling and cleaning of the shells, and the extraction of the meat.

The harvest was planned to be open for just one week. However, after surveying households, MMR staff determined that only 12.5 t had been harvested. This was likely because weather conditions were far from perfect, as well as the fact that many families had other commitments leading up to Christmas. In order to meet the quota, the harvest period was extended for another week by the Island Council, until 13 December. By that date, the quota was reached, and the harvest period was closed.

Processing, buying and grading

After harvesting, the trochus were cooked in order to get the meat out and to clean the shells for shipping. This was usually done by boiling the shells in vats made by cutting 200-litre drums in half, and heating the water using firewood.

A survey of a number of harvesters found that it can be quite difficult to extract all of the meat and gonads from the upper twirls of the shell. This was the case especially for female trochus because the green gonad coil at the top of the shell often breaks off and is left behind, and then rots, making the whole shell smelly. In comparison, it is fairly easy to get the entire animal out whole in male trochus.

Different harvesters had several different methods of attacking this problem. Some recommended cooking the trochus in salt water for several hours, while others used fresh water with the addition of some baking powder, which they thought firmed up the gonad and made for more complete meat and gonad removal. This method, however, affected the flavour of the meat. No good solution was determined.

After several days, most of the shells were cleaned and dried. Grading started on 20 December and lasted for three days. Sellers were paid cash on the spot by the buyer, which was likely to have been a welcome Christmas bonus for them. In general,

Rima Mata of Aitutaki, cleaning her trochus shells in the lagoon (Image: Teuru Tiraa-Passfield)

Trochus shell before and after cleaning (Images: Kelvin Passfield) the shells were received in good condition, and most were A-grade. A few shells that were rejected due to smell were taken away for re-cleaning by the sellers, and then returned in good condition. The buyer was impressed with the quality of the shells, and the way the harvesters had managed to target mainly A-grade shells. In total, 8,830 kg of trochus were graded and packed. This consisted of 12,249 kg (or 65%) of A-grade, 4,269 kg (or 23%) of B-grade, and 2,312 kg (or 12%) of C-grade. Harvesters received NZD 5.50 per kg of dry A-grade shell, and less for lower grades. Overall, an average price of NZD 4.40 was earned. Total pay out to fishers was NZD 83,000.

Tag and recapture experiment

Tag and recapture studies are an ideal method to more accurately determine the population of a single stock, such as the Aitutaki trochus population. A tag and recapture stock assessment was undertaken in conjunction with the 2011 harvest. Prior to the harvest, a number of trochus were marked with a pencil mark inside the lower part of the shell. Any of these marked shells that were collected during the harvest were recorded on forms supplied to the harvesters. A future report will provide information on the results of this tag and recapture study.

Recommendations

The following recommendations are provided in order to try to improve future trochus harvests, both in Aitutaki and any other islands in the Cooks Islands where harvests may occur, such as Rarotonga.

Although minimal, there was some wasted effort by harvesters in collecting shells that were found to be outside the legal range of 8–11 cm. This could have been avoided if accurate measuring sticks were made available to everyone by the Island Council. Although MMR staff did check and reject illegal trochus while they were still alive, it is not certain that everyone could be bothered returning them to the reef in good condition.

Most of the harvesters that were interviewed indicated that there was a lot of work involved in the harvesting and cleaning process, and although they were pleased to receive the income at the end of the harvest, they were not sure they would do the same amount of work again for the same return. Quite a few of the older harvesters gave up before they had reached their quota due to the amount of work involved, and gave their quota to others. Thus, it is in the interest of future harvests to try and find faster and more efficient methods, particularly in regard to cleaning the shells, and if possible adding value to the products, particularly the meat.

Before future harvests, it will be useful to experiment with a number of processing methods to determine the best method to facilitate easy extraction of the meat and cleaning of the shell, both inside and out. A number of ideas have already surfaced during the survey of processors. For example, it was reported that in at least one previous harvest in Rarotonga, a concrete mixer with some gravel and a small amount of water was used to "tumble" clean the outer layers of encrusting algae and other material from the surface of the shell. This would be less labour intensive than the commonly used method of scraping the shell with a knife. Some quality control would be needed to ensure that all shells were properly cleaned, and they may need to still be finished off by hand. It has also been reported that in French Polynesia, people use a metal device to extract the meat from the shells without the need for boiling. These and other ideas need to be investigated and, if possible, trialled prior to the next harvest.

MMR is interested in hearing from anyone who may have information on improved processing methods, as well as information on markets for trochus meat or opercula. In particular, information on how to fully extract the meat from the raw shell would be useful, as the meat may be more valuable as an uncooked product, leaving more options available for processing.

Aitutaki trochus harvests, 1981–2011

Year	Yield (tonnes)	Estimated value per tonne (NZD)	Estimated fishers total earnings (NZD)
1981	≈200.0	850	170,000
1983	35.7		
1984	45.7		
1985	27.0		
1987	45.1	2,000	90,200
1988	18.0	3,000	54,000
1990	26.2	7,000	183,400
1992	28.0	6,350	177,800
1995	34.0	6,000	204,000
1997	18.4	6,250	115,000
1998	34.0	6,500	221,000
1999	18.0	8,250	148,500
2001	37.0	8,500	314,500
2011	18.9	Average 4,405 (5,500 for A-grade)	82,953

Future harvests

It is expected that MMR will continue to survey the trochus population on an annual basis, and when a viable harvest quota is reached (the minimum often being one shipping container or 18 t) or the world price is favourable, this process will take place again. The history of trochus harvests in Aitutaki suggests that a population can sustain a harvest every two years, or possibly more often, if the price is favourable.

Despite the difficulties encountered, valuable lessons were learned. This was considered to be a very successful harvest by all concerned, and the buyer reports that the container is now on its way to Italy, where the shells will be processed and eventually end up as button on high-end Italian designer fashions.

Acknowlegements.

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MMR staff member measuring freshly harvested trochus, and separating out any that are less than 8 cm or larger than 11cm (Image: Kelvin Passfield)

DEVFISH II project implementation update

The European Union (EU)-funded DEVFISH II project began in January 2011. The project is jointly implemented by SPC and the Pacific Islands Forum Fisheries Agency (FFA), and has five operational personnel between the two agencies. The project will run for four years and has two components: 1) domestic tuna industry development, and 2) illegal, unreported and unregulated (IUU) fishing deterrence. The project's principal objective is to increase the sustainable use of highly migratory marine resources, particularly tuna, to alleviate poverty in P-ACP states, and reduce constraints to domestic tuna industry development.

During the first six months of implementation, the project focused on establishing and developing a work plan at the first project steering committee meeting at SPC in April 2011. This was followed by ongoing consultation with members and private sector stakeholders. A detailed work plan was submitted to the EU in July 2011, and with some subsequent modifications, it was approved for implementation. Active implementation began soon thereafter at both SPC and FFA. This article gives a brief summary of some of the key project activities to date, and provides plans for the remainder of the first implementation year (end of June 2012).

At SPC, the project focuses on support and development of national fisheries associations and the Pacific Island Tuna Industry Association (PITIA), and on the coordinated assessment of fisheries and enforcement databases. A round table meeting of national fisheries associations and PITIA was hosted in Fiji as part of the work programme planning. The project also supported PITIA and national association representation at the 2011 Pacific Tuna Forum in Palau. PITIA is playing a key role in ensuring liaison between the project and national associations. In early 2012, the project will support a consultancy study to examine options and opportunities for the sustainable fiscal and programme operation of both PITIA and national fisheries associations.

In support of the coordinated assessment of enforcement and fisheries databases, the project IUU liaison officer, Bryan Scott, was able to undertake a number of country visits to initiate work on improved harmonisation of hardware and software systems between Marine Stewardship Council (MSC) agencies.

At FFA, the project has commenced a number of regional and national level initiatives. As a baseline for measuring project success, the project has supported the publication of the major 2011 FFA commissioned study on "Market and Industry Dynamics in the Global Tuna Supply Chain" (see article on p 23).

A comprehensive curriculum for the training of competent authority (CA) fisheries inspectors has been developed, and the first regional fisheries inspectors training course is scheduled for delivery in the first half of 2012.

A Fairer Slice for Pacific Peoples

DEVFISH II

2011-2014

The project is also providing assistance to five member countries in establishing the legal and organisational frameworks required for CA.

To assist with CA capacity building, terms of reference have been developed for an external audit of established CAs in Papua New Guinea (PNG) and the Solomon Islands, with the first audits scheduled for the first half of 2012. This is intended to ensure readiness for an audit visit from the EU.

In support of industry compliance with CA standards, the project has facilitated HACCP[1] training for processing staff and vessel crews in Fiji, and sensory evaluation training for processing personnel at the Soltai cannery in the Solomon Islands. To ensure that FFA member country processing facilities are operating in compliance with social accountability standards, the project collaborated with the Parties to the Nauru Agreement (PNA) Office, PNG and the Marshall Islands to commission a programme for processing facility certification against the international SA8000 standard. The SA8000 standard is a global social accountability standard for decent working conditions, developed and overseen by Social Accountability International (SAI), which provides certification against international standards in relation to key aspects of employment relations, including child labour, forced labour, health and safety, freedom of association,

[1] HACCP = hazard analysis and critical control points

discrimination, disciplinary practices, working hours, remuneration and management systems. An SA8000 expert was commissioned to undertake processing facility against these standards and assist in setting up documentation systems in support of standards compliance. It is envisaged that the facilities included in the work will also become SA8000 certified in 2012.

In other more regional initiatives, a tender has recently been advertised for a study of regional transshipment with a view to enhancing potential economic benefits to members. This study will be completed by mid-2012. A contract has also been awarded for the preparation of a regional monitoring, control and surveillance (MCS) training needs analysis covering all FFA members. This study will guide the future delivery of MCS training in support of coordinated national MCS strategies. The project is also supporting national initiatives for the coordinated implementation of information management systems. In support of IUU mitigation, an IUU specialist will provide services to members in IUU compliance and EU certification for domestic-registered vessels.

Also in support of MCS capacity building, the project has provided consultancy inputs into the ongoing development of the Pacific Island Regional Fisheries Observer (PIRFO) programme with the development of the Observer Debriefer qualification and training programme, the preparation of PIRFO training audit guidelines, and the development of the PIRFO trainer qualification.

A number of national level initiatives have also been implemented or are in the process of implementation.

In Fiji, assistance has been provided to the Fiji Tuna Boat Owners Association in undertaking the assessment process for MSC certification. Also in Fiji, but with potential implications for other counties involved in the southern albacore fishery, the project has assisted with the first phase of a study to mitigate whale depredation of tuna catches.

In Kiribati, the project is assisting with the establishment of a coordination office for the monitoring of mandatory crewing in the PNA purse-seine fishery.

In Samoa, a study has been commissioned to review economic performance in the small boat tuna longline fishery, and plans are under development for a study of small port development and an examination of alternative engine power options in the small vessel tuna fishery.

Following a project visit to Tonga, a tuna fishery investment strategy will be developed in 2012 and a similar activity is likely to take place in the Cook Islands. The project is also assisting the Cook Islands in considering options for the possible establishment of a liaison office in Pago Pago, American Samoa to provide services to Cook Islands-licensed vessels that use Pago Pago as a key port. This liaison function is also being considered in relation to a possible broader subregional function.

For the Marshall Islands, the project assisted with the publication of an investment promotion information kit to be made available to potential fisheries investors.

A series of country visits has been undertaken in PNG to assist with the preparation of a fisheries sector training, needs analysis study that was completed in October 2011 along with a draft policy on fisheries domestication.

While this is not a comprehensive summary of DEVFISH II activities, it does provide an indication of the range of actions that have been implemented to date.

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FFA releases major global tuna industry status report

The tuna industry is one of the most complex and highly dynamic of the world's seafood industries. Hence, as major stakeholders in the global tuna industry, it is critical that Pacific Island countries have a comprehensive understanding of supply chain dynamics, which extend beyond issues pertaining to tuna resource management. An enhanced understanding of how industry drivers and market dynamics shape the global tuna supply chain and influence the major industry players is critical to Pacific Island countries achieving stronger control and deriving greater economic benefits from their tuna resources.

In recognising the need to develop a systematic approach to improving the provision of accurate and useful global tuna industry and market information to its Pacific Islands members, the FFA Secretariat commissioned consultants, Amanda Hamilton, Antony Lewis, Mike A. McCoy, Elizabeth Havice and Liam Campling to undertake a study and prepare a report on "Market and industry dynamics in the global tuna supply chain".

The report provides an overview of the current status of the global tuna industry in terms of major tuna fishing fleets, tuna trading companies, processing sites and principal markets. The study largely focused on industry and market developments during a 12–24 month period, spanning the beginning of 2009 to late 2010. In addition, future prospects and potential developments in the following 12–24 months (2011–2012) are discussed, as well as important historical events of direct relevance to the status of the current industry. Discussion is also provided on the implications of major industry and market developments for Pacific Island countries.

The report can be downloaded from:
http://www.ffa.int/node/567

Taiwanese purse-seine vessel transshipping in Majuro Lagoon, Marshall Islands (Image: Tony Lewis)

NFMRA withdraws invitation to Spanish purse-seiners to fish in Nauru after refusal to abide by high seas closure

Source: *Nauru Fisheries and Marine Resources News*, 3 December 2011[1]

On 2 December 2011, the Nauru Fisheries and Marine Resources Authority (NFMRA) withdrew the invitation that it had offered to Spanish tuna purse-seiners of the *Organización de Productores de Grandes Atuneros Congeladores* ***(OPAGAC) to fish in Nauru waters in 2012.***

NFMRA has invited all purse-seine fleets with a history of fishing in the Nauru exclusive economic zone (EEZ) to purchase vessel-days from the limited pool of fishing opportunities in the Nauru EEZ in 2012. However, any purse-seiner that fishes in Nauru must abide by the laws of Nauru,[2] and one of these laws[3] — which reflects a formal agreement by all PNA[4] countries that they will not licence purse-seine fishing vessels that fish on large areas of the high seas — apparently stuck in the throat of the Spanish fleet.

Following informal enquiries by OPAGAC asking, in effect, if Nauru still intended to uphold the PNA agreement prohibiting fishing on the high seas, NFMRA withdrew its offer to OPAGAC to bid for fishing days.

The Chairman of the NFMRA Board of Directors, Mr Jesaulenko Dowiyogo said, "This decision to withdraw the offer to the Spanish fleet has my full blessing. We are tired of foreign fleets using their economic leverage to undermine conservation actions by Pacific Island countries."

Chairman Dowiyogo went on to point out that Nauru can afford to do without the Spanish fleet because other fleets already have the capacity to purchase and use all of the purse-seine vessel-days fishing opportunities available in the Nauru EEZ for 2012.

He said, "Because of the PNA Vessel Days Scheme, we can maximise the revenue from our zone without needing to resort to licensing every last fishing vessel out there. Pacific tuna fisheries have reached the limit of their expansion. Any more and they will be overfished, and then we will all lose out — foreign fleets as well as Pacific Island economies. Nauru has learned many lessons about the sustainability of natural resources over the past few years, and we are determined that our tuna resource should go the same way as some of our other resources. With sound national management and effective PNA cooperation there is no reason why the regional skipjack tuna stock should not be fully sustainable, at present levels of catch, into the foreseeable future."

The main purse-seine fleets fishing in Nauru in 2011, in decreasing order of days spent in zone, are:

- the FSM Arrangement[5] (comprising vessels fishing on behalf of other PNA members)
- USA
- Taiwan
- Korea
- Vanuatu

All other fleets spent less than 100 days each in the Nauru EEZ in 2011.

Adapted fom an original illustration by Jipé LeBars

[1] http://nfmra.blogspot.com/2011/12/nfmra-withdraws-invitation-to-spanish.html
[2] See: http://ronlaw.gov.nr/
[3] See: http://sites.google.com/site/naurufisheries/home/legislation/Nauru_Fisheries_Amendment_Regulations_2010.pdf?attredirects=0&d=1
[4] PNA = the group of Pacific Island countries that are Parties to the Nauru agreement, a regional fisheries institution that collectively aims to secure the long-term sustainability of tuna fisheries in the western tropical Pacific, and to obtain maximum economic benefit within those sustainability limits for the member countries whose waters are fished.
[5] http://www.ffa.int/node/30

Implementing the full vessel day scheme[1]

Source: *Nauru Fisheries and Marine Resources News*, 7 December 2011[2]

The Nauru Fisheries and Marine Resources Authority (NFMRA) has changed the basis of its purse-seine fishery licence fee structure for 2012.

Instead of permitting foreign vessels to fish until the limit of Nauru's total annual allocation of vessel fishing-days is reached in return for a fixed licence fee — the so-called "Olympic" allocation — NFMRA is now allowing purse-seine fleets to purchase exclusive vessel-days fishing opportunities. These can only be used in the Nauru exclusive economic zone (EEZ) in 2012.

Under the previous system, the Nauru EEZ had to be closed to most classes of purse-seiners when the Nauru zone allocation was reached. Under the new system, vessels will be able to pace their fishing, and use their fishing days entitlements in Nauru at any point throughout the 2012 season.

The minimum price for a single purse-seine fishing day in the Nauru EEZ in 2012 is USD 5,000, and NFMRA has put 1200 of these vessel-day fishing opportunities up for sale to any vessel-owner or fleet association that pays the access fee for a purse-seine fishing licence, and is willing to abide by the conditions of the licence.

The first block of days was sold yesterday to a fleet, which has been increasing its effort in the Nauru EEZ in recent years.

An additional number of 2012 Nauru fishing days — over 400 — are being held in reserve for development purposes. NFMRA will control the use of these days and the disposition of the 12,000 tonnes of tuna that are likely to result from them.

NFMRA will be inviting interested vessel-owning companies to become partners or contractors in harvesting and marketing Nauru fish caught under this development arrangement.

1 The vessel day scheme (VDS) is a scheme where vessel owners can purchase and trade days fishing at sea in places subject to the Parties to the Nauru Agreement (PNA). The purpose of the VDS is to constrain and reduce catches of target tuna species, and increase the rate of return from fishing activities through access fees paid by distant water fishing nations (DWFNs). The total allocation of fishing days is set and apportioned between Pacific Island members for one-year periods up to three years in advance. Source: http://www.ffa.int/taxonomy/term/6

2 http://nfmra.blogspot.com/2011/12/implementing-full-vds.html

Hauling the purse seine (Image: Marc Taquet FADIO/IRD, Ifremer)

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Rebuilding fisheries: There's a smartphone application for that

***By Mike Sweeney*[1]**

Source: Cool Green Science, The conservation blog of The Nature Conservancy

My daughter and I love to fish (on my iPhone). She's 2; I'm a bit older, but we're both excellent anglers (on my iPhone). Flick Fishing and Fishing Kings are our favorites. It's no substitute for a father-daughter fishing trip, but there's much less gear involved, and we never have to retie our lines. I'm keen on teaching her where her food comes from and never thinking fish comes from the grocery store. Catching things to eat is the world's oldest profession, despite what they say about the other one. If you think about it, of everything we eat today, the only wild animals we still really hunt for food are fish.

The problem is that we're getting too good at it.

That hunt is now going high tech in much bigger ways than my iPhone games. Off our California coast, environmentalists and fishermen have teamed up to use apps and iPads to not only find the right fish, but also to make sure we don't catch them all.[1] Keeping a stable population of fish healthy ensures there will be fish left to fish tomorrow. If you're a commercial fisherman, you are required to record the number of fish you caught and where you caught them. Typically, you send all that data on hand-written logs into the federal fisheries agency and that's the last you see of it. Enter eCatch, a new app developed by The Nature Conservancy and fishermen that lets them load their catch data at sea and have real time access to the latest information on where the fish are — the ones they want to catch and the ones they need to avoid.

Sharing information on what you caught and where, is not the norm for fishermen. They tend to be the original rugged individualists and too often get caught in the race to catch more fish before the other guy does. The results of this have been bad for everyone: rapidly declining fish populations and fishermen going out of business. But a group of fishermen off our coast is trying to change the game by collaborating and sharing information.

The basic idea is that some fish are getting scarce. And when fish get scarce, some get endangered, which means tough regulation that makes it hard to stay afloat. If you want to catch the abundant fish, you need to know a lot about fishing patterns and spend countless hours at sea. Fishermen need to be smart to make sure they don't accidentally catch too many threatened fish and get sent back to the docks. To improve their success they are joining forces with other fishermen to manage this risk. It turns out that sharing catch data is a powerful way to do that. When a group of fishermen teams up and shares what they caught when and where, they build a powerful database of fishing information that helps them all make money and ensure there will be fish to catch tomorrow.

By working together, the fishermen now have a way as an industry to manage their fishery sustainably themselves. The results are pretty impressive so far. Fishermen with iPads are sharing where overfished species are with their counterparts. They're taking advantage of each others' experience at sea by avoiding areas where someone caught overfished species and learning where the more abundant species are. And they're looking at overall trends to see if their fishing grounds are staying healthy and abundant.

Both fishermen and environmentalists are committed to a thriving and strong ocean, and by utilizing technology and sharing information, we will ensure there'll be real fish left for our kids to enjoy.

Boats in Morro Bay, California harbour (Image: Kathleen Goldstein)

[1] Mike Sweeney is executive director of The Nature Conservancy in California.
[2] http://blog.nature.org/2011/11/rebuilding-fisheries-theres-an-app-for-that/
[3] The New York Times has published an interesting article about The Nature Conservancy work in California with fish stocks and the fishers that depend on them: "Partnership preserves livelihoods and fish stocks", available from: http://www.nytimes.com/2011/11/28/science/earth/nature-conservancy-partners-with-california-fishermen.html

Ciguatera fish poisoning in the Pacific Islands (1998 to 2008)[1]

Mark P. Skinner,[2] Tom D. Brewer,[3] Ron Johnstone,[4]
*Lora E. Fleming[5,6] and Richard J. Lewis[7]**

Abstract

Ciguatera is a type of fish poisoning that occurs throughout the tropics, particularly in vulnerable island communities such as the developing Pacific Island countries and territories (PICTs). After consuming ciguatoxin-contaminated fish, people report a range of acute neurologic, gastrointestinal, and cardiac symptoms, with some experiencing chronic neurologic symptoms lasting weeks to months. Unfortunately, the true extent of illness and its impact on human communities and ecosystem health are still poorly understood.

A questionnaire was emailed to the Health and Fisheries Authorities of the PICTs to quantify the extent of ciguatera. The data were analyzed using t-test, incidence rate ratios, ranked correlation, and regression analysis.

There were 39,677 reported cases from 17 PICTs, with a mean annual incidence of 194 cases per 100,000 people across the region from 1998-2008 compared to the reported annual incidence of 104/100,000 from 1973-1983. There has been a 60% increase in the annual incidence of ciguatera between the two time periods based on PICTs that reported for both time periods. Taking into account under-reporting, in the last 35 years an estimated 500,000 Pacific islanders might have suffered from ciguatera.

This level of incidence exceeds prior ciguatera estimates locally and globally, and raises the status of ciguatera to an acute and chronic illness with major public health significance. To address this significant public health problem, which is expected to increase in parallel with environmental change, well-funded multidisciplinary research teams are needed to translate research advances into practical management solutions.

Introduction

The developing Pacific Island countries and territories (PICTs) are under increasing threat from both acute and chronic diseases ranging from HIV/AIDS to obesity. In addition, people residing in PICTs are highly vulnerable to environmental impacts from the sea level rise and extreme weather events associated with global warming. Ciguatera is a prevalent tropical and subtropical disease that has been an under-appreciated cause of acute and chronic disease in island communities and might be increasing in incidence due to increasing vulnerabilities (i.e. poverty, global warming, eutrophication) in these populations (Lehane and Lewis 2000; Lewis 1992).

Ciguatera is caused by the consumption of coral reef fish contaminated by ciguatoxin and related toxins from dinoflagellates (microalgae) and cyanobacteria (Lehane and Lewis 2000; Friedman et al. 2008). The ciguatoxin bioaccumulates up the food web, either directly from incidental uptake by herbivorous fish or indirectly by carnivorous fish (Lehane and Lewis 2000). After the consumption of coral reef fish contaminated with ciguatoxin, people experience potentially severe acute neurologic, gastrointestinal and cardiac symptoms as well as, in some cases, chronic neurologic symptoms lasting weeks to months (Lehane and Lewis 2000, Friedman et al. 2008). Ciguatera occurs globally, in coastal tropical waters, and is particularly prevalent across the PICTs. Cases of ciguatera have also been reported in temperate regions of the world due to travel and coral reef fish export. Ciguatera poisoning is often under-diagnosed and under-reported, with only 2 to 10% of cases reported to health authorities (Friedman et al. 2008). Estimates of the incidence of ciguatera in Oceania have ranged from 0.5/10,000/year in Hawaii to 5,850/10,000/year in French Polynesia (Friedman et al. 2008). Fish is the staple protein source in many PICT communities, with many islands in the region suffering ongoing outbreaks of ciguatera leading to potentially significant impacts on large portions of the population of small

[1] This paper was first published in the December 2011 Issue of *PLoS Neglected Tropical Diseases* (available at: http://www.plosntds.org/article/info%3Adoi%2F10.1371%2Fjournal.pntd.0001416)

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island communities when toxic fish are consumed (Lewis 1992).

Dinoflagellates of the genera *Gambierdiscus,* that grow epiphytically on macro- and turf-algae on coral reefs, produce the ciguatoxins predominantly responsible for the disease known as ciguatera. Coral reef damage, or when algal growth is not controlled by herbivorous fish, provide increased potential habitat for *Gambierdiscus* growth that might increase the risk of ciguatera (Tester et al. 2010). Despite extensive research, we know little about the ecology and the environmental factors that cause the blooms of the ciguatera caustive organisms, nor do we understand the role (if any) of other dinoflagellate genera including *Ostreopsis* (palytoxin producers) and *Prorocentrum* (okadaic acid and dinophysistoxins producers) or marine cyanobacteria (Rongo and van Woesik 2010). Presently, ciguatoxin can only be detected in fish and *Gambierdiscus* in specialized labs, and diagnosis in humans is based almost exclusively on symptoms associated with the recent consumption of a potential ciguateric fish; factors that hamper its effective management and highlight important research needs (Lehane and Lewis 2000; Friedman et al. 2008).

A number of factors have been associated with ciguatera cases and the presence of ciguatoxic dinoflagellates. Military activities causing coral reef damage in the Pacific, including from World War II, and nuclear test explosion programs, have been linked with outbreaks and changing incidence of ciguatera in some locations (Ruff 1989). The prevalence of ciguatera in the South Pacific increases dramatically where average sea surface temperatures are at least 28 to 29^{0}C (Llewellyn 2010). Elevated sea surface temperatures associated with global warming are believed to already be exacerbating the extent and the range of ciguatera (Chateau-Degat et al. 2007; Hales et al. 1999). Reportedly, ciguatera occurrences are most prevalent in the warmest regions of the Caribbean, and all indigenous ciguatera cases have occurred where annual average temperatures are >25^{0}C (Tester et al. 2010). Nutrient enrichment and warming sea surface temperatures have been shown to stimulate *Gambierdiscus* growth, which results in higher cell densities (Parsons et al. 2010).

Benthic dinoflagellate species, including those of the genera *Gambierdiscus*, might have extended biogeographical ranges, induced by human activity. For example, benthic dinoflagellates are likely to be able to colonize previously unoccupied locations through transport in ship ballast (Burkholder et al. 2007). Certain species of *Gambierdiscus* has now been found to be highly ciguatoxic compared to the other species (Chinain et al. 2010), and blooms of these species are likely to contribute most to ciguatera risk.

Given changes in global climate patterns, increased degradation of coastal marine environments through coastal development and land run-off, and increased exploitation of coastal marine resources, the incidence of ciguatera cases is predicted to continue to increase in the future (Tester et al. 2010; Stinn et al. 2000). Therefore, we hypothesized that ciguatera incidence is an increasing human health and ecological concern across the PICTs. To test this hypothesis, we report on changes in ciguatera incidence across the Pacific, and the social consequences of changing ciguatera incidence by comparing two 11 year periods of data: 1973-1983 vs 1998-2008.

Methods

The Secretariat of the Pacific Community, the Institut Louis Malarde (Tahiti), the Institut Louis Pasteur (New Caledonia), and Institute for Research and Development (IRD) organized a Ciguatera workshop held in Noumea, October 2008. At this workshop, many island nation delegates declared a need for the ciguatera concern to be better addressed. To start to understand the current extent and nature of the ciguatera problem, we distributed a questionnaire to all PICTs (Supporting information S1). Ciguatera records used in this study are housed in each PICTs government health institution (Ministries and Departments of Health and Public Health).

Questionnaire

To obtain the ciguatera records for the period of 1998 to 2008, we first contacted the Secretariat of the Pacific Community (SPC), Division of Fisheries, Aquaculture and Marine Ecosystems (FAME) to obtain the list of institutions responsible for maintaining ciguatera records within PICTs. We considered these repositories were comaparable to the data collection repositories used in the Lewis et al. study (Lewis 1986). The questionnaire was sent by email to the institutions in October 2009. Updates on the returning of the questionnaires were sent to PICTs on four occasions over the period, and questionnaires were returned from the PICTs up until April 2010.

The questionnaire was developed by the co-authors in collaboration with the PICTs. The questionnaire included questions and definitions from prior ciguatera studies to provide consistency of data gathering and allow comparison across studies. The 3 key sections of the questionnaire collected information on: 1) Temporal incidence of ciguatera; 2) Environmental disturbance, to examine if coral reef condition and occurrence of coral bleaching and cyclones might influence ciguatera incidence (these data were considered purely speculative on the part of the respondent); and 3) Social consequences of ciguatera including changing diet and associated medical conditions, proactive and reactive management of ciguatera, and the desire for external assistance in response to ciguatera.

Statistical analyses

1) Temporal incidence of ciguatera

To determine whether the per capita incidence of ciguatera has increased significantly, as hypothesized, comparisons are made between the data from this study (1998-2008) and the work of Lewis (1986) who reported on the epidemiology of ciguatera in the Pacific for the years 1973 to 1983. We tested for significant change in ciguatera incidence across PICTs by comparing mean annual incidence (per 100,000 people) within each PICT in each time period using a paired t-test, controlling for missing ciguatera values. We tested for overall change in ciguatera incidence using annual incidence (per 100,000 people) means across all PICTS for the two time periods using a independent-sample *t*-test and linear regression analysis, controlling for missing ciguatera values. All total incidence and incidence mean values were normalized prior to analysis using a natural log transformation. We also present the rates ratio (1998-2008 incidence/1973-1983 incidence), controlling for missing values.

2) Environmental disturbance

We tested whether ciguatera incidence correlated with the incidence of cyclones or bleaching using independent-sample t-test. We also tested whether ciguatera incidence correlated with coral reef condition using spearman rank correlation. We used natural log transformed total incidence (per 100,000 people) within PICTs from 1998–2008 as our measure of incidence for all environmental disturbance analyses, controlling for missing ciguatera values.

3) Social consequences of ciguatera

We tested whether the per capita incidence of ciguatera was associated with diet change, secondary medical problems, reactive management, proactive management, and perceived management benefit from additional support across the PICTs surveyed using independent-sample t-test, controlling for missing ciguatera values. A number of respondents did not complete this section of the questionnaire. Therefore, to ensure that non responses were not due to low or high ciguatera incidence, we also compared incidence rates between PICTs that responded and PICTs that did not, using independent-sample t-test.

Results

Nearly all PICTs responded (17 or 85%), with half fully completing the ciguatera questionnaires. Whilst we contacted the health authorities for the ciguatera data (which were returned by the health authorities in all cases), other questions were left incomplete as they were not directly about the ciguatera health issue or

Table 1. Ciguatera cases and mean annual incidence rates per 100,000 people for PICTs: 1998–2008.

PICT	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Population	Incidence
Cook Islands	215	156	138	133	183	227	469	421	258	245	242	2,687	17,000	1,436.90
French Polynesia	1,890	1,890	702	640	779	620	583	438	-	420	572	8,534	259,600	328.74
Fiji	1,754	2,827	1,932	1,715	1,100	559	547	428	617	772	1,004	13,255	837,000	143.97
Guam	1	7	7	5	5	4	0	4	4	2	3	42	165,000	2.31
State of Hawaii*†	-	41	37	59	68	64	35	27	25	18	31	405	1,250,000	3.24
Kiribati	361	467	675	524	463	184	63	77	46	64	259	3,183	92,500	312.83
North Marianas*	65	30	40	41	40	33	57	81	43	35	29	494	80,400	55.86
Marshall Islands*	-	118	112	178	482	171	233	195	245	178	210	2,122	51,000	416.08
New Caledonia	74	38	22	16	14	4	10	6	24	13	18	239	230,800	9.41
Nauru	0	0	0	0	0	0	0	0	0	0	0	0	10,065	0
Niue	0	0	0	0	20	0	1	2	15	1	11	50	1,500	303.03
Palau*	1	1	0	0	0	0	0	2	1	0	0	5	19,900	2.28
Samoa	1	4	3	2	3	5	2	-	-	-	-	20	180,741	1.58
Tokelau	58	30	39	20	43	20	18	7	14	16	14	279	1,609	1,576.36
Tonga	-	-	-	21	25	34	30	36	-	-	-	146	101,000	28.91
Tuvalu	0	0	12	0	0	0	36	1	34	4	2	89	9,600	84.28
Vanuatu	127	815	873	580	556	811	865	952	974	905	669	8,127	186,000	397.21
Wallis & Futuna	0	0	0	0	0	0	0	0	0	0	0	0	13,400	0
Total	**4,547**	**6,424**	**4,592**	**3,934**	**3,781**	**2,736**	**2,949**	**2,677**	**2,300**	**2,673**	**3,064**	**39,677**	**3,507,115**	**194.63**

*omitted from independent-sample t-test comparing annual means across time periods, and rates ratio calculation.
†omitted from paired t-test comparing national means across time periods.
Note: Total incidence is the average annual incidence (per 100,000 people) for all PICTs for the entire 11 year period, controlling for missing values and excluding the state of Hawaii.
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were sent to the other government authorities to be fully completed.

Within the 35 year period (1973-2008), including the study by Lewis (1986) and this study, there was a clear overall increase in CPF incidence; however, the results show inter-PICT incidence variability between the two time periods (Figure 1). Cook Islands, Vanuatu, Fiji, Tokelau, Marshall Islands, Niue, Tonga, and Palau all have increased ciguatera incidence (Table 3). Others have shown a decrease in ciguatera incidence in comparison to the other PICTs (such as Tuvalu and New Caledonia). From 1973-1983, only four nations demonstrated a ciguatera incidence over 300/100,000; now seven nations have an incidence over this value. Fiji now

Table 2. Ciguatera cases and incidence rates/100,000 for selected islands of the participating PICTs: 1998–2008.

PICT	Island group	Ciguatera cases	Population	Mean incidence**
French Polynesia	Gambier	542	1,337	4,504
	Marquesas	2,636	8,632	3,393
	Tuamotu	3,590	15,510	2,571
	Australes	1,617	6,310	2,567
	Society	2,399	227,807	105
Vanuatu	Penama	1,855	26,600	699
	Sanma	1,933	36,100	488
	Malampa*	1,424	32,700	483
	Torba	329	8,800	341
	Shefa	1,969	54,400	329
	Tafea	537	29,000	169
Marshall Islands	Majuro	1,081	25,400	425
	Ralik chain	366	19,915	186
	Ratak chain	650	5,525	1,177
Kiribati	Southern Kiribati	413	1,519	2,502
	Central Kiribati	630	7,550	755
	Line Island	288	8,809	295
	Northern Kiribati	1,840	60,198	227
	Kanton (Phoenix)	13	41	2,927

*The numbers for Malampa were from 1998–2006.
**Incidence = cases/100,000 people.
doi:10.1371/journal.pntd.0001416.t002

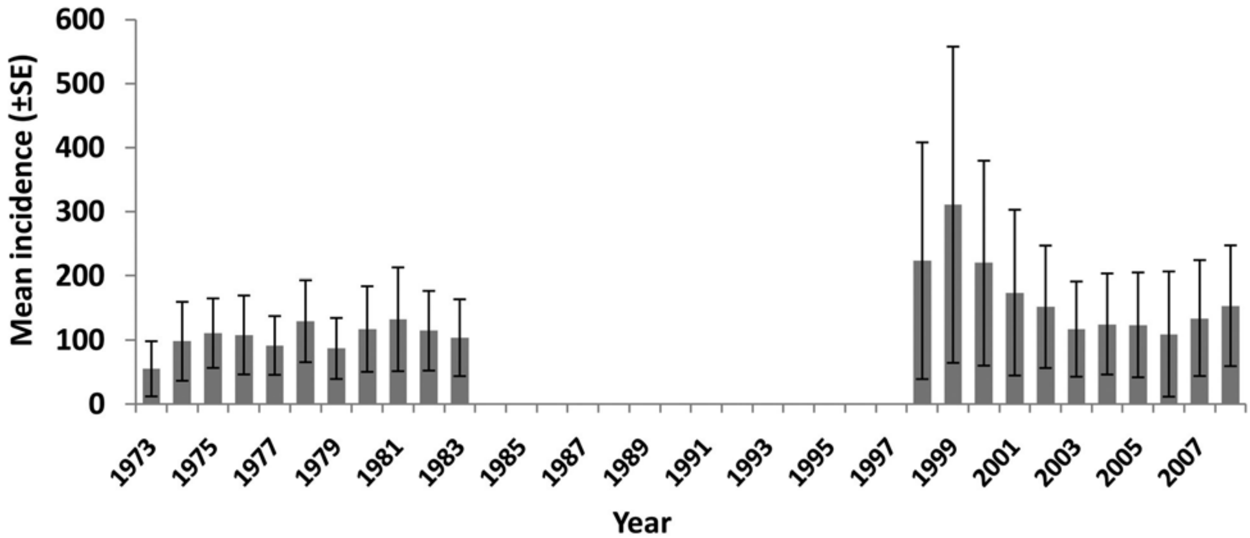

Figure 1. Annual incidence of ciguatera in the Pacific. Mean annual incidence (per 100,000 people) of ciguatera across Pacific Island Countries and Territories (PICT) from 1973-2008 are reported. Hawaii, North Marianas, Marshall Islands and Palau were omitted because comparable data was not available for both time periods.

outranks French Polynesia as the nation with the highest number of ciguatera cases. Previously only four nations had over 2,000 ciguatera cases; recently six nations reported ciguatera cases over this value. Fiji, French Polynesia, Vanuatu, Kiribati, Cook Islands, and Tokelau all demonstrated an increase in the number of ciguatera cases; New Caledonia, Tuvalu and Guam showed a decrease in the number of cases.

Table 3. PICT rankings by ciguatera incidence/100,000: 1973–1983 vs 1998–2008.

PICT	1973–1983		1998–2008		
	Incidence	**Rank**	**Incidence**	**Rank**	**Δ Rank**
Cook Islands	2	16	1,453	2	>15
French Polynesia	565	2	344	3	<1
Fiji	17	11	144	8	>3
FSM	2	16	NR		NA
Guam	8	14	2	14	0
State of Hawaii	NR		3	18	NA
Kiribati	393	4	314	7	<3
Marshall Islands	282	5	416	4	>1
Nauru	11	13	0	16	<3
New Caledonia	148	6	10	12	<6
Niue	84	8	333	6	>2
North Mariana	130	7	56	10	<3
Palau	0	18	5	13	>4
Samoa	57	9	2	15	<6
Tokelau	995	1	1,554	1	0
Tonga	17	12	29	11	>1
Tuvalu	462	3	83	9	<6
Vanuatu	22	10	397	5	>5
Wallis & Futuna	5	15	0	16	<2

1973–1983 data (Lewis 1986); NR = No response.
doi:10.1371/journal.pntd.0001416.t003

Table 4. Change in the incidence of ciguatera: 1973–1983 vs 1998–2008.

	1973–1983 Mean (SD)	1998–2008 Mean (SD)	t	p-value (r^2)
PICT^	167.3 (209.7)	300 (479.6)	−0.065	0.949
Year†	104.3 (21.6)	167.3 (61.5)	−3.617	0.002
Year‡	104.3 (21.6)	167.3 (61.5)	3.114	0.005 (0.33)

^paired sample t-test.
†independent-sample t-test assuming equal variance.
‡linear regression.
doi:10.1371/journal.pntd.0001416.t004

Temporal incidence of ciguatera

The reported cases for the recent 11 year period showed high levels of inter-year variability within and between PICTs. In Fiji, Kiribati and French Polynesia, more cases occurred at the start of the period. Annual reported cases peaked around the middle of the period at Cook Islands, Marshall Islands, Tokelau, Mariana's, and Hawaii. Reported cases in Vanuatu peaked towards the later part of the 11 year period and since 2005, Fiji experienced an increase in the number of ciguatera cases. Finally, Palau, Hawaii, Guam, Samoa, Wallis and Futuna, and Nauru all had relatively consistent incidence rates of under 5/100,000 (Table 1). Additional data relating to ciguatera incidence within PICT archipelagos are presented in Table 2.

Statistical analysis of temporal change in ciguatera incidence showed varied results. There was no statistically significant difference between 1973–1983 mean incidence and 1998-2008 mean incidence across PICTs (p = 0.949), comparing all PICTs (except the State of Hawaii which was not presented by Lewis (1986)) using paired t-test (Table 4). However, there was a highly significant difference in mean incidence, between the two time periods when comparing mean incidence across years (p = 0.002), using independent-sample t-test. Linear regression analysis of annual mean incidence from 1973 to 2008 was also statistically significant (p = 0.005) despite high inter-year variability. The rate ratio (1998-2008 mean annual incidence/1973-1983 mean annual incidence) was 1.60; therefore, there was a 60% increase in the mean annual incidence from the earlier period to the more recent period. Hawaii, North Marianas, Marshall Islands, and Palau were omitted for the independent sample t-test, regression analysis and the rate ratio due to data limitations (Table 1).

Environmental disturbance

Of the 18 PICTs in this study, 11 reported on all (i.e. coral bleaching, cyclone incidence and perceived reef condition), whilst New Caledonia reported only on coral bleaching (Table 5). All three environmental disturbance types were positively related to ciguatera incidence. However, there was no statistically significant correlation between mean annual ciguatera incidence and occurrence of bleaching ($p = 0.20$), cyclone incidence ($p = 0.17$) or perceived coral reef condition ($p = 0.57$).

Social consequences of ciguatera

Responses to questions relating to the social consequences of ciguatera demonstrated that the incidence of ciguatera might be having a negative impact on PICT communities. Seven PICTs reported changes in diet as a result of ciguatera, whilst six PICTs reported that there was no change in diet as a result of ciguatera. Also, seven PICTs reported secondary medical problems (such as diabetes due to dietary changes) as a result of ciguatera. Five PICTs reported both a change in diet and secondary medical problems as a result of ciguatera. Seven PICTs reported taking reactive management measures (such as closure of fishing areas) to manage ciguatera outbreaks, whilst four PICTs reported taking no reactionary measures. Four PICTs reported that preventative management (such as catchment management) was occurring, whilst four PICTs reported that there was no preventative management. Eight PICTs reported that additional support would improve the management of ciguatera, whilst four reported that it would not.

There was a positive and marginally significant relationship between changing diet and per capita incidence of ciguatera ($p = 0.06$), and secondary medical problems and per capita incidence of ciguatera ($p = 0.08$) (Table 6). Neither reactive nor proactive management was correlated with per capita incidence of ciguatera. However, perceived improvement in management as a result of increased support was positively correlated with per capita incidence of ciguatera ($p = 0.013$). There was no significant difference ($p \leq 0.05$) in per capita incidence of ciguatera between nations that did and did not respond to questions on the social consequences of ciguatera.

Table 5. Cyclones, coral bleaching and reef conditions reported by PICT: 1998–2008.

PICT	Bleaching	Cyclone	Reef Condition
Cook Islands	Yes	Yes	Poor
French Polynesia	-	-	-
Fiji	-	-	-
Guam	Yes	Yes	Poor
State of Hawaii	No	No	Good
Kiribati	No	No	Good
North Marianas	-	-	-
Marshall Islands	Yes	Yes	Good
North Caledonia	Yes	-	-
Nauru	-	-	-
Niue	Yes	Yes	Fair
Palau	No	No	Good
Samoa	Yes	Yes	Good
Tokelau	Yes	Yes	Fair
Tonga	Yes	Yes	Fair
Tuvalu	-	-	-
Vanuatu	-	-	-
Wallis & Futuna	No	No	Fair

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Discussion

This study provides four important findings. First, as hypothesized, ciguatera incidence has increased significantly in the Pacific since the 1970s, but there is significant variability in incidence within PICTs since this time. Second, predicting causes of outbreaks and consequent elevated levels of ciguatera is difficult at the scale of this study, highlighting the need for further local-scale research and management action. Third, as reported earlier (Lewis 1992), ciguatera incidence continues to have significant negative effects on PICT societies, including dietary changes and associated medical problems (such as diabetes). Fourth, there has been inadequate response to date, yet

Table 6. Relationships between per capita incidence, and social consequences, of ciguatera.

	No			Yes				
	N	Mean	St.Dev.	N	Mean	St.Dev.	t	*p*-value
Diet change	6	82.14	125.67	6	452.98	571.66	−2.123	0.060
Medical problems	5	90.83	133.53	7	554.38	669.26	−1.958	0.079
Reactive management	4	438.41	681.6	7	379.81	555.13	−0.371	0.719
Proactive management	5	444.54	649.49	4	546.24	619.78	−0.297	0.775
Additional support	4	8.2	13.84	8	525.11	624.19	−2.993	0.013

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there is acknowledgement from a number of PICTs that assistance would aid in the management of ciguatera. Such assistance could provide appropriate support and unified action might lead to solutions to a disease that could be considered an important cause of both acute and chronic illness in the Pacific.

Based on the results of this study compared to historical analyses, the overall incidence of ciguatera per 100,000 people appears to have increased significantly in the Pacific comparing 1973-1983 (mean104 cases/100,000 (Lewis 1986)) with 1998-2008 (mean194/100,000). There has been a 60% increase in the annual incidence of ciguatera between the two time periods based on PICTs that reported for both time periods (Figure 1). Two nations which exemplify the potential degree of change in incidence of ciguatera are the Cook Islands, where the incidence rose from 2/100,000 to 1,554/100,000 between the two time periods; and Tuvalu, where the incidence decreased from 462/100,000 people to 83/100,000 people. Furthermore, while it might appear that ciguatera incidence rates have subsequently fallen, they are still higher than the levels reported earlier by Lewis (1986). The non-significant result from the paired t-test comparing within PICT ciguatera incidence for the two time periods suggests that there is significant variability of ciguatera incidence within PICTs through time. Therefore temporal change of incidence is difficult to predict at the PICT scale. However, the independent sample t-test and regression analysis revealed a regional increase in ciguatera incidence, hence the need for regional action.

Using the conservative estimate that the official reported ciguatera represents 20% of actual incidence (Lewis 1986), then the actual average overall incidence for the region would be 970/100,000 for 1998 to 2008. Others have estimated that only 5–10% of ciguatera cases are actually reported (Friedman et al. 2008). Across the region, using the reported mean values of actual cases for the three periods for which we have data (1,762 for 1973-1983; 2,844 for 1989-1992 (South Pacific Epidemiological and Health Information Services data); and 3,607 for 1998-2008 (current study)) and using a conservative under reporting rate of 80%, we estimate that since 1973 approximately 500,000 PICT inhabitants have had ciguatera.

It is possible that there might be a reporting bias in the data because of increased research and interest in ciguatera compared to the 1973–1983 time period. However, our data demonstrate high variability of ciguatera reporting from 1998-2008 across the PICTs. It is beyond the scope of this study to ascertain the effect of immigration and translocation of people to and from some of these PICTs, with different dietary habits than the local inhabitants, on ciguatera incidence. Given the variability in the change of incidence across the region demonstrated in this study, it is clear that the overall ciguatera trend cannot be extrapolated from data for a single PICT.

We elicited a relatively poor response rate from questions relating to coral bleaching, cyclones, and degraded reef conditions. Such environmental disturbance generally occurs at finer scales, so it may be appropriate to perform a more detailed field surveys in collaboration with environmental, fisheries, and meteorology agencies in the future to better understand such effects. Despite the methodological limitations, we have shown that there is a trend for ciguatera incidence to be higher where bleaching, cyclones, and poor reef condition have been reported.

Stronger relationships were identified between ciguatera incidence and social impacts of ciguatera outbreaks. We found a marginally significant positive relationship between changing diet and the incidence of ciguatera, and associated medical problems and incidence of ciguatera. Such problems increase financial and social burdens on PICTs. Addressing the underlying causes of ciguatera outbreaks will reduce this burden, enabling PICT authorities to redistribute their limited resources to other priorities. Management action and prevention do not correlate with ciguatera incidence highlighting the lack of a unified and systematic approach for addressing ciguatera in the region. A clear desire for assistance exists within the PICTs that have high ciguatera incidence, suggesting that PICTs would be highly receptive to an external body aiding in enabling unified and systematic action. In addition to exploring new and better apporaches to detection and treatment, research is needed into the causes of ciguatera outbreaks, including environmental and anthropogenic parameters, to explain the hypotheses raised by this study.

Limitations of study

It is possible that the unusual collaboration of the majority of the PICTs in this project might have contributed to the observed increased reporting of ciguatera (as well as other unidentified infrastructure changes), and thus a possible reporting bias for the more recent 1998-2008 data when compared with the 1973-83. However, these data represent a decade of reporting during a period of competing public health interests and lack of surveillance resources for ciguatera in the PICTs. As with all ciguatera studies where the case definition does not include active confirmation of ciguatoxin in the fish consumed, there is the possibility of the misclassification of reported cases; however, this situation has not changed from the 1970s (Friedman et al. 2008).

It is also beyond the scope of this study to speculate on the causes of the high spatial and temporal variability of ciguatera (Tester et al. 2010). This study, instead, aimed to demonstrate that ciguatera is still of major and possibly growing concern in the region. Addressing ciguatera will require significant investment in research and continuing education campaigns. If the suspected disturbances (including coral bleaching, cyclones, shipwrecks, and port facilities) are major causes of ciguatera outbreaks, then it is likely that the general temporal pattern of increased outbreaks will continue in the region, and be a far more expensive concern in the future, if our understanding of, and response to, ciguatera is not extensively improved.

Conclusion

Despite over 50 years of ciguatera research in the Pacific, no comprehensive region-wide action has occurred to better manage ciguatera. Based on this study, an estimated 500,000 persons might have contracted ciguatera in the last 35 years, corresponding to a lifetime prevalence of 25%. It is remarkable that ciguatera has largely been ignored by the PICT national governments, with only two nations having an ongoing monitoring program and only one nation having a small unit devoted to researching ciguatera (Toxic Micro-algae Unit of the Institut Louis Malarde, French Polynesia). Given the rapidly changing physical environment (including global warming, extreme weather, and coral reef degradation) as well as the dependence of local populations upon fish for their physical and cultural survival, research into improved disease treatment and toxin detection, and a better understanding of the environmental factors contributing to ciguatera, are required to help reduce the likely growing adverse impacts of ciguatera.

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Artisanal and industrial FADs: A question of scale

Tahiti conference reviews current FAD use and technology

Foreword

Since ancient times, fishers have known about the natural tendency of pelagic fish such as tunas, mahi mahi, sharks and marlins to gather around floating objects. Beginning in the early 1980s, fish aggregating devices (FADs) have gradually become essential and preferred tools for tuna fishing around the world. This technique is used at two very different scales.

In coastal areas, local fishers moor FADs on the sea bottom in depths of 50–2,500 metres in order to encourage tuna to gather not too far offshore, where small artisanal fishing vessels can catch them. At that scale, anchored FADs are an excellent fisheries management tool that allows fishing effort to be moved away from coasts, where resources are both limited and fragile, towards the open ocean where tuna resources are not as sensitive at such scales.

In the open ocean, tuna purse-seine operators profit from large pelagic fishes' propensity to aggregate; they do so by fishing around FADs that have been deliberately set adrift for fishing purposes, and which are monitored at large geographic scales by electronic tracking beacons. One purse-seine operator can have up to 100 drifting FADs (dFADs) equipped in this way. Therefore, catches by industrial fleets can reach tens or even hundreds of thousands of tonnes in a single area of the ocean. These dFADs are tools that may be considered to be "too" efficient but getting rid of them would strike a heavy blow to the world's tuna canning industry. In fact, the volume of catches around these dFADs (by all types of fishing combined) accounts for about 1.8 million tonnes, or 43%, of the 4.2 million tonnes for the three main tuna species worldwide. It has been suggested that purse-seine fishing around dFADs is leading to catches of small, undersized bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*), unwanted bycatch such as mahi mahi (or dolphinfish, *Coryphaena hippurus*) and wahoo (*Acanthocybium solandri*), and species that are extremely sensitive ecologically such as sharks and sea turtles.

It was against this backdrop that the French Research Institute for the Exploitation of the Sea (IFREMER), French Polynesia's Ministry of Marine Resources, the Secretariat of the Pacific Community (SPC) and the French Institute of Research for Development (IRD) together decided to hold an international conference on "Tuna Fisheries and FADs" to review the use of this particularly effective tool for worldwide harvests of large pelagics, in particular tuna and related species.

The conference (held in Tahiti in November 2011) was attended by nearly 150 participants from 40 countries and 3 oceans and the Mediterranean Sea. The most original aspect of this conference was that it brought fishers, managers and scientists together around a common theme. Three and a half days of the meeting were devoted to scientific presentations divided into five different theme-based sessions.

- Session 1:
  Artisanal fisheries and anchored FADs
- Session 2:
  Industrial fisheries using anchored or dFADs
- Session 3:
  Understanding aggregation
- Session 4:
  Ecosystem impacts of FADs
- Session 5:
  Socioeconomic impacts of FADs

The final two days featured four round table discussions led by expert panels (four to five experts for each discussion), interacting directly with all participants and guided by the priority issues below:

- Round table 1:
  Anchored-FAD design and technology: Durability and effectiveness
- Round table 2:
  Socioeconomic impact and management of regional FAD programmes
- Round table 3:
  dFADs: How to manage this very effective tool
- Roundtable 4:
  Research on the double topic of anchored and dFADs

The summaries presented below — written by the expert groups and rapporteurs — shed new light on the development of anchored FADs and dFADs. The summaries present proposals and recommendations from different groups (i.e. fishers, managers, scientists) directly involved in current fishing practices, and help identify research issues and priorities pertaining to FADs, which are of particular importance for the future of tuna resources and fisheries.

Round table syntheses

Round table 1.
Balancing anchored FAD design for costs, longevity and aggregation efficiency

Expert panel: Marc Taquet (IFREMER, Chair — *Marc.Taquet@ifremer.fr*), Michel Blanc (SPC, rapporteur), Kim Holland (University of Hawaii, rapporteur), Paul Gervain (PLK Marine), David Itano (Pelagic Fisheries Research Program, Hawaii), William Sokimi (SPC), Mainui Tanetoa (Direction des Ressources Marines, French Polynesia).

General overview of discussion

Because different types of FADs can be used for different purposes such as artisanal and subsistence fishing for food security, sportfishing, and industrial-scale harvesting, there is a need to codify FAD terminology. The most basic distinction is the difference between anchored FADs and the dFADs used in industrial fisheries. For anchored FADs, there is an existing terminology used by SPC:

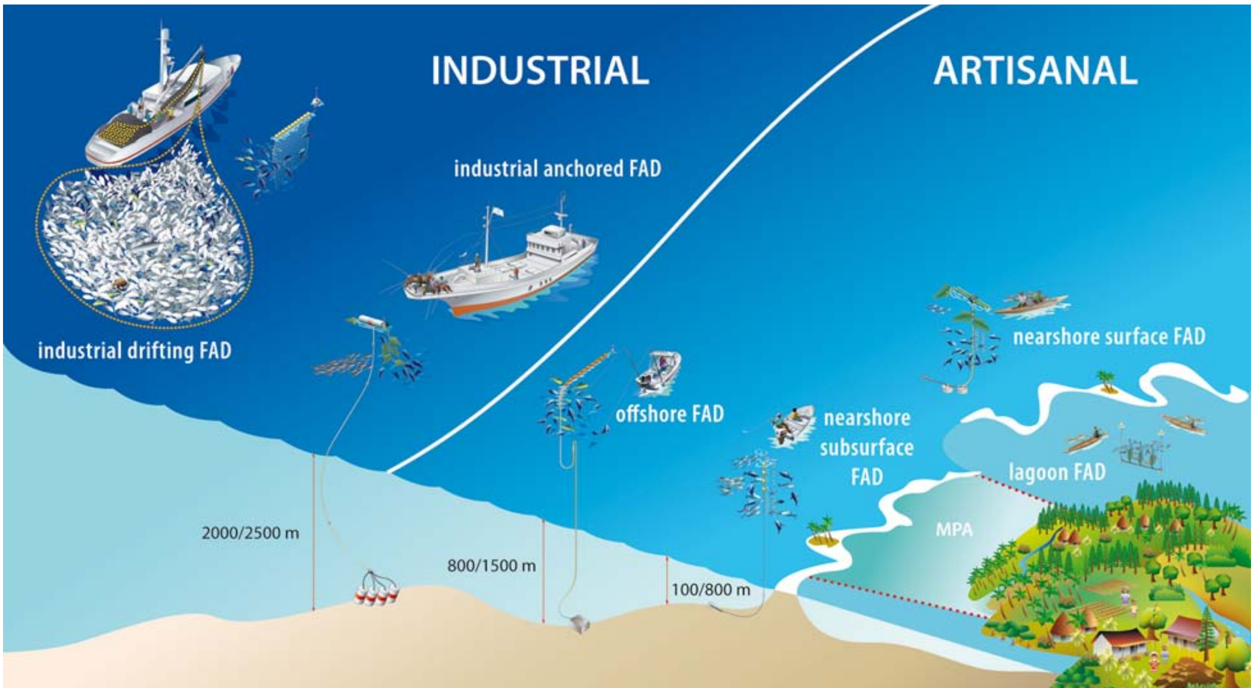
- lagoon FAD (surface and subsurface) — Used primarily to support artisanal and subsistence fisheries.
- nearshore FAD (surface and subsurface) — Typical maximum depth is 500 m. Used to support subsistence, artisanal and sportfishing activities.
- offshore FAD (currently all surface). Typical maximum depth is 2,000 m. Used to support artisanal, sportfishing and industrial fishing of various scales.

The term "Indian Ocean design" was frequently used during discussions. This design generally refers to a FAD constructed with light- to medium-weight mooring lines and a surface flotation section comprising a string of small and medium floats that lay on the ocean surface.

Different types of user groups must be considered when deciding where to locate FADs. The requirements of subsistence fishers using canoes or small motorized vessels are different than those of modern sport fishers and commercial fleets. Similarly, the type of FAD used (and its constituent components) depend on the capabilities of local agencies to fund and deploy the FADs.

For lagoon and nearshore FADs, there is an emerging trend toward the deployment of subsurface designs. These FADs are increasingly used in conjunction with the establishment of marine protected areas (MPAs) as part of community-based resource management programmes.

There have been significant advances in the design of FAD systems and in the types of materials and components used to construct FADs. These advances have resulted in increased longevity of FADs. There may



Different types of FADs used in tropical seas (Illustration: Jipé Le Bars, SPC) be a need for an updated technical manual to assist user groups in designing and deploying FADs tailored to specific locations and user groups. Importantly, the design and deployment strategies for FADs are dependent on the size and reliability of funding available for the project.

Specific items discussed

Materials. There have been significant advances in materials and engineering for all types of FADs, and the general trend has been to reduce the number of components (e.g. shackles, swivels) in mooring systems. This reduces cost and the number of weak links in the system, and increases longevity. In the Maldives and the Caribbean, nylon or polypropylene ropes with a steel wire core have proven to be successful in providing secure mooring systems that resist damage from fish bites and fishing gear. New synthetic ropes made of Kevlar-type materials are also showing promise as mooring systems for FADs.

In general, heavy anchors such as cement blocks are used, although lighter anchoring systems (e.g. grapnels, engine blocks) are also used, especially for nearshore and lagoon FADs. Lighter anchors are beneficial for a number of reasons, including reduced cost and ease of deployment from small vessels. However, several analyses from different regions indicate that insufficient anchor weight was responsible for FAD loss.

Stainless steel components are not necessary and may even be detrimental, although they are used successfully in some places (e.g. Maldives) for certain functions (e.g. mooring attachment points).

For lagoon FADs, biodegradable and recycled components are frequently used.

Maintenance. There are differences in opinion regarding the need for maintenance programmes. For properly designed systems (using, for example, spherical buoys and adequately large anchors) with long life spans, maintenance may not be necessary or cost effective. Systems with global positioning system (GPS) transmitters, which allow "real time" monitoring of a FAD's position, facilitate recovery when a FAD goes adrift and, thereby, minimise regular maintenance costs. On the other hand, FADs using the Indian Ocean design require regular and thorough maintenance of surface components.

Aggregators. For nearshore and offshore FADs, the use of aggregators[1] is generally favoured by fishers although there are no empirical scientific data to support their effectiveness. Generally, larger surface areas tend to be more effective than smaller ones. Aggregators may increase drag, and this should be considered in designing long-lasting FADs. Using aggregators as separate components (e.g. double-headed FAD, Indian Ocean style, Maldives style) may be preferable to placing aggregators on the mooring line.

Maldives (top) and Indian Ocean (bottom) artisanal FADs. On the Maldives FAD, aggregators are attached to the array of small buoys floating on surface, not to the main mooring line

Electronics. There is increasing use of sonar buoys to give real time estimates of fish abundance at FADs, and GPS receivers and transmitters are being used to monitor whether or not FADs are on station and when they break loose. There is a need for an updated technical manual for FAD construction and deployment technologies.

Data collection. For all types of FADs, the strengthening of data collection systems (biological, engineering, socioeconomic) is essential to quantifying the generally accepted positive impacts of FAD programmes. These data are crucial to securing sustainable funding for national FAD programmes.

Lagoon FADs. There is an increasing demand for FADs in lagoons and other sheltered inshore waters. This is especially true in rural areas where they can be used in combination with MPAs and to enhance food security and to re-direct fishing effort away from benthic and epibenthic reef fishes to small pelagic species. However, the effectiveness of these FADs may be site specific — sandy bottom lagoons are good locations. Lagoon FADs are cheap and can be made of several designs from a variety of recycled and biodegradable materials.

[1] Aggregators are appendages made of loose netting, mussel ropes or coconut fronds, attached below the raft, which are supposed to increase the FAD's attractiveness.

Nearshore FADs. Nearshore FADs are useful for addressing a number of contemporary issues (e.g. food security, promotion of sportfishing and related businesses, support of small-scale commercial fishing). They can also be effective in preserving coral reef biodiversity by shifting fishing effort away from reef fish species to more resilient pelagic species.

There is a need to conduct a comparative study (life span vs cost) of several nearshore FAD designs that have recently been used. Most designs are typically inexpensive (i.e. less than USD 2,000).

Subsurface designs are gaining momentum and are being increasingly used in several countries. Advantages include reduction of vandalism, suitability for areas of heavy maritime traffic, and longer lifespan due to reduced wear and tear. They are usually less expensive than surface designs for similar depths. There may be limitations of deployment depth for subsurface FADs beyond which the "cons" outweigh the "pros". For example, deployment in deep water requires very high precision, which in turn requires appropriate vessels and equipment, as well as expertise.

Fishers initially tend to be negative about subsurface FADs so there is a need for education, the use of surface marker buoys to assist in finding the FAD (at least in the beginning), and research into the aggregation success of subsurface FADs. There are existing examples of successful deployments at depths up to 500 m (Tonga, Fiji), although questions persist regarding the types of fish these FADs attract (e.g. mahi mahi) and the maximum depth they can be deployed accurately. This needs future research. Because their precise locations may not be known to all fishers, subsurface FADs may be vulnerable to being fouled by longline gear.

Offshore FADs. Offshore anchored FADs support industrial, artisanal and sportfishing activities that use a wide variety of motorized vessels. The mooring line is usually the most expensive component, so cost-effectiveness depends on balancing the depth (usually related to distance offshore) with the capabilities of the user group.

There are significant deployment challenges for subsurface FADs in deep water, and consequently, to date, all offshore FADs use surface floats. Use of steel core rope or cable is appropriate for at least the uppermost sections of the mooring, and this is replacing conventional rope in some instances. There is a trend to reduce the number of elements (e.g. swivels) on the mooring line.

Although "boat-shaped" floats are used and have some advantages (e.g. ease of construction, housings for instruments), mechanical analysis suggests that spheres are best shape for most purposes. Double-headed systems seem effective in aggregating fish and in extending FAD life. However, regular maintenance operations are required.

Recommendations and points of agreement

- Anchored FADs are a cost-effective way of redirecting fishing effort from nearshore benthic fish species to more resilient pelagic fisheries. These FADs are useful for food security and for promotion of economic activities such as sportfishing.
- Data collection is vital to promoting financial and political support for FADs.
- Subsurface FADs have many positive aspects (including lower costs) and are becoming increasingly popular.
- Reducing the number of components in the mooring system increases FAD longevity.
- There is a need for a new technical manual describing modern FAD technology.

FAD maintenance may require acrobatic skills. Changing the buoy light, Hawaii (Image: David Itano)

Round table 2

Socioeconomic impacts and management of domestic FAD programmes

Expert panel: Marc Taquet (IFREMER, Chair — *Marc.Taquet@ifremer.fr*), Beatriz Morales-Nin (Mediterranean Institute for Advanced Studies (IMEDEA)/University of the Balearic Islands (UIB)/Consejo Superior de Investigaciones Científicas (CSIC), rapporteur), René Galzin (Centre de Recherche Insulaire et Observatoire de l'Environnement (Criobe)/Centre national de la recherche scientifique (CNRS)/École Pratique des Hautes Études (EPHE), rapporteur), Olivier Guyader (IFREMER), David Itano (PFRP), Lionel Reynal (IFREMER), Michael Sharp (SPC), Stephen Yen Kai Sun (Direction des Ressources Marines, French Polynesia).

Purposes, objectives and drivers of domestic anchored FAD programmes

Socioeconomic, environmental and political drivers were identified as the primary motivations for the launching of domestic FAD programmes. Although anchored FADs have been used since ancient times, the review of case studies shows that many anchored FAD programmes have been developed recently, beginning in the early 1980s. The objectives of these programmes vary, but there are some common themes. One of their main objectives is to increase fishing efficiency through increased catch per unit of effort (CPUE), and a reduction in fishing costs, primarily due to a reduction in searching time. Expected benefits are improved earnings and increased food security of high quality, and ciguatera-free protein for local communities. In some cases, programmes have aimed at reducing country dependence on seafood imports and, in a limited number of cases, allowed for the development of exports. Safety-at-sea issues are also considered to be an important benefit of coastal FAD programmes, especially for small-scale fleets with limited range. In other cases, anchored FADs have been set for recreational fishing or charter-tourism development. And, anchored FADs are sometimes used for scientific monitoring of marine ecosystems.

When environmental and resource aspects are considered, anchored FADs are considered to be a tool to reduce fishing pressure on coastal ecosystems via enabling the transfer of fishing effort from coastal fish to pelagic fish. Coastal FADs are increasingly highlighted as offering alternative fishing opportunities that can protect reef and lagoon and demersal environments (i.e. MPA establishment). FADs can also relieve fishing pressure on coastal environments that have been degraded by pollution, ciguatera contamination, invasive species and climate change.

On political and institutional levels, anchored FADs have also been seen as a way to reduce conflicts between neighbouring countries by reducing incentives for fishermen to follow the movement of target species into foreign exclusive economic zones. The group also noted that FADs have a cultural dimension and can become a mechanism to improve and foster the organisation of fishing communities and cooperatives and fishery management efforts.

Interactions, conflicts and access regulation

The review of case studies shows that the main users of anchored FADs are small-scale fishers who mainly use hook-and-line gear. However, industrial-scale fisheries operating large commercial vessels using other techniques (e.g. purse-seine) are operational in some regions, particularly in the western Pacific. Recreational fishing may benefit from anchored FADs installed for commercial purposes and vice versa; some FADs, however, are maintained for the benefit of only one fishing sector.

Conflicts and interactions between individual fishermen and/or FAD user groups were recognized as a significant issue in some areas that needs to be mitigated by an outside, impartial organization that can facilitate communication and management efforts. Due to the international scope of the conference, a wide range of access regulation arrangements to anchored FADs was noted, including preferential access (FAD licenses and permits, territorial use rights, catch limits) to commercial fishermen or other user groups; and restrictions on fishing gear types. This was considered to be a positive proposal to manage user conflict. Currently, many FAD fisheries are open access, which may significantly reduce the benefits of such management measures, or the programmes themselves.

It was recognized that access issues are complex and need to be addressed at the local level, and cannot be standardized across all regions. General guidelines could be developed at a global scale, with inputs from all user groups. These guidelines could lead to the development of voluntary domestic codes of conduct for responsible anchored FAD fishing in order to minimize conflicts and interactions between users. Guidelines to minimize conflict while fishing on FADs should be developed through input from all user groups into a voluntary code of conduct for responsible FAD fishers wherever FADs are deployed and widely distributed.

Management of FAD density and interactions in coastal areas

The management of anchored FAD density emerged as one of the most important issues to be considered in relation to resource utilization and conflict resolution. The optimal number and density of anchored FADs in a given fishery is difficult or impossible to determine given the diversity of contexts (e.g. target species, gear type), but evidence from several studies indicates that "more" is not necessarily "better". Excessively high FAD density can lead to tangling of mooring lines, aggregation interaction or competition between neighbouring FADs, especially when FAD setting is unregulated. The problem with FAD overcapacity is high FAD programme costs in combination with a loss in local productivity and catchability due to FAD competition and/or interaction (diminishing marginal returns). Conversely, the number of FADs in a given area can be regarded as insufficient where individual FADs act as separate units with no overall benefit from the combined aggregative effect of the entire FAD array, which can occur when the FAD programme is not fully funded or well planned.

The number of permitted FADs in a given area is a key management concern, which must be determined by carefully planned scientific studies and can not be separated from the issue of access regulation. It was noted that the development of management measures must include stakeholder input from all sectors to ensure that management measures are accepted and enforceable.

FAD management should be strongly linked to broader marine spatial planning mechanisms to avoid potential interactions that can seriously impact anchored FADs (submarine cables, shipping lanes, protected species habitats, tourism and development). Inadequate planning and regulation may result in significant user-group conflicts. Even if some FADs are constructed with biodegradable materials, the impacts of their loss — especially on coastal, coral reef and sea floor habitats — must be more clearly assessed and anticipated.

When large-scale fisheries exist that are not compatible with anchored FAD moorings or small-scale fisheries, they may have to be separated by regulation. This has occurred in some regions where large-scale tuna longline and purse-seine gear has been excluded from coastal waters where anchored FADs are maintained for the benefit of small-scale fishers. Studies indicate that a physical separation of gear types can also reduce interaction and competition issues.

Funding and maintenance

The group noted the need to promote long-term sustainable FAD funding in all contexts. Long-term budget allocation must incorporate FAD maintenance, replacement or recuperation when lost, data collection, training and management. Evidence from existing programmes indicates that FAD programmes need to explore innovative avenues for continued funding that may include fees from user groups, funds derived from fishery permits or violations, external private funding, core government infrastructure budget, fishery development funds, and taxes levied on fishing gear.

Private sector funding, maintenance and management of FAD programmes was identified as an ideal scenario, however it is recognised that this may result in user conflict. With good cooperation and governance, private sector funding is deemed appropriate, however if this fails, public sector funding and management of FAD programmes would be required.

Maintenance and renewal frequency and cost data are required to establish optimal maintenance routines and FAD designs.

Some case studies revealed that the longevity of anchored FADs is greatly improved with frequent maintenance. Increased FAD longevity has significant implications on cost and benefits of FADs, and further research is required in the design of FADs, deployment site, and maintenance frequency, to improve the life of an anchored FAD.

Monitoring and data collection

The need to define minimum requirements to obtain high quality data with an acceptable level of uncertainty was recognized, which would then be used to establish data collection and monitoring protocols. It was noted that monitoring and data collection systems must be designed and established with the fishing community well before the first FAD is deployed. Sampling methodologies could be carried out to generalize the results at a more global scale. Moreover, the use of standardized forms for catch and effort reporting are required to facilitate information comparisons, especially in the case of shared resources. Minimum requirements include long-term robust catch and effort surveys for different gear types, and socioeconomic data collection (from vessels and households to supply chain of fish products) for cost-benefit analysis. The importance of agencies to actively pursue the collection and verification of high quality data useful for CPUE and socioeconomic analyses was recognized.

In addition to developing data collection and monitoring protocol, economic studies are required to understand the impact that FADs have on the domestic fisheries, including the socioeconomic costs and benefits of anchored FADs and research into longer lasting FAD designs.

Research is needed to determine the direct and indirect socioeconomic costs and benefits of anchored FADs, and to improve the efficacy of FAD development initiatives and promote best practice to achieve socioeconomic objectives.

Round Table 3:
dFAD: How to manage this very efficient fishing tool?

Expert panel: Marc Taquet (IFREMER, Chair — *Marc.Taquet@ifremer.fr*), John D. Filmalter (South African Institute for Aquatic Biodiversity (SAIAB), rapporteur), David Itano (PFRP, rapporteur), Laurent Dagorn (IRD), Alain Fonteneau (IRD emeritus), Michel Gougon (Organisation de Producteurs de Thon congelé - ORTHONGEL), Patrice Guillotreau (Université de Nantes), Martin Hall (Inter-American Tropical Tuna Commission - IATTC), Juan Pedro Monteagudo (Organización de Productores Asociados de Grandes Atuneros Congeladores - OPAGAC).

Positive and negative impacts of FADs

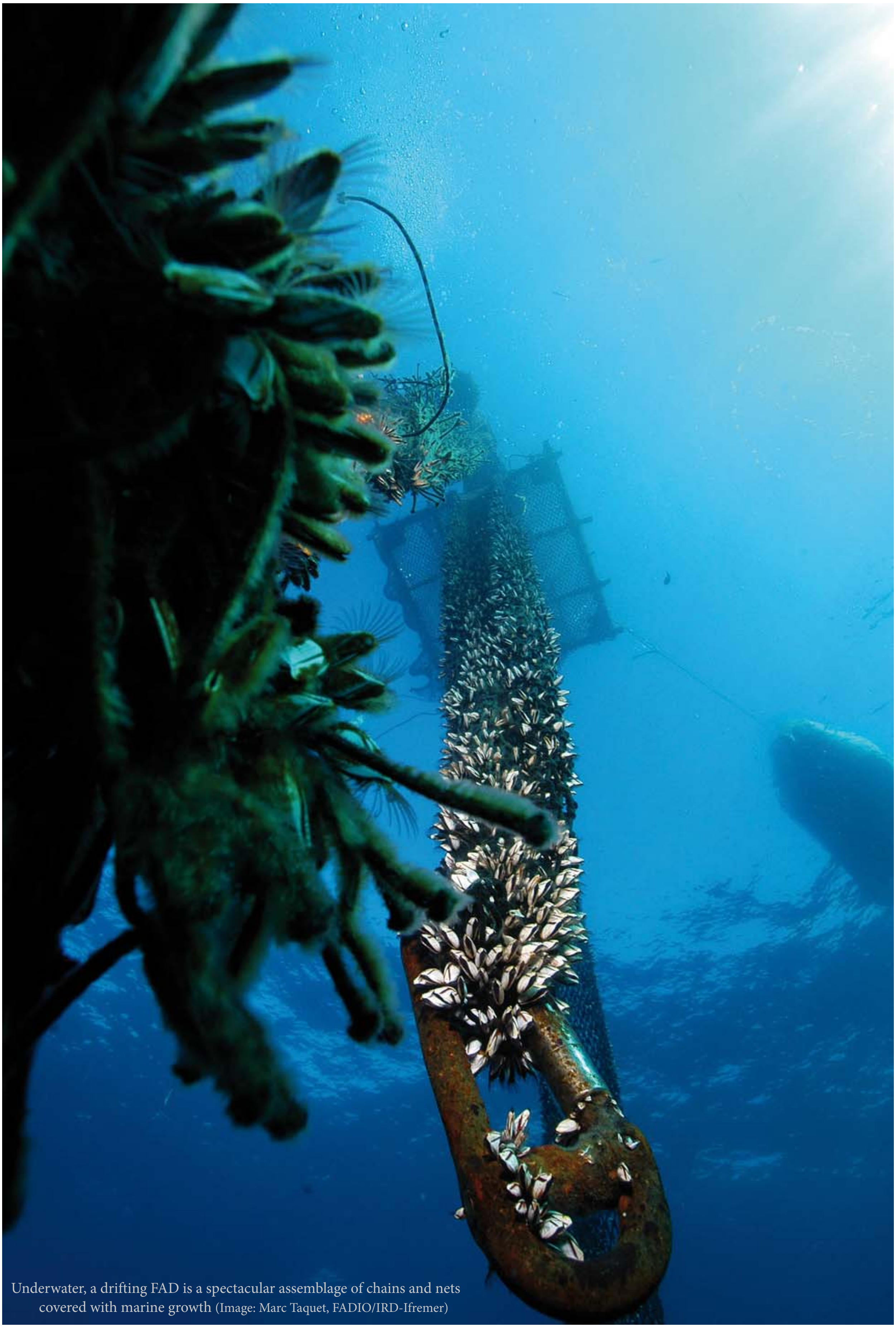
The efficiency of purse-seine fleets in all tropical oceans has improved, with drifting FAD (dFAD) and floating object sets now responsible for over half of the global tuna production. Their use has vastly improved the economic viability of tuna seining through reduced fuel and operational costs, and has allowed successful fishing in previously unexploitable fishing grounds and in areas and seasons when unassociated schools are unavailable. Sonar-equipped GPS locating buoys, coordination with supply vessels and an ample supply of dFADs work to virtually eliminate "zero catch" days resulting in high annual production. Given high and rising fuel costs, the utilization of dFAD technology was recognized as a necessary aspect of tuna production for the global canning industry.

Unfortunately, the unconstrained use of this very efficient fishing tool has resulted in negative impacts to target and non-target resources. Increased dFAD use can lead to large increases in fishing mortality of juvenile yellowfin and bigeye that contributes to growth overfishing. Bycatch levels of sets on floating objects — including dFADs — of oceanic sharks (primarily silky (*Carcharhinus falciformis*) and oceanic white tip (*C. longimanus*)), marine turtles, istiophorid billfish and certain pelagic bony fish (mahi mahi, wahoo, rainbow runner, etc.) are higher than for any other purse seine set type.

Drifting FADs are often constructed of surplus purse seine netting and usually have a panel of net suspended below the raft or float to a depth of 15 meters or more. This webbing can entangle FAD associated animals, including species of particular concern such as marine turtles, cetaceans and oceanic sharks. Lost or abandoned dFADs become marine debris and can impact coral reefs or end up in coastal areas and cast up on beaches.

While expansion of fishing grounds can help to distribute exploitation over a broader area, it is theorized that previously unexploited areas may represent natural reserves or "stock sinks" that help to replenish heavily exploited areas. Drifting objects tend to aggregate particular species or life stages that can contribute to differential exploitation with negative ecological impact.

On surface, a drifting FAD is a simple bamboo raft equipped with a radio beacon (Image: Marc Taquet, FADIO/IRD-Ifremer)



Underwater, a drifting FAD is a spectacular assemblage of chains and nets covered with marine growth (Image: Marc Taquet, FADIO/IRD-Ifremer)

Finally, dFADs in areas of high-speed directional drift may transport fauna away from normal areas and habitats, possibly to less favourable areas.

Data gaps and need for additional information

Significant data gaps and information needs were noted that must be improved to allow for the effective management of global purse-seine fisheries. More and higher quality data on dFADs and dFAD fishing operations are necessary for management purposes.

Basic technical data are needed on:

- the number of unique dFADs used per trip per boat, with comparisons between different fleets;
- the total number of active dFADs in a fishery (in the water with actively monitored electronic device attached); and
- dFAD trajectories throughout a fishery region.

The manner in which dFADs are constructed, deployed and fished by fleet type, and in comparison between different oceans, needs to be better recorded and understood by scientists and managers. These parameters are highly technical, requiring close collaboration and understanding of the fisheries and should, at a minimum, include:

- details of dFAD construction type, materials and depth;
- dFAD fishing techniques by fleet and region;
- use of technological adaptations to enhance aggregation (e.g. use of light, bait, depth of appendage, colour and type of streamers);
- characterization of dFAD use during fishing trips (i.e. numbers of dFADs set on or available that were previously deployed, appropriated, lost, recovered, or converted, log to dFAD); and
- documentation of changes in fishing gear and dFAD fishing practices over time.

Significant data gaps were also recognized in relation to the ecological impacts of dFAD use, including the need to understand "population dynamics" and trajectories of dFADs in relation to tuna and bycatch resources. Drifting FADs can be viewed and studied as a dynamic population of floating objects that are born (seeded), mature (aggregate species), migrate (drift) and die (sink, drift ashore, are recovered or stolen). Better information on all these processes is necessary for management purposes.

More and higher quality data on bycatch entanglement, species-specific bycatch levels, discard levels, fate of discards, and the broader ecological significance of bycatch and discard removals from the pelagic ecosystem need to be collected and processed.

Science and industry research initiatives to address these needs

The purse-seine industry has taken the initiative to study and promote ways to reduce the negative impacts of dFADs on the ecosystem. Specific projects were noted, including those that explored the use of sonar GPS buoys, echo sounders and sonar equipment to improve pre-catch estimation and selectivity for better targeting and bycatch reduction. The industry has also been involved in the testing of dFADs designed to minimize entanglement of sea turtles and other bycatch species. Some purse-seine companies have self-imposed FAD management plans, limited annual FAD usage per vessel per year, and are working on a declaration for responsible dFAD use (due in 2013).

Scientific research programmes that work collaboratively with industry were noted as a highly desirable and efficient approach because they allow experiments to take place on the high seas within the fishery under realistic commercial conditions, often using purse-seine vessels rather than research vessels. Further collaborative research was encouraged. Completed and ongoing projects of note included:

- FADIO (Fish Aggregating Devices as Instrumented Observatories of pelagic ecosystems),
- MADE (Mitigating ADverse Ecological impacts of open ocean fisheries),
- ISSF (International Seafood Sustainability Foundation),
- Purse Seine Bycatch Mitigation Project, and
- Skippers Workshops (to gain information from fishermen experienced in FAD fishing).

FAD management options

The meeting noted several ways to manage dFADs to mitigate their impact on target and bycatch stocks and their influence on the pelagic environment. These included the well-known mix of input and output controls, the most basic of which would be a control on the total number of vessels in a fishery and the number of dFADs deployed. The urgent need for the development and adoption of FAD Management Plans that are standardized across fleets and regions was recognized.

Management of input controls attempts to maintain or reduce fishing effort by controlling some aspect of the fishery that contributes to total fishing effort, such as a limit on the:

- number, type and capacity of vessels in the fishery;
- numbers of dFADs deployed (e.g. per boat, trip, year, fleet, area);
- number of electronic buoys allowed per fleet or fishery; and/or
- number of FAD sets allocated to a fishery sector.

Mechanisms to reduce vessel or fishing efficiency can also be imposed, such as a limitation on net size and depth, restrictions on the time of set, a limit on the underwater depth of a FAD, and a ban on the use of lights. There was strong support for banning FAD supply vessels that greatly increase the effective effort of a purse-seine operation. Time and area closures can also be applied to a fishery on a permanent, seasonal or variable (time or area) basis.

Output controls attempt to control effort by establishing a maximum level of catch, generally through the establishment of a total allowable catch (TAC). In this case, a TAC could be set for species or sizes of particular concern (such as juvenile bigeye and yellowfin tuna less than 60 cm). A TAC can be vessel-specific or by fleet, region, year or fishery.

A number of technological or economically driven initiatives to reduce dFAD impacts were discussed, including altering FAD design, changes in fishing methods, and bycatch marketing. Technical solutions could include the:

- design and promotion of non-entangling and/or biodegradable dFADs;
- development of fishing methods and practices to reduce impacts on undesirable catch, especially oceanic sharks and tuna of undesirable size;
- better utilization of finfish bycatch (e.g. mahi mahi, wahoo, rainbow runner) through vessel storage modification, freezer technology and market development;
- development and testing of release gear and techniques (e.g. sorting grids, use of large mesh, release chutes, modified brailing); and the
- testing of bycatch release techniques and gear from the net and vessel, and determining survival rates of released bycatch.

The development and adoption of FAD management plans was considered to be a key element towards effective regional management of dFADs. Currently, efforts are in place to adopt FAD management plans and some regional fishery management organizations (RFMOs) are requiring this of each member. However, the potential benefit of these plans is greatly reduced by the fact that RFMOs have not yet agreed on the data fields and information required for science and effective management. It was recognized that FAD management plans should be adopted by all fishing entities and should require vessels to report the number and fate of deployed and fished dFADs per trip. Management plans should also include:

- a ban on the use of FAD supply vessels;
- clarification on the role of observers in relation to data collection vs. Monitoring, control and surveillance; and
- information that identifies the ownership and responsibility of lost or abandoned dFADs.

It was recognized that the use of dFADs has greatly increased the economic viability and potential yield from tuna fisheries worldwide, and that it is not reasonable to abandon this highly efficient tool. Drifting FADs and their electronic marking buoys should be considered as individual units of fishing gear that must be managed to preserve the viability of pelagic ecosystems and sustainable tuna fisheries.

Dense aggregation under a drifting FAD (Image: Marc Taquet, FADIO/IRD-Ifremer)

Round table 4

Research priorities on anchored and drifting FADs

Expert panel: Marc Taquet (IFREMER, Chair — *Marc.Taquet@ifremer.fr*), Alain Fonteneau (IRD emeritus, rapporteur), Fabien Forget (Rhodes University, rapporteur), Laurent Dagorn (IRD), Martin Hall (IATTC), Kim Holland (University of Hawaii), Jean-Claude Gaertner (Université de Polynésie française), René Galzin (Criobe/CNRS/EPHE).

The following recommendations were endorsed by the meeting:

Scientific use of FADs — Develop and improve scientific FADs equipped with a wide range of monitoring and recording equipment (e.g. scientific sounders, underwater cameras, recording of sound and environmental parameters, new tags). These scientific FADs should be actively used in scientific programmes designed and implemented in full cooperation with industry. These FADs should be also used in selected areas of particular significance, for instance in the Mozambique Channel (dFADs) or in areas of dense anchored FAD use (i.e. Papua New Guinea), as well as after any moratorium on dFAD use.

Basic fishery data — Improve data on size and species composition from all purse-seine effort for target and bycatch species, and incorporate new technology such as the electronic monitoring of fishing operations. There is a need to better understand the behaviour of target and bycatch species on dFADs to improve selectivity using a variety of methods including tagging, tracking, acoustics and video gear.

Drifting FAD moratoria — Restrict fishing areas and/or implement spatiotemporal moratoriums on FADs (by RFMOs) in conjunction with scientific research to monitor the dynamics of tuna associated with dFADs before, during and after using scientific FADs, research vessels or fishing vessels in the moratorium strata.

Feeding studies — Conduct comparative stomach content analyses on tunas caught in free and FAD-associated schools in different parts of the world. The results are of key importance to evaluating the impact of dFADs on the pelagic ecosystem, understanding interactions between species (i.e. tuna natural mortalities), and quantifying diversity in offshore pelagic areas.

Environmental impact of FADs — Reduce (to nearly zero) environmental pollution due to lost dFADs (sunk or drifting onto reefs or coasts), in agreement with the MARPOL convention[2] incorporating provisions that stipulate the responsibility for damage and impacts of lost or abandoned FADs. Biodegradable and non-entangling FADs should be developed by scientists and fishermen, and the universal use of these FADs should be developed as soon as possible by all purse-seine operators using dFADs at sea.

Bycatch reduction — Find methods to pre-estimate aggregation composition (bycatch to target species ratio), to reduce encirclement and mortality of bycatch and to study the survival rate of discards and released bycatch with a special focus on oceanic sharks and undersized tuna.

Industry collaboration — That the industry fully cooperates with scientists by sharing data (acoustic, FAD positions, FAD drift tracks) with the aim to understand the dynamics of dFADs and their impacts on ecosystems. There is a need to understand how many dFADs are in use by area, fleet and season which is far easier to determine with industry support.

Comparative research — Conduct comparative studies (between oceans and regions) on anchored FADs and dFADs. These studies are essential to better understanding biological, oceanographic and ecological mechanisms and processes related to FADs. A possibility would be the creation of an online network of FAD scientists to foster communication and collaboration.

FAD mooring designs — Design anchored FADs that have longer life spans in order to optimize investments, and develop subsurface FAD technology for deep offshore areas.

Socioeconomic studies — Monitor the biological (catch per species and size, fishing effort) and economical (price of catch, operative costs) variables that are required to evaluate the impact of FADs on resources, and analyse socioeconomic gains. This basic information is important for obtaining funds for anchored FAD deployment programmes. Standard sampling methods for data collection should be developed and used. Research should also focus on the analysis of fisheries dynamics and on the impact of FAD management measures, especially access regulation, and funding schemes.

[2] The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It was adopted in 1973 at the International Maritime Organization (IMO).

Investment profile for anchored nearshore fish aggregating device

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Anchored artisanal fish aggregating devices (FADs) can be highly effective in increasing fishery yields and reducing production costs; however, there are a number of variables that impact on the efficacy of FADs. These variables have significant implications for the financial yield and economic returns from FADs. This article documents the variables that determine whether a positive or negative return on investment (RoI) is achieved for FAD programmes, and provides recommendation to improve the likelihood of a positive return.

Introduction

The effectiveness of an anchored FAD is often measured in terms of its aggregating efficiency and improved yield to the fishing community. This is a reasonable measurement if we consider FADs as sunk costs; however, administrators of FAD programmes should adopt a long-term investment outlook for FADs and manage the variables that determine whether FADs derive a positive or negative economic return.

FAD programmes are too commonly thought of as short-term, project-driven activities. As in any infrastructure project, FADs should be considered as long-term investments that attract sustained budget with the objective of supporting domestic artisanal fisheries and increasing domestic production.

> **Return on investment (RoI)**
>
> When we discuss return on investment (RoI) of a FAD programme, we are referring to the improved productivity and cost savings that are realised by the fishing sector when fishing near and around FADs, in comparison with the investment expended for deploying and maintaining FADs.

Some of the expenditures that are incurred throughout the life of a FAD include materials for fabrication, deployment expenses, maintenance, replacement and management.

The financial return from FADs depends on a number of variables, which are outlined below. This article only considers the direct benefits of FADs, which are improved productivity and cost savings to the fishing community. Indirect benefits and costs are not considered due to the complexity of measuring these.

Calculating the financial benefits of FADs

In determining an investment profile, the financial returns to the fishing community must be calculated. This section describes each benefit and the method for quantifying these benefits. Equations are provided to assist with the calculations.

Change in catch rate

The effectiveness of a FAD in aggregating fish can be measured in terms of change in catch per unit of effort (CPUE). In other words, what is the CPUE when fishing near FADs ($CPUE_{FAD}$) in comparison to the CPUE when fishing in open water ($CPUE_{OW}$)? The difference between the two (ΔCPUE) (equation 1) multiplied by the price of fish (PF) gives us the change in revenue per unit of effort (ΔRPUE) (equation 2).

Fishing effort

The benefits of FADs can only be realised when the fishing community fish near FADs. Without any effort dedicated to fishing near FADs, productivity benefits cannot be realised.

When multiplying total fishing effort (TE) by the change in revenue per unit of effort from fishing FADs, we can determine the impact that FADs have on the total revenue (TR) of the fishing industry (equation 3)

Change in cost

Direct cost savings, via reduced fuel consumption and/or labour, contribute to determining financial return from a FAD.

Change in fuel consumption (ΔFC) per unit of effort is the difference between the open water fuel consumption (FC_{OW}) and the fuel consumed when fishing near FADs (FC_{FAD}) per unit of effort (equation 4). When multiplying ΔFC with the cost of fuel (C_F) we can estimate the savings of fuel (FS) to the fishing community per unit of effort (equation 5).

Total fuel savings (TFS) to the fishing community is the fuel saving (FS) per unit of effort multiplied with the total fishing effort at FADs (equation 6).

Calculating savings in labour costs is difficult due to the fact that fishers do not usually go home when they reach a given level of production; instead, they continue fishing until time, fuel or space (in the hold) runs out. Labour savings can be measured by calculating the effort required to fill a vessel's hold. That is, the vessel capacity (VC) divided by $CPUE_{OW}$ less the vessel capacity divided by $CPUE_{FAD}$ (equation 7). The result is the change in labour (ΔL), in terms of hours, to fill the hold. Multiplied with the cost of labour (C_L), we derive labour savings (LS) per vessel (equation 8).

To estimate the labour saving benefit to the entire fishing industry, an average vessel capacity (AVC) or fleet profile is required. When multiplying the AVC by labour savings, we can estimate the total labour savings (TLS) (equation 9), in terms of dollars saved in labour to the fishing industry.

The change in total cost (TC) from FADs is calculated by the total fuel savings plus the total labour savings (equation 10).

Now that we have determined how to calculate the direct financial change as a result of FADs, we can identify other variables that impact on whether a positive RoI is realised.

Equations

- $\Delta CPUE = CPUE_{OW} - CPUE_{FAD}$ (1)
- $\Delta RPUE = \Delta CPUE \times P_F$ (2)
- $TR = \Delta RPUE \times TE$ (3)
- $\Delta FC = FC_{OW} - FC_{FAD}$ (4)
- $FS = \Delta FC \times C_F$ (5)
- $TFS = FS \times TE$ (6)
- $\Delta L = (VC / CPUE_{OW}) - (VC / CPUE_{FAD})$ (7)
- $LS = \Delta L \times C_L$ (8)
- $TLS = AVC \times LS$ (9)
- $TC = TFS + TLS$ (10)

Return on investment

Longevity

Longevity (T), in terms of the life of an anchored FAD, significantly affects whether a positive or negative return is achieved.

For example, if the value of the FAD is $10,000 and it takes 100 days of fishing to achieve the equivalent benefit (TR + TC), then at 100 days a neutral return is achieved (i.e. exactly cover costs). In this case, if the FAD's longevity is less than 100 days, then a negative return is realised.

Therefore, the aggregation of total financial benefits of FADs over time must exceed the investment expense to realise positive returns, which is why longevity is important.

Investment, maintenance and management cost of FAD programmes

The cash flow generated from increased revenue (and reduced costs) need to exceed the upfront investment (I) and ongoing maintenance (M) of the FAD. Once this is achieved, then we begin to realise a positive RoI (equation 11).

Indirect impacts of FADs

Only direct benefits are considered in this article. If considering the indirect impacts (X) of FADs, a positive RoI would be achieved over a shorter period of time than when only considering direct benefits. The positive indirect impacts (e.g. reduced pressure on the reef, driving tourism, import substitution, sea safety) and negative indirect impacts (e.g. domestic price decline, resource depletion) of FADs are difficult to measure, so they have been omitted from the investment profiling.

Positive return on investment is achieved when:

$$(TR + TC) > (I + M) \qquad (11)$$

Aggregation of all affects of a FAD

Achieving a positive RoI is dependent on the investment and maintenance costs, the change in total revenue, the change in costs (fuel and labour), and the indirect impacts of FADs. Putting all of these benefits together, a positive RoI is subject to the time that the anchored FAD lasts.

RoI is calculated as:

$$RoI = I_o + \sum_{n=1}^{T}\left(\frac{(TR_n + TC_n + X_n - M_n)}{(1+r)^n}\right)$$

Where: r = the discount rate
n = number of years

Given the variability in investment expense, aggregating efficiency and cost implications — which can change from one FAD to another depending on location, bathymetry and season — there are no averages that can universally be applied for an investment profile. Considering this, a hypothetical example is given to display the investment profile of a FAD over time.

FAD investment profile

To present the investment profile of a FAD, a hypothetical situation if formulated, which only accounts for change in CPUE. That is, all other variables, such as change in costs and indirect impacts, are assumed to remain the same. This assumption is made due to the complexity of adjusting for the wide array of factors in formulating an example.

For the hypothetical investment profile, the following parameters have been applied:

- Investment and deployment cost for a FAD is $5,000;
- Annual maintenance cost for a FAD is $1,000;
- Price (per kg) for fish is $5; and
- Discount rate of 10% per annum is applied.

These figures are realistic; however, there are few data to support the change in CPUE as a result of FADs. Therefore sensitisation of CPUE change is required.

The investment profile considers three scenarios, each with high, medium and low changes in CPUE. Numerically, these changes in CPUE are assumed to be 5 kg hr^{-1}, 3 kg hr^{-1} and 1 kg hr^{-1} for each respective scenario. Additionally, annual effort dedicated to fishing near FADs is sensitised to be low (250 hours), medium (500 hours) and high (750 hours).

Figure 1 displays the affect that effort and catch rate have on whether a positive or negative return is achieved.

Consider scenario 1, which allocates 250 hours of fishing effort per year. Clearly, with a low effort coupled with a low CPUE change of 1 kg hr^{-1}, the FAD cannot achieve a positive return due to the ongoing maintenance costs outweighing the increase in CPUE. However, when effort is increased to 750 hours per year a positive RoI is achieved after two years when CPUE change is low.

Time, or FAD longevity, also has significant implications on whether a positive return is realised. Again, consider scenario 1 and the median CPUE change of 3 kg hr^{-1}. In this scenario, a positive RoI is realised after two years. Consider the implications if the FAD is lost after one year — a negative return would be realised when, if the FAD had lasted for its expected life, a positive return would have occurred. Furthermore, the additional benefits that are derived after year 2 are not realised when the FAD is lost. In all scenarios, excluding scenario 1 with low CPUE change, the longer the FAD lasts, the higher the return on investment.

From this, two essential FAD management policies should be adopted. First, fishers should be encouraged to increase fishing effort at FADs so that any benefits from increased CPUE are realised. Second, regular maintenance to increase the life of a FAD should be practiced, with budget allocated for ongoing maintenance and replacement of worn components.

Discussion

FAD programmes in Pacific Island countries and territories are usually project based with short-term investment outlooks. Benefits of FADs, however, are often only realised over the medium term, as in the case of scenario 1. Therefore, for an economy to realise the full benefit of a FAD, management measures, such as frequent maintenance, need to be sustained.

Assuming that FADs do increase catch rates, the above scenarios show that the longer the life of a FAD, the higher the return on investment.

Recommended management measures for FADs include:

- Sustained long-term budget allocation for deployment, maintenance and replacement of anchored nearshore FADs.
- Implementation of data collection to better quantify the efficacy of FADs.
- Improved promotion of the use and purpose of FADs to increase fishing effort at FADs.
- Development of a FAD fishing code-of-conduct for all users of FADs.
- Development of FADs that have improved longevity (i.e. subsurface FADs).

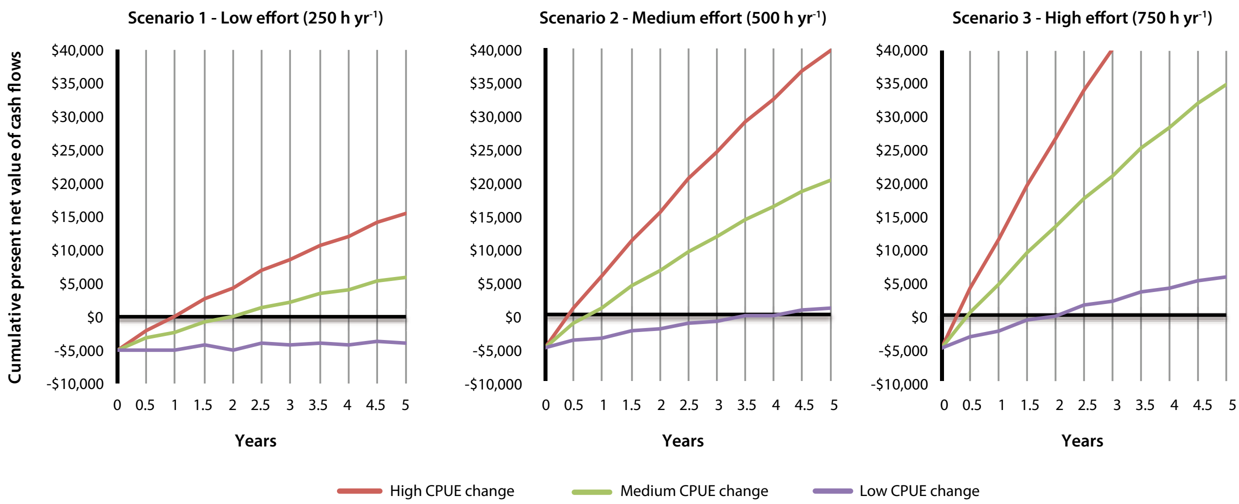

Figure 1. Investment profile for FADs based on low-, medium- and high-effort scenarios