Fisheries Newsletter

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Editorial

Three important SPC projects concluded in 2009.The SPC Regional Tuna Tagging Programme ended when the fishing vessel *Soltai 105* arrived in its base port of Noro, Solomon Islands on 15 October 2009. But, with more than 260,000 fish tagged and 4,000 fish stomachs collected, the data analysis should keep SPC's Oceanic Fisheries Programme busy for awhile (see article on p. 5). Funded by the European Union, the PROCFish/C and CoFish projects ended in December 2009. These two ambitious projects aimed at providing SPC's Pacific Island members with scientific information for use in planning the sustainable management of their reef fishery resources (see article on p. 13).

Can FADs assist with food security in two costal villages affected by the earthquake that struck Solomon Islands' Western Province in April 2007? Is there a way forward for tilapia aquaculture in the Pacific Islands region? Can special management areas (SMAs) be considered a success in Tonga? These are just three of the many questions to which authors have tried to reply. I hope you will enjoy this issue; don't forget to send in any fisheries-related news that you would like to share with other readers.

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A red-hybrid tilapia reared on Efate Island in Vanuatu. Sold under the market name of "perche cerise" (cherry perch), it has a good growth rate in culture and a very attractive colour (see article p. 24). (Photo: Paul Ryan)

in This Issue

SECRETARIAT OF THE PACIFIC COMMUNITY
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SPC ACTIVITIES

NEARSHORE FISHERIES DEVELOPMENT AND TRAINING SECTION

Initial fish silage test in Niue

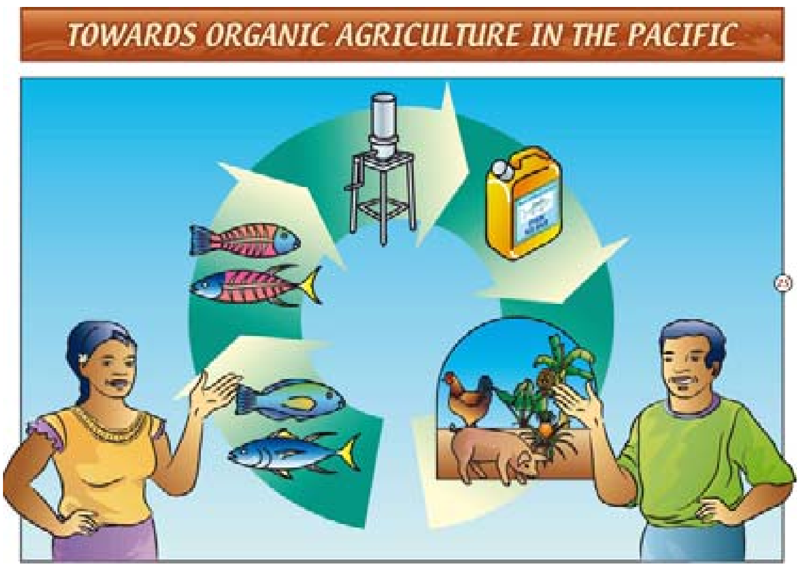
On 2 October 2009, Angus McNeil (Nelson Consultants) and Michel Blanc (SPC's Fisheries Training Adviser) took the weekly flight from Auckland, New Zealand to Niue. In their personal baggage they carried latex gloves, safety goggles, a pH-metre and a large guillotine cutter. Those of us who have been forced to give up our Swiss army knife or nail clippers to airport security might wonder how they were allowed on…

Their toolkit was, in fact, extra gear that would be needed to produce fish silage. The process is simple: fisheries waste is recovered and put through a grinder. The enzymes in the fish cause it to liquefy while the natural formic acid that is added inhibits putrefaction, and in particular the awful smell. The result is a brownish liquid that can be used as fertiliser, either by pouring it directly on the ground or spraying it on plants. It can also be used as a feed supplement for pigs and chickens (see *Fisheries Newsletter* #126 for a detailed description of the process and how this product is used). The product can be stored for up to two years.

Following a pilot project in 2008 that SPC conducted on Lifou Island in New Caledonia, and a presentation that was made at the 6th SPC Heads of Fisheries meeting, Niue asked SPC to hold a training session on producing fish silage there.

Upon their arrival in Niue, Angus and Michel, together with Brendon Pasisi, Director of Niue's Department of Agriculture, Fisheries and Forestry, assembled the motorised grinder that had been shipped from New Zealand. The cutter, which was to be used to pre-cut big pieces of fish, particularly the heads, was bolted to a workbench. Formic acid had been ordered well ahead of time and fish waste was collected for this trial run.

Operations began on the second day. Vanessa Marsh from Niue Fisheries worked with another woman to chop up the fish with the cutter, while Brendon and Angus worked at the grinder. The ground fish waste was collected in a bucket under the machine.



A page of the comic book on fish silage produced by SPC
(see: http://www.spc.int/coastfish/Fishing/Silage/Silage.htm)

On average, fishing activities on Niue produce 1.5 tonnes of waste per month that can be used for processing. About one tonne comes from the offshore fishing activities of the island's only longliner. The remainder comes from about 20 motorised boats and aluminium skiffs, which mainly trawl for wahoo. In addition, there are a number of small canoes used for fishing around Niue, but these are not economically viable as a source of waste for processing, as they catch relatively few fish, and are spread out around the island.

The grinder is a prototype adapted from gear found on some fishing boats, particularly in New Zealand. Small reef fish grind up much more easily than large oceanic fish that have very large and hard heads. The grinder seized up several times and even after smaller pieces were cut with the guillotine, the motor ended up "blowing a gasket". We found an electronics engineer who was able to identify the broken part. By the afternoon, the grinder was once again ready to use and Angus and Michel made a giant leap forward in the learning curve for this project.

Several batches of ground waste were prepared over the week and mixed with formic acid. These trials confirmed that the amount of viscera, which contain the liquefying acid, and the freshness of the waste have an effect on the hydrolysis process. The 15 farmers and fishers who attended the fish silage training session each left with a litre of freshly made fertiliser, which they will be able to dilute and test on farm and food crops.

Vanessa Marsh from Niue Fisheries adds formic acid to the ground fish waste.

Enriches the earth and nourishes bacteria

Fish silage is not new, and Australia and New Zealand have produced and used it for many years. Fish silage is a natural product that can be used for organic farming, and is of particular value due to the fish oil and trace elements it contains.

Regular fertilisers made from fish waste are emulsions, in which the fish oil has been removed (it is used for other purposes, most notably in the cosmetics industry). Because consumers want high nitrogen levels, these emulsions are high in urea, which can be absorbed directly and efficiently by plants. These fertilisers do not help enrich the soil or protect plants from pests, however, because they harm the soil's microbiology.

In contrast, fish silage enriches the soil and contains all the nutrients that micro-organisms need (e.g. trace minerals, selenium, omega oils). By feeding the bacteria and fungi in the soil, fish silage helps improve and preserve soil structure. As a result, lower nitrogen, phosphorus, and potassium levels are required, because their yields are increased by the soil's microbiology. Bacteria act like nitrogen captors in the soil, while bacteria on leaves transport the nitrogen the plant takes out of the air. Thus silage poured on the ground or sprayed on leaves contributes to the reproduction of such "worker" bacteria. The bacteria's activity and the enzymes they secrete enrich the soil and nourish the plants. We also know that micro-organisms in the soil reduce the need for water, which leads to better resistance during drought-like conditions.

In addition to being a source of nutrients, the texture of the fish oils in the silage helps hold nutrients in the soil longer. In addition, the sticky nature of silage makes herbicides used in farming adhere to the plant, thereby ensuring they do not drain into the ground and then into the water table.

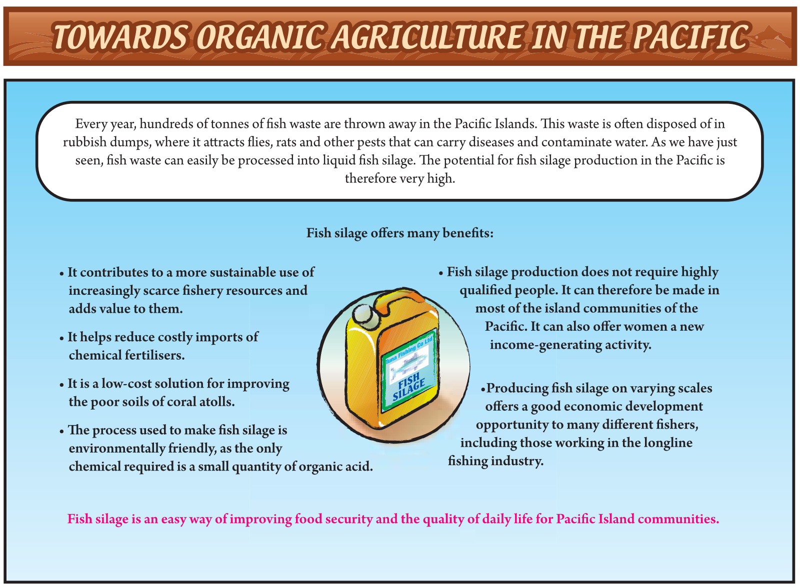
Sustainable development and economic activity

Using fish silage for fertiliser contributes to sustainable agricultural development. The environment is preserved, and rather than targeting optimal yields over the short-term (e.g. one season), producers condition and protect their main resource — the soil — thereby making their activities sustainable.

Sustainable development is at the heart of SPC's concerns, and the advantages of fish silage extend beyond farming. This project combines the practical needs of the fishing industry (which must deal with its waste), a growing awareness of the need to preserve our environment, and the economic imperative to create work for island communities.

SPC has produced a comic strip that describes the stages involved in producing fish silage, including a summary of the project's advantages in terms of sustainable development.

The fish silage project is a very accessible example of a sustainable development project.



Manual grinders are available, meaning silage can be produced at an individual level as well as on an on industrial scale. The pilot projects on Lifou and Niue were funded by SPC, but communities that want to invest in this activity will find that the initial investment is well within their means and they will get rapid returns on that investment.

It costs about AUD 20,000 for a big machine like the one used on Lifou and about AUD 4,000 for a grinder like the one used on Niue.

In Noumea, New Caledonia, the existing volume of fish waste and potential market for silage suggest a high potential for this type of investment. The Cook Islands and Nauru have also shown interest in this technique.

Workshop participants could go back home with a bottle of freshly made fish silage.

Meanwhile on Niue…

Fish silage continues to be produced on Niue. The fertiliser is being tested on various farm produce to measure both its nutritional and financial advantages. Niue will have to organise the collection of fish waste, build appropriate facilities, identify who will be in charge, and set a per-litre price for silage.

Fair winds and happy sailing to Terii Luciani…

One of the direct results of the severe financial crisis SPC experienced in 2009 was a "freeze" placed on several professional staff positions. The Marine Resources Division did not escape from this and it was with very heavy hearts that we had to say goodbye to Terii Luciani at the end of December.

Terii joined the Fisheries Training Section in 1997 from the French Polynesia Fisheries Department. He brought his development experience in island settings, his knowledge of aquaculture, and his strong computer and desktop publishing skills. Terii then became Fisheries Training Adviser when the Training and Development Sections were combined into one unit.

Terii's many talents perfectly matched those of the other members of the new Section: William Sokimi, Steve Beverly, Jonathan Manieva, Christine Bury, and Jennifer Corigliano. A short, very fruitful period (2006–2009) then followed; the Section was active and innovative in several areas such as shallow-water inshore FADs, fish silage production, and developing coastal sport fishing. Terii took part in these initiatives while continuing to coordinate the Section's capacity building activities, including holding yearly courses on safety at sea and fisheries techniques, and keeping our databases up to date. He also brought an "artistic touch" to all our documents, manuals, posters, brochures and DVDs.

Our team is deeply grateful for his 12 years of contributing to capacity building in the Pacific Islands fisheries sector.

Thanks for everything and happy sailing, Terii!

OCEANIC FISHERIES PROGRAMME

Pacific Tuna Tagging Progamme: End of the adventure

The fishing vessel (FV) *Soltai 105* arrived in its base port of Noro, Solomon Islands on 15 October 2009, marking the end of SPC Pacific Tuna Tagging Programme activities involving the last pole-and-line fishing company in the tropical Pacific.

Catch, tag and release activities in full action on the FV *Soltai 105*.

Summary of results

Since August 2006, and after 19.5 months of chartering the FV *Soltai 6* and FV *Soltai 105*, nearly 250,000 fish (see Table 1) have been tagged and released in 10 countries including Indonesia, the Philippines, Palau, Federated States of Micronesia, Marshall Islands, Kiribati (Gilbert Islands), Nauru, Solomon Islands, Papua New Guinea and Tuvalu (Fig. 1). The two vessels covered an astonishing 44,564 nautical miles, equivalent to more than twice the Earth's circumference

FV *Soltai 6*.

By 19 January 2010, nearly 13% of all tags were recovered (Table 1) and recaptures are still coming in from various unloading points.

Using two smaller, longline-type vessels from Hawaii, three central Pacific tagging cruises, lasting four to six weeks each, were concluded in 2008 and 2009. These cruises targeted the US National Oceanic and Atmospheric Administration Tropical Atmosphere Ocean oceanographic buoys anchored along the 155°W and 140°W meridians. The cruises increased the overall spatial coverage of tag releases and also greatly increased the number of bigeye tuna releases (Table 2).

An anchored US National Oceanic and Atmospheric Administration TAO oceanographic buoy.

Of the conventional tags, 886 archival tags were deployed during all cruises and 10% have been recovered so far, providing SPC's Pacific Tuna Tagging Programme with more than 5,500 days of data, containing fascinating aspects of tuna behaviour. A dedicated database has been set up, allowing scientists to extract specific information from the 8.3 million records.

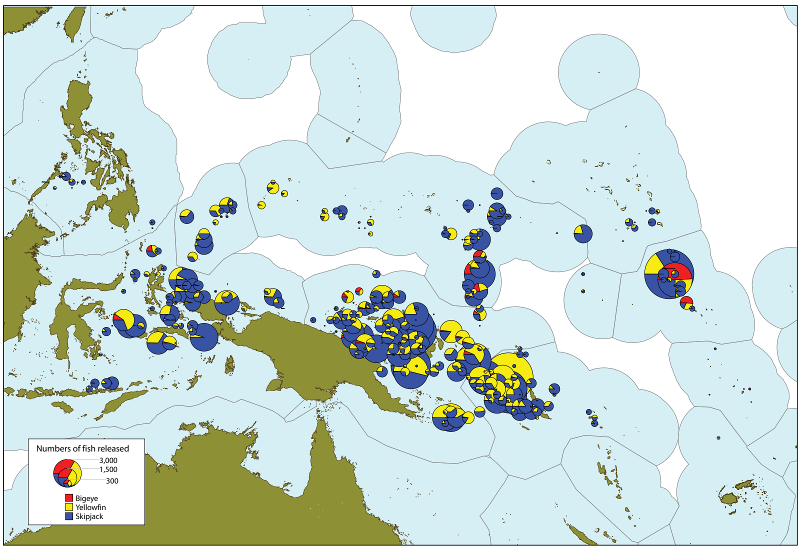


Figure 1. Releases per species, and per 0.5° squares.

Inserting an archival tag requires some surgical skills…

More than 4,000 fish stomachs were collected and almost 3,000 Fatmeter measurements were taken (see *Fisheries Newsletter* #128 for more details) during the cruises. To date, 1,768

Table 1. Conventional tag release/recapture summary by school association (as of 19 January 2010).

	Releases				Recaptures							
School association	Skipjack	Yellowfin	Bigeye	TOTAL	Skipjack	%	Yellowfin	%	Bigeye	%	TOTAL	%
Unassociated / Free school	30,382	6,060	612	37,054	3,129	10.3	528	8.7	66	10.8	3,723	10.0
Log	12,223	7,078	204	19,505	1,050	8.6	411	5.8	29	14.2	1,490	7.6
Anchored FAD	102,503	52,797	2,982	158,282	15,002	14.6	8,619	16.3	655	22.0	24,276	15.3
Drifting FAD	5,994	6,237	522	12,753	599	10.0	474	7.6	87	16.7	1,160	9.1
Marine mammal or whale shark	1,402	960	33	2,395	112	8.0	47	4.9	1	3.0	160	6.7
Current line	563	371	6	940	32	5.7	24	6.5	1	16.7	57	6.1
Seamount	3,316	1,958	2,226	7,500	178	5.4	153	7.8	195	8.8	526	7.0
Island or reef	9,477	2,057	5	11,539	815	8.6	152	7.4	0	-	967	8.4
TOTAL	165,860	77,518	6,590	249,968	20,917	12.6	10,408	13.4	1,034	15.7	32,359	12.9

Table 2. Central Pacific cruises tag release/recapture summary by school association

	Releases				Recaptures							
School association	Skipjack	Yellowfin	Bigeye	TOTAL	Skipjack	%	Yellowfin	%	Bigeye	%	TOTAL	%
Anchored FAD	262	525	771	8,558	6	2.3	36	6.9	701	9.0	743	8.7
Tagging vessel	30	33	1,074	1,137	0	0.0	0	0.0	14	1.3	14	1.2
TOTAL	292	558	8,845	9,695	6	2.1	36	6.5	715	8.1	757	7.8

Table 3. Archival tag release/recapture summary by school association

	Releases				Recaptures							
School association	Skipjack	Yellowfin	Bigeye	TOTAL	Skipjack	%	Yellowfin	%	Bigeye	%	TOTAL	%
Island or reef	24	9	0	33	0	-	0	-	0	-	0	-
Seamount	11	60	53	124	0	-	4	6.7	0	-	4	3.2
Current line	0	2	0	2	0	-	0	-	0	-	0	-
Tagging vessel	0	0	2	2	0	-	0	-	0	-	0	-
Marine mammal or whale shark	0	3	1	4	0	-	0	-	0	-	0	-
Drifting FAD	2	6	7	15	0	-	0	-	0	-	0	-
Anchored FAD	38	230	328	596	1	2.6	31	13.5	42	12.8	74	12.4
Log	8	11	0	19	1	12.5	0	-	0	-	1	5.3
Unassociated / Free school	14	63	14	91	2	14.3	7	11.1	0	-	9	9.9
TOTAL	97	384	405	886	4	4.1	42	10.9	42	10.4	88	9.9

Measuring fish and collecting stomachs and their contents.

shore, and the amount required for 30 people could quickly rise to impressive sums. In some small island countries, local banks were not unable to provide the amount needed.

Food shopping for 35 people for two weeks is also a test in remote places but luckily it was possible to exchange fruits and vegetables for fish at the baiting grounds. About 20 kg of rice were consumed every day onboard the FV *Soltai 6* and the FV *Soltai 105*.

stomach contents have been analysed and 190 different species have been identified within the 53,091 prey counted.

Behind the scene

Behind these dry numbers, which reflect the success of the tagging experiment, hides the immense organisation of this programme.
Before the tagging cruises began:

- The Soltai fishing company[1] fished only in local waters and was unable to support all of the necessary requirements involved in having both boat and crew outside Solomon Islands exclusive economic zone.
- Most of these Solomon Islands fishermen had no passport and had never been overseas.
- Boats had to be modified (especially for accommodations and the addition of a small office) and serviced before departure (See *Fisheries Newsletter* #118).

In fact, in addition to overseeing the research project itself, SPC scientists were in charge of a large fishing vessel and its 30 crew members, which was quite a challenge.

Dealing with very different clearance procedures when arriving in a new country can be quite frustrating. Numerous administrative forms were completed, including those for immigration, quarantine and customs. Thankfully, we had a reliable printer onboard!

Another big task was to manage the money to operate the boat during cruises of up to five months. Bank accounts specifically for the project were set up in some countries, but having a cheque book didn't resolve everything. For example, fuel companies rarely accept a personal cheque to pay for 60,000 liters of diesel oil (needed to fill the boat fuel tanks). Also, crew members needed cash when on-

Trading food in Gasmata, Papua New Guinea

Trading coconuts and bananas for fish in Satawan, Federated States of Micronesia.

What's next?

Tagging

The main purpose for tagging tuna is to obtain information on stock status. It has been suggested that instead of organising a large tagging experiment every 10–15 years, it would be more efficient to conduct "ongoing tagging" (i.e. two to three months every year) to regularly update the data needed for stock assessments. The FV *Soltai 105* and its well-trained crew would have been the perfect tagging platform for this purpose but the future of the few pole-and-line vessels remaining from the Soltai fleet is currently less than certain.

Soltai pole-and-line vessels in port in Noro, Solomon Islands.

Two additional central Pacific tagging cruises are scheduled for May and October 2010.

Analysis

We expect a final tag recovery rate of around 15%. No doubt the amount of information collected will keep the Stock Assessment and Modelling section of SPC's Oceanic Fisheries Programme busy for quite a while!

First use of the data will be presented during the next Scientific Committee of the Western and Central Pacific Fisheries Commission, which is scheduled to be held in Tonga in 2010.

1. The Soltai fishing company ceased its fishing activities in 2009.

NEW SPC PUBLICATION: Longline terminal gear identification guide

This new SPC publication will help observers, researchers, and captains of longline boats to correctly identify hooks, swivels, trace lines and baits used in pelagic longline fishing. It is important for longline terminal gear to be correctly identified because it has an effect not only on target species catch rates, but also on catch rates and post-release survival of bycatch species, including marine turtles. The guide is divided into four sections: hooks used in longline fishing, swivels, trace lines, and baits (including lightsticks). Of these, the most important are longline hooks. Past and current research shows that the use of large circle hooks reduces the catch rate of some bycatch species while improving (or not affecting) the catch of target species. Circle hooks also improve the chances of post-capture survival of released bycatch species. Standardisation of hook types and sizes is therefore very important for data recording and analysis for observer logsheets, wheelhouse logsheets, and for scientific studies on the effects of terminal gear on catch rates and post-capture survival.

The pocket-size guide (95 mm x 135 mm) is printed on plastic for use in a marine environment. It was printed with financial support from Australia and the Pacific Islands Forum Fisheries Agency.

For more information on this publication and ways to obtain copies, please contact:

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COASTAL FISHERIES MANAGEMENT SECTION

Community-based ecosystem approach to fisheries management: Guidelines for Pacific Island countries

Implementing the ecosystem approach to fisheries (EAF) management in Pacific Island countries is becoming important for managing the region's coastal fisheries. This has been reflected in the recommendations of the sub-regional joint Food and Agriculture Organization of the United Nations (FAO)/SPC EAF workshops held in Nadi, Fiji (November 2008), and in Guam (March/April 2009). The two respective workshops requested the formulation of a manual and guidelines to integrate EAF components into existing coastal resources management programmes, which are in most countries implemented by communities with national agencies or non-governmental organisations (NGOs) playing a supportive role.

Managing a resource or fish stock in isolation from its ecosystem ignores the fact that the very ecosystem that the resource or fish species depends on is being affected by fishing activities and other human activities. Fishing can affect an ecosystem by 1) catching unwanted species, 2) causing physical damage to habitats, 3) disrupting food chains, and 4) causing changes in biodiversity. Other human activities unrelated to fishing — such as agriculture, forestry and development — can also affect marine ecosystems, including the species that are part of them. The effects of climate change also often exacerbate human impacts on an ecosystem.

It is pointless to address the problem of depleted fish stocks merely by placing controls on fishing activities if the key threats to their recovery are related to other human activities and natural factors that cause ecosystem degradation. For these reasons, fisheries authorities are replacing narrow, target species-based fisheries management strategies with a broader approach that attempts to manage fish stocks as components of marine ecosystems. Under an EAF, the usual concern of fisheries managers (i.e. the sustainability of target species) is extended to address the sustainability of an ecosystem on which a fishery depends, which includes people and fish stocks. EAF addresses both human and ecological well-being and merges two paradigms: that of protecting and conserving ecosystem structure and functioning, and that of fisheries management, which focuses on providing food, income and livelihoods for humans.

Because the objective of EAF is the sustainable use of entire ecosystems as well as target species, non-fisheries activities that impact marine ecosystems must also be managed, even though these activities may be outside the responsibility of fisheries authorities. In addition to fishing, target stocks are affected by non-fishing factors, including climate change, coastal development, pollution, and the loss of critical habitats by reclamation. Because of the broad issues involved, fully implementing an EAF requires collaboration and cooperation between communities and a range of government agencies responsible for managing activities that impact on marine ecosystems.

In instances where communities are involved in managing fisheries, actions are already being taken to protect key ecosystems such as coral reefs and mangroves. In other words, addressing human impacts on ecosystems is not a new concept within community-based fisheries management.

A community-based ecosystem approach to fisheries management (CEAFM) represents a combination of three different perspectives: fisheries management, ecosystem management and community-based management. An appropriate definition of CEAFM is the management of fisheries — within an ecosystem context — by local communities working with government and other partners. The close involvement of communities accentuates the fact that humans are an integral part of ecosystems and their needs must be addressed.

In an effort to assist countries with implementing their CEAFM programmes, SPC and FAO in partnership with The Nature Conservancy developed guidelines for implementing national CEAFM programmes. The guidelines are intended to help communities, government agencies and NGOs in Pacific Island countries to work together to develop and implement community-owned fisheries management plans for a designated area. Although the guidelines are particularly designed to enable a government fisheries agency to work with communities to manage coastal areas, they may be used by any group, including community leaders, an environmental agency, or an NGO, for the same purpose.

The guidelines that have been drafted give some background, including a summary of key issues with regard to coastal ecosystems in Pacific Island countries, and present step-by-step guidelines and simple tools to assist communities and their partners in creating and implementing community plans that reduce human impacts on ecosystems and ensure that catches of seafood species are sustainable. The guidelines also provide some basic requirements for implementing a CEAFM.

Developing a national coastal management framework for Vanuatu

The Vanuatu Fisheries Department requested assistance from SPC's Coastal Fisheries Management Section in developing a framework for implementing its integrated coastal management project. The project, "Enhancing coastal and marine ecosystems resilience to climate change through coastal governance and conservation measures", was established by the Pacific Regional Environment Programme's Coastal Zone Management Programme, and was spearheaded by the National Fisheries Authority. The project envisages developing a coastal fisheries management plan for selected communities and assisting those communities in developing actions not only to manage coastal fisheries, but also to build resilience toward the impacts of non-fisheries activities and climate change.

Kalo Pakoa, Project Coordinator, stated:

> "One of the main objectives of the project is to develop a framework policy to bind all our effort towards our adaptation in the long term. The issue of climate change is so broad involving many sectors whose responsibilities are guided by different legislations, priorities and overlapping responsibilities. Working together can be very difficult and complicated; we therefore need a framework policy based on our local situation to guide us forward. With global phenomenon at the rise in terms of climate change and sea level rise, we in Vanuatu can contribute immensely to strategic actions only in a coordinated manner."

In response to Vanuatu's request, SPC's Coastal Fisheries Management Section conducted a national consultation workshop and funded two officers from Vanuatu to undertake a two-week attachment at SPC's headquarters in Noumea.

The aim of the workshop was to initiate the process for developing a national framework for an integrated management approach to coastal ecosystem and fisheries. The workshop considered fisheries and non-fisheries impacts on the marine environment and the effects of climate change on fisheries resources. The process provides guidelines on implementing strategic actions to improve the natural resilience of marine ecosystems and livelihoods of local communities who are dependent on marine resources.

In opening the workshop, the Director General of Vanuatu's Ministry of Agriculture, Quarantine, Forest and Fisheries, Jeffery Wilfred, stressed that the impacts of climate change are no longer a future threat:

> "Right now, changes in weather patterns brought about by changing climatic condition are affecting the very basics of our lives, increased rainfall, floods and erosion and increasing frequency and intensity of tropical cyclones. Rising sea surface temperature has already caused mass loss of our corals to bleaching and crown of thorns outbreak which threatens fisheries and marine based economies and livelihoods. Climate change is affecting the resources and the ecosystems upon which we rely on for our food security needs, water supplies, agriculture landscape and the productivity of our reefs and oceans."

Fisheries are a "down stream sector", which depend very much on the quality of coastal ecosystems. Waste derived from land-based sources ends up in the sea and when the marine ecosystem is damaged, fisheries and marine biodiversity are the first to be affected.

The purpose of the attachment of Kalo Pakoa (Project Coordinator) and Touasi Kalsaria-Tiwok of the Department of Environment was to develop a draft national framework based on recommendations from the national workshop. The Coastal Management Framework is a policy document intended to inform and guide the Department of Fisheries as the lead agency on coastal environmental matters and other line agencies, whose activities are linked to the coast, to improve strategic decision-making in order to address the impact of climate change. It is also developed to promote and ensure compliance of existing measures to achieve sustainability through promotion of sound practices by line government agencies and communities.

Change of Coastal Fisheries Management Adviser at SPC

The Coastal Fisheries Programme's Coastal Fisheries Management Adviser, Ueta Fa'asili finished with SPC after nine years of service in December. Ueta has been instrumental in developing and promoting community-based fisheries management in the region, and in more recent times, has expanded this to include ecosystem approach to fisheries principles within a community-based approach. The CFP staff wish Ueta well in his future endeavours.

Ueta Fa'asili headed the Coastal Fisheries Management Section from 2000–2009.

Ian Bertram, currently Secretary for Fisheries in Cook Islands, will take up the position of Coastal Fisheries Management Adviser in mid-January 2010. Ian will manage not just coastal fisheries management, but also coastal fisheries science, as these two work areas have been amalgamated into the Coastal Fisheries Science and Management Section. Ian joins SPC with a broad and varied background in coastal fisheries science and management gained through his years of working with the Ministry of Marine Resources in Cook Islands. Ian has a Bachelor's degree in Fisheries from the Australian Maritime College and has worked his way up through the ranks from Fisheries Trainee in 1988/1989, to Hatchery Manager at Aitutaki in the early to mid-1990s, then as Director of Economic Development in the late 1990s and Director of Aquaculture and Inshore Fisheries in the early 2000s, before becoming Secretary of Fisheries in July 2004. The CFP staff welcome Ian to his new position with SPC.

Ian Bertram will join SPC as the new Coastal Fisheries Management Adviser in mid-January.

AQUACULTURE SECTION

Wallis and Futuna delegation visits New Caledonia aquaculture facilities

The French Pacific Fund granted funds to Wallis and Futuna for a project aimed at determining the potential for aquaculture development in the territory.[1] As part of this project, a delegation from Wallis and Futuna came to New Caledonia in October 2009 to visit aquaculture facilities and meet with key stakeholders of New Caledonia's aquaculture sector.

The initial phase of this project determined whether aquaculture could be developed in Wallis and Futuna given its social and economical contexts, and also determined which commodities should be considered. Jacques Trichereau from IDEE (Ichthyo Developpement Eau Environnement) Aquaculture initially identified two key products: marine shrimp and finfish. Although these commodities would need to be imported as post-larvae or fingerlings, both have promising potential in a country where the demand for seafood is high but the supply is currently low, and mostly imported at prices that often exceed the population's buying power (see *Fisheries Newsletter* 129:19–20).The delegation from Wallis and Futuna comprised two representatives from the fisheries services (Bruno Mugneret and Amalia Fotofili), one from the fishermen's association (Kusi Toa), one from the government (Petelo Lié), and one from the department of the environment (Aurélie Chavez). The delegation , which's, met with specialists and gathered technical information while visiting research centres and production sites. The visits were very enriching for the delegation. Upon arrival and after several presentations delivered at SPC, they travelled to Ngo Bay where they visited Aqualagon rabbitfish hatchery and grow-out project, and met with manager Frank Legarrec.

Jacky Patrois (third from left) from the French Research Institute for Exploitation of the Sea (IFREMER) showing a broodstock tank to the Wallis and Futuna delegation at the St Vincent Center.

A visit was made to the French Research Institute for the Exploitation of the Sea (IFREMER) where Jacques Patrois described various aspects of shrimp aquaculture that the research centre works on. Other shrimp facilities, such as the Eori hatchery in Bourail (Bruno Castelain) and later a large (Webhuione) and a small prawn farm managed by a family (John Kuhn), were also visited. These visits to shrimp farms were extremely useful and helped the Wallis delegation to understand the ins and outs of this industry in New Caledonia. Although the social, economic and environmental contexts are much different in these two countries, practical information was taken home by the delegation along with some understanding of a commercial approach to shrimp aquaculture development. Participants' awareness was also raised on biosecurity issues and ways to deal with these issues.

A visit was also made to the Northern Province aquaculture research laboratory in Kone where the delegation met with Nathalie Baillon and Claire Marty. This project is currently under construction and aims at having a fully functional multispecies fish hatchery operational by late 2010. The species that will be produced in the future are of interest to Wallis and Futuna, and the laboratory could well be a fingerling supplier for the future industry there, along with Aqualagon. The laboratory also acts as a regional training centre. Discussions were held on the possibility for Wallis to use the centre to gain practical experience on tropical fish farming.

Bruno Castelain (left) from the Northern Province, briefing the Wallis and Futuna delegation prior to the Eori Hatchery visit.

Other official visits were made to government agencies in New Caledonia such as the Southern Province Fisheries Department (Thomas Réquillart and Bernard Fao) and the Department of Environment (Emmanuel Coutures), where everyone shared their experiences with enthusiasm.

This visit was a success thanks to the willingness and generosity of all stakeholders. It is now up to Wallis and Futuna to determine if, and how best, to develop their aquaculture sector.

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1. The Wallis and Futuna aquaculture development plan will be available online in early 2010 at www.spc.int/aquaculture.

REEF FISHERIES OBSERVATORY

End of an era — PROCFish coastal and CoFish projects come to an end

The coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development project (PROCFish/C) began in March 2002, funded by the European Union through the eighth European Development Fund (EDF). The project covered the eight African, Caribbean and Pacific (ACP) countries in the Pacific (Fiji, Kiribati, Papua New Guinea, Vanuatu, Samoa, Solomon Islands, Tonga and Tuvalu) and the three French Overseas Territories in the Pacific (French Polynesia, New Caledonia, and Wallis and Futuna). The project's aim was to provide Pacific Island ACP governments and community leaders with the basic information necessary to identify and alleviate critical problems that prevent the better management and governance of reef fisheries, and plan appropriate future development.

Two years later, in May 2004, a sister project was agreed on and started under the European Union's ninth EDF funding, the Pacific Regional Coastal Fisheries Development project (CoFish). The project covered six new Pacific ACP countries (Cook Islands, Federated States of Micronesia, Marshall Islands, Nauru, Niue and Palau) and had exactly the same objectives and aims as the PROCFish/C project. The joint projects were designed to implement the first ever comprehensive multi-country comparative assessment of reef fisheries (including resource and human components) in the Pacific Islands region, using identical methodologies at each site in order to:

- provide a baseline and help fill the massive information gap hindering the effective management of reef fisheries;
- improve information linkages between intergovernmental and governmental institutions and small-island community processes;
- provide methodological training and, by working directly with Pacific Islanders, foster the development of management plans and policies;
- ensure that information reaches the appropriate targets through local workshops and national and regional colloquia; and
- generate a large body of published information for permanent reference.

The expected outputs from the projects were:

- a first ever region-wide comparative assessment of the status of reef fisheries using standardised methodology;
- application and dissemination of results in country reports comprising a set of "coastal fishery resource profiles" for sites in each country in order to provide information for coastal fisheries development and management planning;
- a set of indicators/proxies, or fishery status reference points, for use as guidance when developing local and national reef fishery management plans and monitoring programs;
- toolkits (manuals, software and training programmes) for assessing and monitoring reef fisheries and increased capacity in using standardised survey methodologies across fisheries departments in participating countries;
- data/Information management systems – regional and national databases; and
- although not specified but proposed, follow-up projects that use this information to address specific challenges commonly experienced by fisheries departments and target communities, thereby working towards improving resource management in the region.

To achieve project outputs over a period of almost eight years[1], a comparative analysis of reef fisheries in 17 Pacific Island countries and territories was carried out using standardised survey methodologies. These methodologies included commercial finfish species through underwater visual census (UVC) surveys (Fig. 1), and invertebrate resource surveys using a range of methodologies (Fig. 2), some of which were species specific. In addition to in-water surveys, socioeconomic surveys of coastal communities involved in both subsistence and commercial harvesting of finfish and invertebrates in the surveyed areas were conducted (Fig. 3). Table 1 summarises the countries surveyed and the approximate timing of the survey work.

In total, 63 sites were surveyed in 17 participating countries and territories. In the cases of Niue and Nauru, the whole country was surveyed as a single site. A report was produced for each country and territory, summarising the results of the finfish and invertebrate resource surveys, and socioeconomic surveys for each site. A single set of resource management recommendations was also included in the report for each site. For many of the participating countries and territories, the PROCFish/C and CoFish survey data are the only data available, and so these can

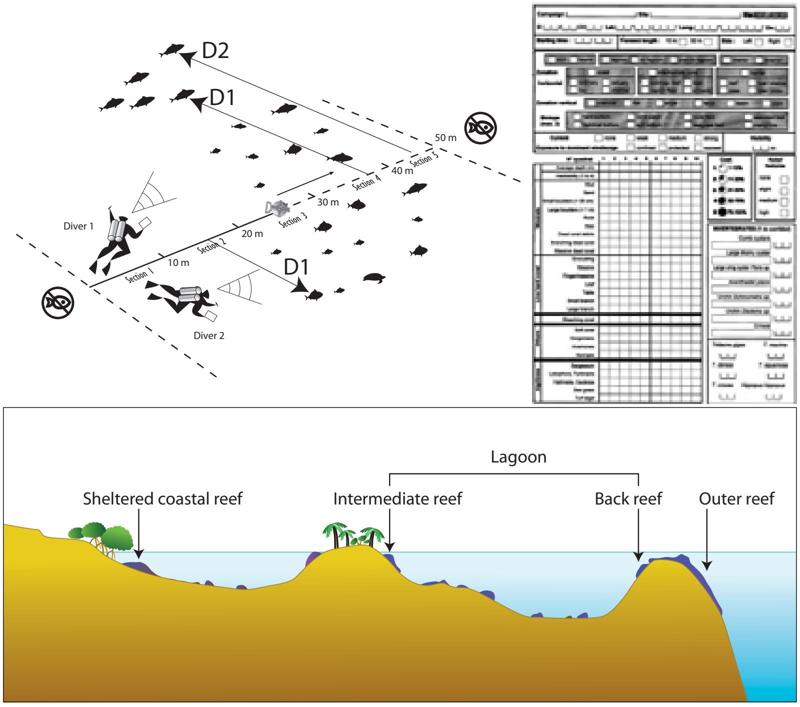

Figure 1. Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses.

Each diver recorded the number of fish, fish size, distance of fish from the transect line, habitat quality, using pre-printed underwater paper. At each site, surveys were conducted along 24 transects, with six transects in each of the four main geomorphologic coral reef structures: sheltered coastal reefs, intermediate reefs and back-reefs (both within the grouped "lagoon reef" category used in the socioeconomic assessment) and outer reefs.

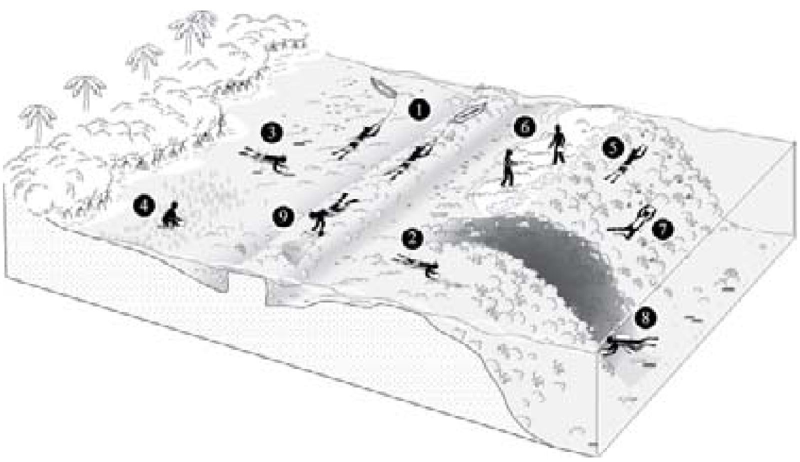

Figure 2. Assessment of invertebrate resources and associated environments.

Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epibenthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal molluscs (4); searches to determine trochus and beche-de-mer aggregations in the surf zone (5), reef edge (6) and using scuba (7); and deep dives to assess deep-water sea cucumber populations (8).

be considered as baseline data for future surveys or assessments to identify changes in stock status.

In addition to the standardised surveys, eight specific surveys were undertaken at the requests of governments on certain species that needed scientific assessment for management purposes. These surveys focused mainly on commercial invertebrate species such as trochus and beche-de-mer and were conducted in the Federated States of Micronesia (Kosrae, Pohnpei and Yap), Palau, Samoa, Tonga and Vanuatu, where there was concern regarding exploitation, or where the government wanted to open the fishery. In the case of Cook Islands, the survey focused on parrotfish at Palmerston Atoll where there has been a long history of commercial harvesting.

The PROCFish/C information system (Fig. 4) was built around a central database containing three bodies of data: data collected by the PROCFish/C team during site surveys, external data used for analysis and calculations (for example biological data), and a document repository with reports and unstructured data. Software modules allow data entry, query and analysis by the PROCFish/C team, and attachments and can be used either to access the central database or a stand-alone database installed with the software. Each country and territory has been provided with a copy of the information system with their specific data, so additional data collected at the national level can be included and analysed.

During the course of the projects, two manuals were produced and published with two others drafted. A manual on

Table 1. Countries and territories surveyed by the PROCFish/C and CoFish projects with approximate timing and number of sites surveyed.

Country/territory	Approximate timing of fieldwork/surveys	Number of sites surveyed
Tonga*	November and December 2001, March to June 2002; re-survey April to June, September and October 2008	6 re-surveyed 4
Fiji Islands*	September to November 2002, April to June 2003; re-survey June and July 2007, and February 2009	6 re-surveyed 4
New Caledonia**	March, April and November 2003; January, February, April, June, August and November 2004; April and May 2005; January to March 2006; and January and February 2007	5
Vanuatu	July to December 2003	4
French Polynesia	September to October 2003, January to March 2004; and May to June 2006	5
Kiribati	May to November 2004	4
Tuvalu	October to November 2004, and March to April 2005	4
Niue	May and June 2005	1 (country)
Samoa	June 2005 and August/September 2005	4
Nauru	October and November 2005	1 (country)
Wallis and Futuna	August to December 2005 and March 2006	3
Federated States of Micronesia	April and May 2006	4
Papua New Guinea	June to November 2006	4
Solomon Islands	June to September 2006 and December 2006	4
Cook Islands	February and October 2007	4
Palau	April to June 2007	4
Marshall Islands	August and September 2007	4

* Tonga and Fiji were initially surveyed under the "joint application of demography and ecology in evaluating the role of coastal fisheries resources in the Pacific Islands — DemEcoFish project", then re-surveyed under PROCFish/C

** Because New Caledonia was the home base for project staff, surveys were conducted when time permitted between survey work in other countries.

UVC finfish survey methodologies was one of the first outputs of the project, although as the survey methodologies were refined, some parts of the manual became obsolete, including some of the analysis formulae. This manual has been redrafted to take account of the changes as well as simplifying the methodology so that a monitoring regime can be established in-country based on the techniques described. This manual will be finalised under the EU project "Scientific support for the management of coastal and oceanic fisheries in the Pacific Islands region (SciCOFish)", which is

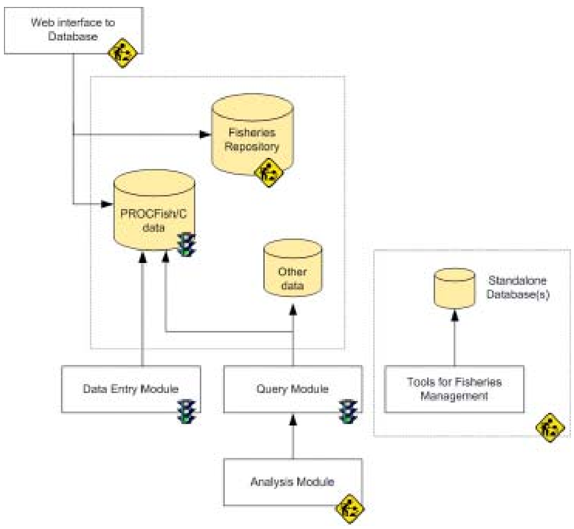

Figure 4. The PROCFish/C and CoFish information management system.

scheduled to start in 2010. The other draft manual covers survey methodologies for invertebrate species using a mix of approaches. This manual will also be finalised and printed under the SciCOFish project, which will focus on assisting Pacific Island countries with setting up and running monitoring finfish and invertebrate programmes.

The final manual produced by the PROCFish/C and CoFish projects focuses on a proposed method to plan, conduct and use socioeconomic fisheries surveys in Pacific Island countries and territories to help communities and managers to improve reef fisheries management. The manual is mainly aimed at fisheries officers and staff engaged in governmental and non-governmental organisations and institutions, and is complemented by software called SEMCoS. Both the manual and the software follow the same structure and make the link between the manual, data entry and data retrieval. A series of three sub-regional workshops were held in 2007 and 2008 to train staff members from each of the 17 participating countries in the methodologies and analysis covered in the manual.

Capacity building was a main component of the projects, and this was provided through the hiring an attachment for six months in some countries to assist with project implementation, or several attachments for shorter periods. During the surveys themselves, counterpart officers from fisheries departments and other organisations were trained in how to conduct finfish, invertebrate and socioeconomic surveys. A series of three sub-regional workshops was conducted in 2008 covering the UVC methodologies used by the project, with two fisheries staff per country trained over a 10-day period. Many workshop participants were also involved in the in-country survey work, so this was more of a refresher training for those fisheries officers.

The final component of the projects is the production of a report covering the regional assessment across the 63 sites in the 17 participating countries and territories, which also included the identification of indicators on reef fisheries status. Most of the data analysis has been completed and some sections of the report drafted, with the regional report to be finalised and released in early 2010. Some of the interesting points coming out of the regional assessment include the very low stock levels in most countries across the region for the commercial invertebrate species, sea cucumbers and trochus. There are some exceptions, such as French Polynesia and some sites in Palau and Cook Islands, and some countries now have management arrangements in place to try to rebuild stocks in the future. Small fish size is another concerning factor coming out of the data analysis, with over 65% of the total fish recorded being 20 cm in length or less.

Harvey Renguul (on the right), PROCFish local counterpart in Palau, conducting a finfish survey.

Farewell to the last of the PROCFish/C and CoFish staff

Mecki Kronen (Community Fisheries Scientist) and Franck Magron (Reef Fisheries Information Manager) who have been with the project from the start in March 2002, both finished with the project in October. However, Mecki stayed on at her own expense to finalise the write-up of the socioeconomic component of the regional assessment. Mecki will be starting a new position as Project Officer with the European Union office in New Caledonia in 2010, and we wish her well with her new position. Franck will stay with SPC in a different capacity as he will be the coordinator of a project on "Monitoring the vulnerability and adaptation of coastal fisheries to climate change" that is being funded from Australia's International Climate Change Adaptation Initiative.

The Project Administrator for the project, Marie-Therese Bui, has also been with the project since the start and she will assist with the final auditing of project accounts in early 2010. Marie-Therese will also remain at SPC, now being the Project Administrator for the Fisheries Science and Management Section of the Coastal Fisheries Programme. The Technical Support Officer, Céline Barre, has been with the project since April 2008, working on the formatting and layout of the 17 country reports. Céline finished in December, and is currently looking for a job and would like to stay in the region and work.

On behalf of all of the staff that have worked on the PROCFish/C and CoFish projects over the years, SPC would like to acknowledge with thanks the funding support of the European Union, and the collaborative support of the staff from the fisheries departments or fisheries services, environment or conservation departments, other scientific institutions, and parts of the private sector in the 17 participating Pacific Island countries and territories where fieldwork was undertaken. Special thanks is also given to the chiefs, elders, mayors, community groups and community members across the 63 sites that were surveyed, for without their cooperation, support and assistance of these groups, the project would not have been as successful as it has.

Franck Magron
former Reef Fisheries
Information Manager.

Mecki Kronen
former
Community Fisheries Scientist.

Céline Barre
former Technical Support Officer.

Transplanted trochus from Fiji to Tonga

By Bob Gillett

In the Pacific Islands region, the natural distribution of trochus is limited to a line between Yap Island in Micronesia and Wallis Island in western Polynesia. During the past 70 years there have been numerous attempts to introduce trochus to new areas. Starting with work by the Japanese in the western Caroline Islands in the 1920s, at least 70 transplantations have taken place between Pacific Island countries.

Between August 1992 and January 1995 about 2,300 trochus were transferred from the Lau Group in Fiji to various islands in Tonga (Table 1). A visit to the handicraft market in Nuku'alofa in October 2009 revealed that a substantial number of handicrafts were made from the progeny of the transplanted trochus.

Table 1. Summary of the Fiji to Tonga trochus transplants.

August 1992	Fiji to Tonga (Vava'u)	545 shells collected from Lakeba Island, Lau Group and flown by commercial aircraft to Tongatapu. 250 of these were flown to Vava'u and placed on the reef west of Tapana Island. In early 1998, several juveniles were found by the Fisheries Depart and by the Japan International Cooperative Agency (JICA) near the Pangaimotu causeway. An additional 384 shells were transferred from Tongatapu to Vava'u in July 1998.
May 1994	Fiji to Tonga (Tongatapu)	1,172 shells were collected from Lakeba Island. 1,070 of these were delivered live to Tongatapu. The majority were eventually placed on a reef in northwest Tongatapu; some juveniles reported by JICA in mid-1998.
January 1995	Fiji to Tonga (Ha'apai)	594 shells were collected at Lakeba Island and transplanted to Uoleva Island, Ha'apai. An additional 350 shells were transferred from Tongatapu to Uoleva in July 1998.

Handicrafts made from transplanted trochus, and sold at Nuku'alofa market, Tonga.

Nearshore fish aggregating devices: A means of habitat protection and food security in post-disaster Solomon Islands

by Dr Joelle A Prange[1], Cletus P. Oengpepa[1] and Dr Kevin L Rhodes[2]*

In April 2007, an earthquake measuring 8.1 on the Richter scale triggered a tsunami and caused land and reef uplift and extensive damage to fringing coral reefs in areas of Western Province, Solomon Islands. Consequently, some coastal communities suffered detrimental effects to their fishing grounds through the partial or complete loss of coastal habitats (including coral reefs, seagrass beds and mangroves).

Solomon Islands coastal communities are heavily dependent on marine resources and coastal fisheries for their livelihoods. Because the reef and coastal ecosystems impacted by the earthquake would take time to recover, there was concern that fishing pressure would impede recover, as local communities tried to meet their daily needs from a compromised coastal resource.

In the aftermath of the tsunami, in an effort to assist communities in Western Province, the World Wide Fund for Nature, Solomon Islands (WWF-SI) received funding from the David and Lucille Packard Foundation for a project on "Post-disaster fisheries and marine conservation recovery activities in the Western Province, Solomon Islands". The WorldFish Center worked in partnership with WWF-SI on this component of the project, with the goal of examining whether nearshore fish aggregating devices (FADs) could help to maintain food security, while diverting fishing effort away from recovering reefs.

FADs were deployed at three earthquake-affected coastal communities (Rarumana, Pienuna and Buri). The simple, cost-effective FADs were made primarily from locally available materials (e.g. empty fuel drums, cement anchors) and imported ropes and floats. The FAD deployment sites were in nearshore coastal areas, both near the outer part of a reef and lagoon system (40 m) and on island dropoffs (100–200 m).

The FAD raft structure was made from locally available bamboo, held together with a car tyre and rope. Maintenance visits indicated that the raft materials have a life of approximately nine months and it is envisioned that communities will be able to maintain the raft component of the FAD after the project ends.

Figure 1. Fishers remain in awe at the uplifted reef on the island of Ranongga after the 2007 earthquake.

Figure 2. Rarumana community members transport the raft component of their FAD to the sea for deployment.

Two of the communities where the FADs were deployed were able to protect and secure the FADs for more than 12 months. One of the deployed FADs was lost about six months after initial deployment (suspected sabotage), highlighting the need for better planning with the community, more widespread communication and further consideration of FAD placement.

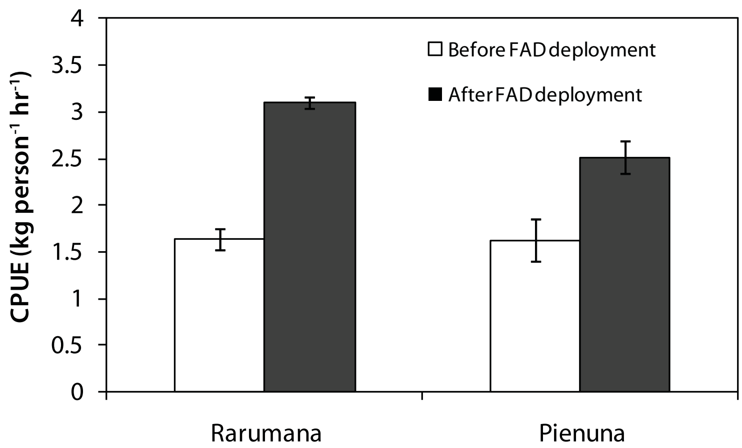

Figure 4. Average fishing catch per unit of effort (kg person^{-1} hr^{-1}) at the two study sites (Rarumana and Pienuna) before and after the FAD deployment.

Figure 3. Nearshore FAD deployed at Rarumana.

Catch per unit of effort (CPUE) data (before and after FAD deployment) collected by the communities has provided an initial assessment of FAD effectiveness. The data suggest that the two FADs were successful in attracting fish within a few weeks when appropriately located. Higher CPUE was recorded after deployment of the FADs, and CPUE was markedly greater for FAD fishing compared with reef fishing (at Rarumana), suggesting that nearshore FADs can be effective in supplementing food and income for Solomon Island coastal communities.

Although there was clear anecdotal evidence that reef fish and coral communities changed as a result of the disaster, it is unclear whether reef fish standing stock also changed as there was no pre-disaster information available to gauge the effect on reef fish catch volumes and composition. Nonetheless, CPUE data provide some interesting insights into the reef and FAD fisheries that can be used to help develop a future research focus for management within these communities. Fishers were able to adapt their fishing efforts by targeting FADs to increase CPUE. In addition fishers rapidly acquired and used knowledge about fishing at the FADs to target certain fish at certain times of the day and lunar phases. In some situations, fishers used FADs not only for target species for consumption and sale, but also for catching baitfish, thereby allowing more desirable fish to be caught elsewhere (e.g. deepwater snapper), which was a previously underutilized fishery.

The results from this work indicate that FADs have the potential to divert fishing effort away from reef systems by making pelagic fish more accessible to village fishers. The notable increase in the catch and weight of fish from FADs indicates that FADs may in fact increase the quantity of fish that coastal reef dwelling communities catch and consume, thereby contributing to increased protein intake and community health.

This is the first project in Solomon Islands to examine the utility of FADs in altering fishing habits, and improving the availability of fish for local disaster-affected coastal communities. The catch data collected through this project provide a preliminary indication that FADs may act to reduce pressure on reefs following perturbations such as natural disasters and overfishing.

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The diet of tunas: A global comparison

By Valérie Allain, SPC Fisheries Scientist (Ecosystem Analysis) and Jock Young, CSIRO Senior Research Scientist

In October 2009, 14 scientists from research institutes in France, Australia, USA, Spain, and two Pacific regional organisations — SPC and the Inter American Tropical Tuna Commission (IATTC) — met in Sète, France for a one-week workshop on tuna diet.

The workshop was sponsored by the international programme Global Ocean Ecosystem Dynamics through its programme on Climate Impacts on Oceanic Top Predators (CLIOTOP). CLIOTOP is devoted to the study of top oceanic predators within their ecosystems, and is based on a worldwide comparative approach among oceans. The goal is to improve knowledge and to develop a reliable predictive capacity for single species and ecosystem dynamics.

The workshop was one of the activities of the CLIOTOP working group on "trophic pathways in open ocean ecosystems". Entitled "Feeding in tunas – a global comparison", the aim of this meeting was to answer this question: "Can a comparison of top predator diets within and between the Pacific, Indian and Atlantic Oceans lead to an understanding of the effects of ocean warming in these predator communities?"

This workshop gathered seven datasets from tuna and other pelagic top predator diet studies covering the three oceans. The information will enable a large-scale analysis to identify differences between oceans and regions. The data come from two studies in the Indian Ocean (one of them also covers the Atlantic Ocean), one from the eastern Pacific Ocean (IATTC), two from the western Pacific Ocean (including SPC), and two from the Atlantic Ocean. These data were collected between 1969 and 2009.

The focus was on eight species: bluefin (*Thunnus thynnus*), yellowfin (*T. albacares*), bigeye (*T. obesus*), albacore (*T. alalunga*), skipjack (*Katsuwonus pelamis*), swordfish (*Xiphias gladius*), lancetfish (*Alepisaurus ferox*), mahi-mahi (*Coryphaena hippurus*), and gathered a total of ~20,000 fish.

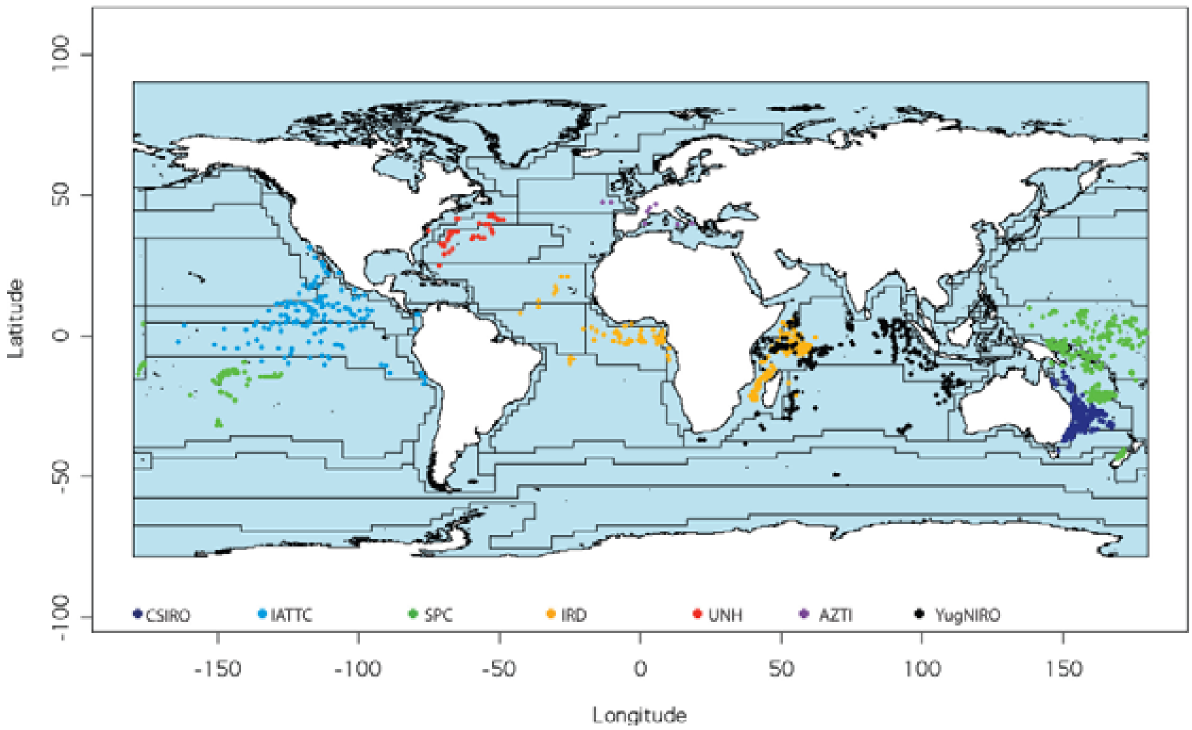

Figure 1. Stomach sample positions in relation to ocean and to Longhurst biogeographic zones (see footnote).
CSIRO: Commonwealth Scientific and Industrial Research Organisation; IATTC = Inter American Tropical Tuna Commission; SPC = Secretariat of the Pacific Community; IRD = Institut de recherche pour le développement UNH = University of New Hampshire; YugNIRO= Institute of Marine Fisheries and Oceanography (Ukraine); AZTI = AZTI-Tecnalia, Centro tecnológico experto en Investigación Marina y Alimentaria (original map by Petra Kuhnert).

The first workshop objective was to assimilate and check data from stomach content datasets. This objective continued to be the major focus of the workshop, and many issues regarding data standardisation arose and were solved.

Initial examination of the database revealed a prey species list of ~600 taxa from ~300 families. Using these data, our major objective was to examine the relationship between latitude and prey composition. However, other environmental, physical and sampling variables were included in the multivariate regression tree analysis, such as Longhurst area,[1] year of collection, sea surface temperature, predator species, predator length and fishing gear.

The regression tree resulting from the overall comparison identified the Longhurst zone, followed by predator species and fishing gear (linked to fishing depth), as the major variables of diet composition among top predators.

This work is still in progress and more analysis will be conducted during 2010 to try to improve our understanding of trophic relationships in pelagic ecosystems.

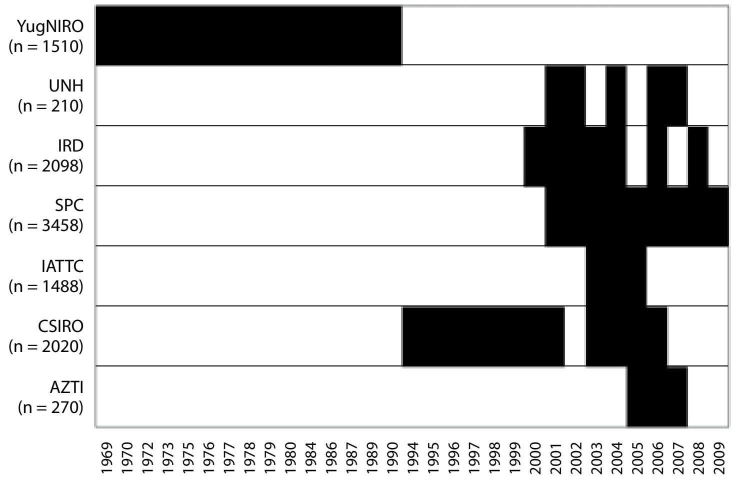

Figure 2. Stomach sample collections by project and year.

1. Based on values and variability of parameters such as temperature, water masses and circulation, wind, nutrients, primary production, ecosystem functioning, Longhurst divided the oceans into biogeographic provinces characterised by specific ecosystems (see Figure 1).

From left to right: Robert Olson (IATTC, USA), Frédéric Ménard (IRD, France) and Jock Young (CSIRO, Australia), the three scientists who coordinated the workshp on tuna diet.

A new diploma in aquaculture at the Nelson Marlborough Institute of Technology

NMIT Diploma in Aquaculture (Fish Farming and Fishery Management) (Level 5)

Programme introduction

The New Zealand-based Nelson Marlborough Institute of Technology (NMIT) has developed a new Diploma in Aquaculture in consultation with Dr Mark Burdass from Sparsholt College in the United Kingdom, which will be delivered as an industry-based, highly applied programme. The Institute will look to produce technically skilled, management-aware graduates who will be an asset to both the local and international aquaculture industry.

Throughout the two-year programme, students will learn concepts and acquire technical skills by working together to solve open-ended problems based on real life industry situations. Many of the courses will be integrated around key major projects and industry placements. This combination of theory and practical training will provide students with an excellent background to move into the aquaculture field.

Cawthron Institute is a principal industry partner involved in the aquaculture infrastructure. NMIT is currently in the process of building a shared practical training resource at Cawthron's Aquaculture Facility at Glenduan, to be opened in mid 2010. Communication links have also been established with the Seafood Industry Training Organisation and industry providers as the programme's content and logistics continue to be developed. A substantial dialogue has already taken place with industry to ensure the programme meets their needs. This dialogue will be an ongoing process to ensure the programme remains industry focussed and relevant.

Start date

The programme will begin in July 2010 and will consist of a range of single semester papers that will allow students to join at multi-entry points, thereby encouraging flexibility. This is a model currently utilized in the successful NMIT Diploma in Viticulture and Wine Production.

Delivery mode

Students will have the option of studying two years full time or by part time throughout the length of the programme.

Courses

Subjects will include aquatic animal anatomy and physiology; aquatic ecology; fishery management; aquaculture; finfish and shellfish health and nutrition; Maori aquaculture interests; business and environmental management.

Aquaculture industry experience

The NMIT Diploma in Aquaculture programme will include an industry experience component for students not already working in the field. Students will spend a minimum of eight weeks (at least two weeks of each term) working in industry to hone their learned skills.

For more information on this programme, please contact:

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TILAPIA FISH FARMING IN THE PACIFIC - A RESPONSIBLE WAY FORWARD

In many islands of the Pacific, the environmental costs from past introductions of tilapia have already been paid. How can people in these places now responsibly obtain the expected social benefits?

Tim Pickering
SPC Aquaculure Officer
(TimP@spc.int)

This question emerged as the main theme of a meeting of regional and international experts hosted by the Secretariat of the Pacific Community (SPC) in Noumea, New Caledonia in December 2009. On one hand, tilapia farming is one of the readily available options to regional food security concerns. On the other hand, tilapia is an introduced species, which raises concerns about its impacts on the biodiversity of indigenous freshwater fish.

The SPC meeting — "Future directions for tilapia in the Pacific" — found that tilapia farming is already making a useful contribution in the region, and has much more still to offer. But careful planning will be needed to obtain the anticipated economic and social benefits while avoiding further environmental costs.

Pacific Island countries will face an increasing shortage of fish for domestic consumption. Recent results of environmental and demographic studies presented by SPC show that the region's growing populations will need an additional 100,000 tonnes of fish by 2030 if present per capita fish consumption (essential for dietary health) is to be maintained[1]. Even with good management, the region's coastal fisheries will not be able to supply the increased quantity of fish needed to meet the projected future demand. Without good management, and combined with threats to coral reefs by climate change, the supply of fish from coastal reef fisheries is in fact likely to decrease.

To cope with future demands for fish, the time to start planning is now. Governmental and regional agencies have identified two main options to make up the projected shortfall in fish supply: 1) allocate more of the region's tuna catch to domestic food security needs, and 2) develop small-pond aquaculture. The aquaculture option is a good one for providing fresh fish to rapidly-growing urban centres, and to inland populations, in countries with adequate land and freshwater resources for fish farming.

Tilapia — An obvious choice

Small-scale fish farming requires simple production methods. The type of fish chosen for farming must be one that is simple to breed and feed. There are presently no obvious candidates among the indigenous fish in the Pacific Islands region. To identify and develop any local species with potential for aquaculture takes time. Typically, 10 or 15 years of scientific research is needed before a new fish species reaches commercialisation, even if it has the attributes needed for mass production.

Tilapia was introduced in much of the region in the 1950s and 1960s. It is one of only a handful of fish species available worldwide that is ideal for successful low-cost farming. It is easy to breed and grow without needing high technology, eats a range of low-cost foods, and tolerates a wide range of pond conditions. Originally from Africa, tilapia is now so domesticated for farming in Asia and the Americas that it has been dubbed "the aquatic chicken".

Internationally, farmed tilapia is a commodity. The SPC meeting heard from US Tilapia Association past-president Professor Kevin Fitzsimmons that tilapia has now reached the top five preferred "sea foods" in the USA, overtaking salmon for the first time during 2009. "The amazing thing about tilapia is how rapidly sales continue to grow: in 2000, global consumption was worth USD 1.75 billion, in 2005, this had reached USD 2.5 billion, and in 2010 it will be USD 5 billion". Secretary-General of the Network of Aquaculture Centres in Asia and the Pacific (NACA), Professor Sena De Silva concurred, informing regional representatives about the huge contribution to rural food security and livelihoods now being made by tilapia farming in Asia. "If we ask whether tilapia, as an introduced alien species in Asia, is a 'friend' or a 'foe', the answer is overwhelmingly that it is now a 'friend' to millions of our people".

Farming tilapia for food security is not a new idea in the Pacific. Fiji and Papua New Guinea (PNG) both have long-standing policies of government support for tilapia farming in rural areas. PNG's representative at the meeting, Peter Minimulu (National Fisheries Authority), reported that somewhere between 10,000 and 20,000 household-scale tilapia farms now exist in PNG's remote highlands and northern coastal provinces. This level of activity makes PNG the Pacific region's leader in tilapia farming. Fiji's Department of Fisheries similarly encourages and supports rural small-scale tilapia farming, by providing farmer training, hatchery services and marketing assistance.

Household-scale, versus medium-scale enterprises

The SPC meeting heard from WorldFish Center representative Dr Randall Brummett, based in Cameroun, about central Africa's past experiences in small-scale tilapia farming development targeting poor households. "As an approach to food security, such projects are better than giving out food relief. But without a deliberate and accepted policy to provide ongoing subsidies, such as giving out fingerlings for free, they are not usually self-sustaining businesses", he said.

The more promising approach now being taken in Africa is one of medium-scale enterprises. These larger fish farms have economies of scale to support infrastructure such as fish hatcheries or feed mills. Smaller-scale operators can then also access these services. Most importantly, jobs are created — on the farms themselves and in supporting industries. "In the last 10 years, African aquaculture has finally started to grow," said Dr Brummett. "The difference has been a switch to a business-like approach with a focus on markets and profits. To earn enough to keep their fish farms running, people have to be able to get their product out of the village because their neighbours have little spare cash to buy fish."

Vanuatu already boasts one such medium-scale enterprise. Vate Ocean Gardens is operated by Paul Ryan in Lake Manuro on Efate Island, using floating-cages to culture an attractive red-colour variety of hybrid tilapia sourced from Thailand. "It's become a nice little business", says Mr Ryan, whose regular harvests of fresh "perche cerise" ("cherry perch") are usually sold out in Port Vila within two hours. "I grow the fish in a small lake already degraded by previous fish introductions and by the dumping of tree rubbish from land-clearing, so our tilapia farm is not only economically viable, it has little additional negative environmental impact." At the meeting, representatives from Guam, Saipan and American Samoa reported that they too have successful commercial operators growing and selling tilapia, mainly in backyard operations that rear the fish intensively in swimming pools or cement tanks.

The Pacific was given the "wrong" tilapia

The species of tilapia introduced to the Pacific was the Mozambique tilapia (*Oreochromis mossambicus*), whereas 90% of the tilapia farmed globally today is Nile tilapia (*Oreochromis niloticus*). Distinctions between the two species are not always clear-cut because they hybridise easily. However, the Mozambique tilapia is generally much slower growing (in culture) and potentially more invasive because it is more tolerant of salt water.

To make matters even worse, the particular Mozambique tilapia distributed throughout the Pacific are reputedly the inbred descendants of less than a dozen fish found at a place in Indonesia in 1939. As a result, according to a recent study supervised by geneticist Professor Peter Mather of Queensland University of Technology: "... the Mozambique tilapia in the Pacific are so lacking in genetic variation that improvement by selective breeding will be almost impossible", he said.

For Nile tilapia, however, improved varieties are now available, which have been selected to give better growth performance when domesticated in pond conditions using formulated pellet feeds. Some countries in the region such as Fiji and PNG are already using these varieties for farming. Other countries in the region wishing to establish successful tilapia farms will need to ignore the feral Mozambique tilapia already present in their rivers and use a domesticated variety of Nile tilapia. "Domesticated varieties do better in culture with good feeding", advised Prof. De Silva, "but they don't do so well as feral types if they escape into rivers. This is especially so with red hybrids, whose bright colour makes them more easily caught by fishers or by hunting birds like herons and cormorants".

Mozambique tilapia were stocked into many inland water bodies of the Pacific region during the 1950s and 1960s, as part of efforts to increase freshwater fisheries production. It is unsuitable for aquaculture. (Photo: Tim Pickering).

Managing environmental risks of tilapia

The SPC meeting was briefed about threats to biodiversity among the region's freshwater fishes by Suva-based Dr Aaron Jenkins of Wetlands International – Oceania. Dr Jenkins includes feral tilapia among several threats to indigenous river fishes in the Pacific. "In Fijian streams, we've found that the presence of tilapia along with deforestation is associated with the absence of as many as 10 of the indigenous fish species." Pacific Island river fishes are more vulnerable to these multiple threats than those in Australia or Asia, he says, because more of our species have early life history stages that spend time in the ocean, and so cross several habitats during their lives.

An experimental tilapia pond constructed on the initiative of Mr Fred Manu in 2002 in North Malaita, as a village-level development project. The growth rate of the tilapia was so slow that the project was suspended. This is because only Mozambique tilapia is presently available in the Solomon Islands. (Photo: Tim Pickering).

Prof De Silva commented on Asia's experience that tilapia do not easily invade pristine clear-running forested streams, but prefer slower-moving muddy rivers in open sunlit countryside. "If deforestation occurs, tilapia will move in. They can often be found at the scene of the crime, but are not necessarily the criminal." Dr Jenkins counters that the unusually high level of connectivity between all sections of Pacific Island rivers and the ocean itself means that ecosystem-based approaches are needed for protection of our indigenous fishes, many of which are "endemic" (not found anywhere else). "Resource owners and managers will need to take into account all likely threats throughout the entire river, to avoid loss of species or further reductions in useful indigenous food fishes such as the Fijian *vo*.

"It's increasingly important to protect the invasive-free status of those river catchments that are still pristine". Dr Jenkins recommends that the distributions of indigenous species, and of tilapia, be mapped and used as guides for aquaculture planning. "We definitely need policies in place to avoid introducing tilapia into remaining areas of high conservation value", he said.

The way ahead for tilapia farming

It is obvious that the demand for fresh fish in the region will increasingly drive new initiatives to farm tilapia. Already the region is witnessing an expansion from household-scale fish farming projects to economically viable medium-scale enterprises based on aquaculture of this versatile fish. Participants at the SPC-hosted meeting "Future directions for tilapia in the Pacific" have helped to clarify the main issues still to be addressed if this industry is to expand in a responsible and environmentally sustainable way.

The success of new entrants to tilapia farming will depend on being able to work with suitable domesticated varieties. This means having the capacity to manage aquatic-species quarantine protocols at the national level. It also means carrying out an import risk assessment for the proposed new variety, to ensure that no characteristics (such as higher salt tolerance) are added to the local feral tilapia gene pool that may increase invasive properties any further. Zoning approaches to aquaculture planning can be developed to protect areas of high conservation value from the introduction of tilapia. The need for, and viability of, a tilapia farming industry should be assessed country by country and province by province, before any decision is made to go ahead with it. SPC plans to work with its member countries and territories, and other stakeholders, to further develop these and other ideas in support of sustainable and profitable tilapia farming in the Pacific Islands region.

1. See *Pacific Island Business*, October 2007: "Fish – cornerstone of future food security"

SUCCESS OF SPECIAL MANAGEMENT AREAS IN TONGA

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Success stories of coastal fisheries management within the Pacific Islands region have been few and far between. One particular situation in Tonga, however, appears to be quite successful and is deserving of more attention.

Background

The Kingdom of Tonga — an archipelago in the South Pacific comprising 168 islands — stretches 800 kilometers and has a total land area of 678 km². As of January 2009, Tonga's population was estimated to be slightly greater than 100,000 (Gillett and Cartwright 2010) with over 70% of its residents living on the main island of Tongatapu. Tonga is unique in being the only sovereign monarchy in the Pacific Islands, and has the distinction of being the only island country in the region to have avoided formal colonization.

Inshore fisheries management in Tonga

Tonga is unlike many other Pacific Island nations with respect to traditional management of inshore fisheries. The difference being that in the mid-1800s, King Taufa'ahau Topou I united all of the Tongan islands into a kingdom, establishing himself the sole owner of the land and sea. A proclamation by the king during this time stated that 1) all Tongans had equal fishing access to all Tongan waters, and 2) any traditional claims to the local control or management authority over fishing areas were abolished. In other words, traditional communal-based fisheries management was extinguished, and any Tongan could fish wherever they pleased, whenever they pleased. This situation is often referred to as an "open access" fisheries management regime.

Problems of open access fisheries management regimes

Petelo et al. (1995) give some disadvantages of open access fisheries in Tonga:

> This system may have worked reasonably well in the era of subsistence fisheries, but it has fairly recently collided with commercial realities and the carrying capacity of inshore resources.
>
> This lack of community control creates conditions that do not encourage a long-term relationship with the resource. The first-come-first-served regime now prevailing is incentive to harvest as much as possible, as fast as possible. Fisheries management in Tonga is currently being attempted on a centralized basis.
>
> One frequent comment from villagers in Ha'apai is that, even if a community conserves and manages its adjacent marine resources, it may be a useless exercise as outsiders can, and have, moved in to overharvest.
>
> For many of the villages in Ha'apai, the priority concern is the fact that Tongans from anywhere, especially commercial operators from Tongatapu, could harvest the food resources adjacent to villages thereby affecting the food security situation.

Wilson et al. (2008) conducted research on the effects of open access fisheries on 'O'ua Island in the Ha'apai group, citing additional problems:

> The reef system of 'O'ua, due to its richness in fish resources, has been subject to intense fishing by the people of 'O'ua, neighboring islands and small commercial vessels from Tongatapu. This has led to the damage of coral reef and other habitats in the area and the serious depletion of fish resources. So much so, that it threatens the people of 'O'ua's future food security and development prospects.

Gillett et al. (1998) give two additional drawbacks of open access fisheries in Tonga:

> Recently there has been an increased amount of commercial fishing activity in inshore areas adjacent to villages by

> Tongans from outside the communities. Given the limited production of the inshore areas, the benefits from this outside commercial activity appear to be, at least to some extent, at the expense of the subsistence food supply.
>
> It is somewhat ironic that the coastal communities in the outer islands of Tonga with limited opportunities for nutritional or economic advancement are, in effect subsidizing outside commercial operations.

What is being done about problems regarding Tongan open access fisheries?

In 2002, a new fisheries law was enacted, which included a provision for special management areas (SMAs). A main feature of the Fisheries Management Act 2002 is that:

> "the Minister may, in consultation with the Committee, designate any local community in Tonga to be a coastal community for the purposes of community-based fisheries management, and may prescribe the rights and responsibilities of such a coastal community in respect of the SMAs, or part thereof".

An SMA grants a community management control of its inshore resources; in effect, providing a community with the basic tools and skills for better management initiatives. The main objectives of a management plan are to 1) enforce the authority to exclude outsiders from entering an SMA, 2) establish marine parks, and 3) implement restrictions on harvested resources, including, size limits and catch amounts.

A discussion with the head of Tonga's Fisheries Division in Nuku'alofa (Sione Matoto Vailala pers. comm., September 2009) indicated that six communities had applied and been selected for the SMA program. These communities are 'O'ua, Felemea (see photo), and Ha'afeva in Ha'apai; Ovaka in Vava'u; and 'Atata and 'Euaiki in Tongatapu.

Wilson et al. (1995) further commented on the selection process of the SMA program on 'O'ua in Ha'apai:

> The 'O'ua community made a request of the Department of Fisheries in March 2005 to assist them in establishing a Special Management Area as a means to help ensure that there will be enough fish for their families today and for their children in the future. This historical event was marked and officially opened by the Minister for Agriculture and Food, Forests and Fisheries, Hon. Sione Peauafi Haukinima on 1 November 2006.

SMAs: Advantages and drawbacks

Dr Sione Vailala Matoto pointed out to me the positive and negative effects that SMAs are having on the six selected communities. Since the initiation in 2006, Matoto stated that these selected communities feel much greater ownership towards their adjacent resources than anytime in recent history. These coastal communities now have an incentive to conserve and protect for the future, and outsiders are no longer able to fish there, (ie. What the communitiy conserves today, will not be taken by outsiders tomorrow). Other comments made by Dr Matoto suggest that since the SMA programs have been put into effect, villagers have gained significant fishery and financial resources. Communities with established SMAs provide protection for valued species such as lobsters, clams and bece-de-mer. In communities without SMAs, however, these resources were either decimated by locals or outsiders.

Drawbacks of the SMA program tend to be centered on the communities not involved. These outside communities do not like the fact that they are being restricted from open access fishing, or are being denied access to a place where they once used to fish. Secondly, financial restraints of Tonga's Fisheries Division make it difficult to establish an SMA in a timely fashion. Many communities have applied, knowing the advantages of the program, but the application process is slow due to a lack of funding.

Other opinions on the SMA initiative

Besides Sione Matoto's input, there have been various outside opinions on the development and success of this program. Semisi Fakahau, Pacific Islands Forum Fisheries Agency fisheries advisor to Tonga, states that, since the Tongan beche-de-mer fishery has been opened, communities involved with the SMA program have been highly appreciative that they now have protection from commercial operators from Tongatapu that take large amounts of their inshore resources. In addition, Robert Gillett, former fisheries advisor to Tonga who maintains contact with Ha'apai communities, indicates that the SMA program represents one of the most positive developments in the management of coastal resources in Tonga.

Current status of SMAs

The most recent annual report released by Tonga's Fisheries Division (Fisheries Division 2008) states the following status of SMA communities:

> 'O'ua's management strategies include replenishing on the fish habitat reserve with giant clams, recording fish catch information, monitoring SMA boundary lines, and closely watching the SMA partition and enforcing their management plan actions.
>
> The Ha'afeva people have achieved their goal in the development process for their SMA with the completion of their Coastal Community Management Plan (CCMP). Meetings are currently being held in order to promote awareness of fisheries laws as well as management skills.
>
> The Felemea community is in the development process for their SMA with a goal of establishing their Coastal Community Management Plan. A district officer conducted the latest meetings, where fisheries law and management were the topics of discussion.
>
> Ovaka, 'Atata and 'Eueiki communities are now near completion with respect to the development of their Coastal Community Management plans. These plans included awareness about fisheries activities, conservation and management as well as regulations that directly apply to community small-scale and subsistence fishing. This process has evolved during number of visits to ensure each community understands the management process. Each village has agreed to the conditions put forth by the district officer and has set a completion date of June 2008.
>
> Other communities having shown great interest in the SMA program include Hunga and Taunga in Vava'u and Fonoi and Nomuka in Ha'apai. Each community has put in a request asking the Ministry for assistance in the SMA development process. However, as stated by Dr Matoto above, assistance to these interested communities was not possible due to various reasons, including lack of resources and financial constraints.

What the future holds for SMAs

According to Tonga's Department of Fisheries website, a main goal in implementing SMAs is to raise awareness of the approach of community management as a long-term strategy to achieving environmental sustainability and economic stability and growth in Tonga. As it stands now, SMAs have been a tremendous success in terms of Tongan in-shore fisheries management, deserving national attention. Communities all around Tonga have taken notice of this program's success.

The main establishment issue however, lies in the hands of Tonga's Fisheries Division and its financial constraints. With a substantial amount of national and international awareness, publicity, and funding, there is no doubt that SMAs could be a major turning point for fisheries management in the country.

Why this is a governance success story

Given the major decline in Tonga's inshore resources, I believe the most successful aspect of the SMA program is how SMAs are promoting the sustainable fish stocks for the future. They do it by inviting a community to participate in something that is inherently in their self-interest by allowing the exclusion of outsiders, resulting in less competition, and more abundant inshore resources for the adjacent community. It now seems there is light at the end of the tunnel for both Tonga's Fisheries Division and SMA communities in terms of maintaining and sustaining a healthy fisheries environment. Other important aspects of SMA governance successfulness include:

- Protect the future of fisheries by giving local communities the essential tools for managing inshore resources.
- Unlike with open access fisheries, there is no pressure to take as much as possible as fast a possible.
- Bonds between the community and inshore resources are stronger.

- Communities have little to lose and much to gain from this program.
- Tonga's Fisheries Division has strengthened its links to fishing communities that now see the division as a partner.
- Law enforcement now lies in the hands of participating communities; activities such as entering an SMA without unauthorization or engaging in illegal fishing are being closely monitored.
- If a community does not want an SMA, they do not have to, it is purely in their self interest, no one is forced to join the program.

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'Uiha Island in the Ha'apai Group, Kingdom of Tonga.

COMPARATIVE STUDY OF THE STRUCTURE OF COMMERCIAL FISH POPULATIONS ON MOOREA, FRENCH POLYNESIA

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Introduction

Coral reef populations are characterised by large spatial and time variability and high levels of diversity. Many studies have made comparisons of fish populations in coral reef environments. In French Polynesia, Galzin and Harmelin-Vivien (2000) studied qualitative and quantitative variations in fish populations in space and time. We know that coral reef populations do not remain steady over time but, rather, fluctuate at a variety of scales (e.g. daily, monthly and seasonal). In addition, we can see that such populations are also unstable on a spatial scale (Galzin 1987b). Moorea's fish population is not spread out evenly around the island (Galzin 1985; Galzin 1987a). Its distribution is linked to ecological factors such as coral cover and physical factors such as the height of the water column as well as hydrodynamic conditions (Galzin 1985). Other studies have shown that the structure of reef fish communities depends on reef geomorphology, which is a key element (Bell and Galzin 1984; Galzin 1987a; Adjeroud et al. 2002), and on different types of fishing pressure (Russ and Alcala 1989; Labrosse et al. 2000). In the Pacific, fishing pressure is strongly tied to population density (expressed as the number of inhabitants per square kilometer). In addition, increases in fishing effort result in changes in target populations (Jennings and Lock 1996) and even in the entire fish community (Jennings and Polunin 1996). Studies on the effects of fishing on reef ecosystems and fish populations have covered several variables, including size, basic outline of target fish life cycles, relative abundance of the species or the reef community's trophic structure (Jennings and Lock 1996; Jennings and Kaiser 1998). The purpose of comparative studies on fish communities of commercial interest (i.e. fish harvested as food) between a protected area and a zone subject to fishing, is to identify resource status bioindicators. This makes it possible to design tools to properly manage the resource. Among such tools are marine protected areas (MPAs), whose use has significantly grown around the world. As a tool to sustainably manage both biodiversity and fisheries yields, MPAs protect endangered species and promote tourisism activities. The reserve effect of MPAs has both spatial and temporal components (Francour 2000). The spatial component includes differences between protected and unprotected zones (Russ and Alcala 1989; Harmelin-Vivien et al. 1995; Francour 2000). The purpose of this study is to identify the effects of fishing on certain ecological characteristics of target fish communities by comparing an exploited zone and an MPA.

Materials and methods

Moorea is one of 14 islands in French Polynesia's Society Islands group (Fig. 1). Volcanic in origin, it is 25 km northwest of Tahiti at 149°50 W and 17°30 S. It is triangular in shape and has a surface area of 134 km^2 and a 70-km-long coastline. Its summit, Mount Tohivea, reaches a

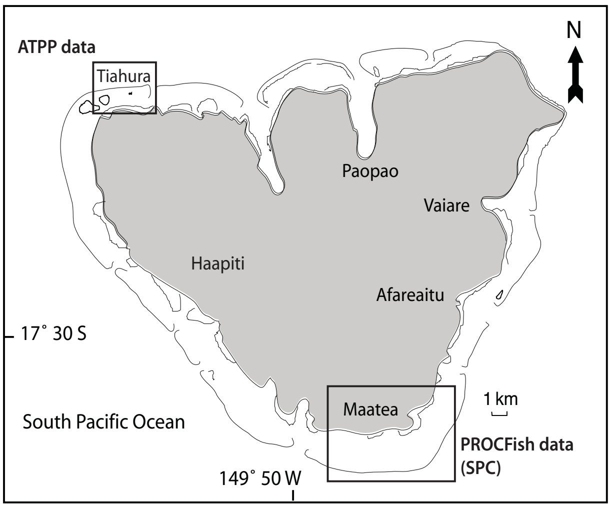

Figure 1. The two study sites on Moorea, French Polynesia.

height of 1,207 m. The island is surrounded by a barrier reef that marks the borders of a 49 km² lagoon, whose width varies from 500–1500 m, in depths of 0.5–30 m. There are 11 passes of varying depths (10–70 m) through the reef that boats use (Galzin and Pointier 1985). Tiahura, a favourite site for reef community studies since 1971 (Fig. 1), is located northwest of the island. Tiahura's transect is an imaginary 1,040-m-long line perpendicular to the coast (Fig. 2). It is divided into 22 stations forming squares 50 m long on each side, with 5 stations on the fringing reef, 9 on the barrier reef, 6 on the outer slope and 2 in the channel (Galzin 1985). In June 2006, the Pacific Regional Oceanic and Coastal Fisheries programme collected data in the village of Maatea in the southern part of Moorea (Vigliola and Boblin 2006). A total of 24 transects were set up on all the habitats (6 on the fringing reef, 6 on the intermediate reef, 6 on the barrier reef and 6 on the outer slope) (Fig. 3). For this analysis, only data from two geomorphologic units were used for each of the two sites (i.e. the outer slope and barrier reef).

Every year since 1990, a CRIOBE research team has collected qualitative and quantitative data on the barrier reef and outer reef slopes as part of the ATPP (Temporal Population Patterns Programme). Fish are counted by divers at a set distance that is ideal for monitoring fish populations without disturbing them over time (Harmelin-Vivien et al. 1985). On the barrier reef, the census zone covers a 100 m x 200 m rectangle, divided into 200 quadrates measuring 50 m x 2 m each laid out parallel to the coastline, with 10 sample units chosen randomly. On the outer slope, the arrangements are

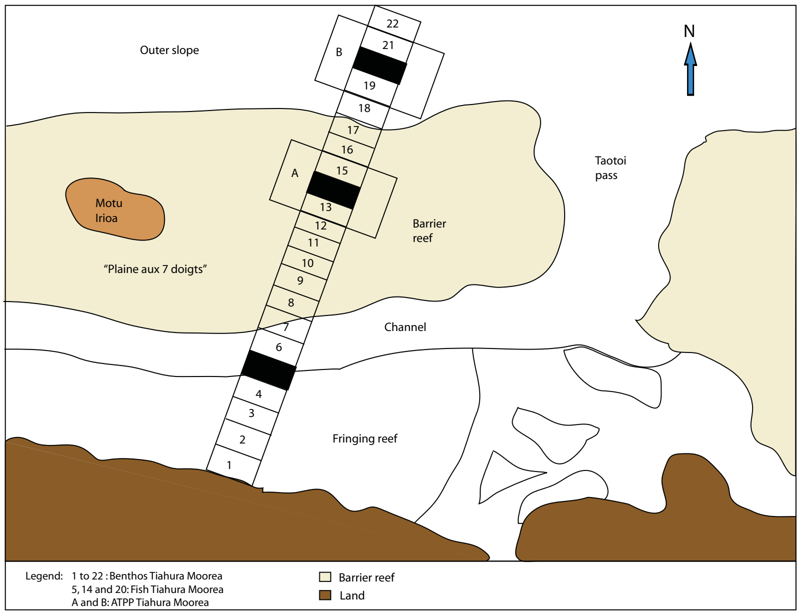

Figure 2. Position of fish stations in the Tiahura sector (A and B). Source: CRIOBE (ATPP Programme).

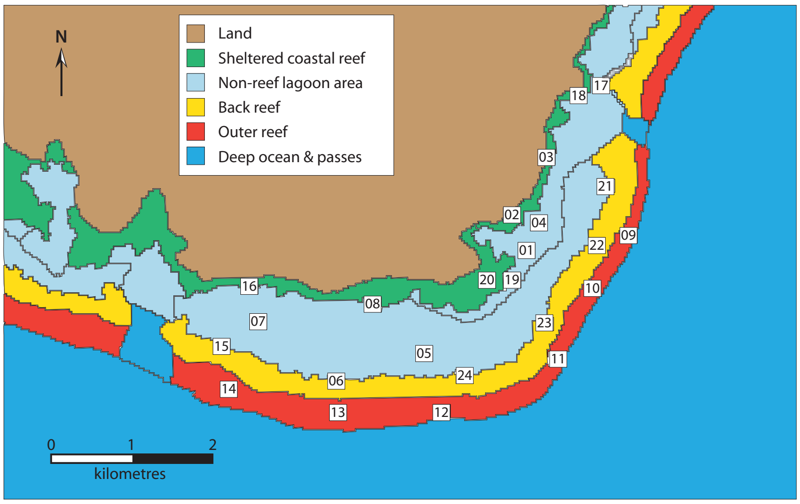

Figure 3. Location of the 24 fish census transects (PROCFish data) in the southern part of the island at Maatea. Source: Andrefouet S. (IRD Noumea) modified by Vigliola and Boblin (2006).

similar but there are only eight sample units.

As part of the coastal component of the PROCFish programme and the Pacific Regional Coastal Fisheries Development Programme (CoFish), the Secretariat of the Pacific Community (SPC) conducted census surveys on Moorea in 2006. Censuses of commercial fish populations were done visually along transects at variable distances (Labrosse et al. 2003). The sampling strategy used on Moorea (Vigliola and Boblin 2006) (Fig. 3) was the same PROCFish has used in 17 countries and on more than 60 islands.

In order to compare the two datasets, PROCFish's technique was standardised with ATPP's, by setting observation distances at 1 m on either side of the 50 m transect (i.e. a surface area of 100 m^2).

Data density was calculated as follows: D = N/S

D: number of fish m^{-2}

N: number of fish observed;

S: sample surface = 100 m^2

For theses comparisons, we only analysed the data for the 22 commercial species that were common to both PROCFish and ATPP.

In order to identify changes in the trophic structures of populations subject to fishing pressure, the commercial fish selected were divided into five trophic groups: four main groups (micro-algae eaters, macro-carnivores, piscivores, macro-algae eaters and one combined group (mixed piscivores /macro-carnivores) (Kulbicki 1992).

To test the differences between trophic groups, a single-classification-category variance analysis (ANOVA) was carried out. To identify means that were significantly different, a multiple comparison student Newman-Keuls test was performed.

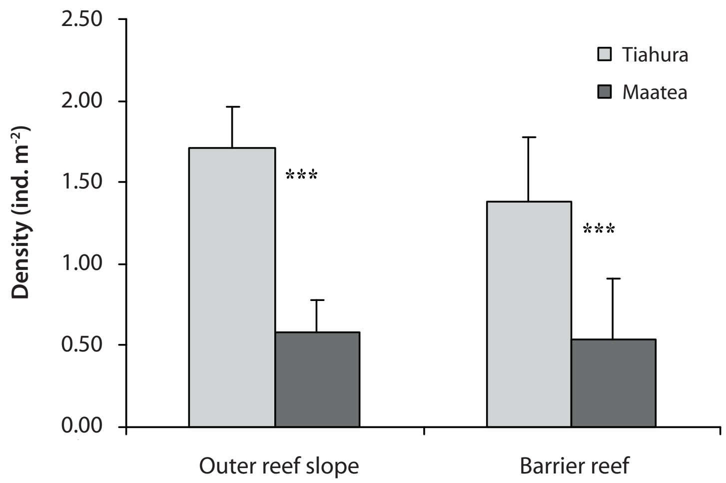

Figure 4. Mean densities (ind. m^{-2}) (± standard deviation) of food fish for the two morphological zones at each site. Meaning of codes $p < 0.000$ (***).

Results

At both sites, the highest total species richness was found on the outer slope and the lowest figures were on the barrier reef. Tiahura had a higher mean commercial species density than Maatea (Fig. 4). A T mean comparison test showed a net difference in total density between the two outer slope sites (t = -9.3038; dl = 12; $p < 0.000$) and the barrier reefs (t = -4.2742; dl = 14; $p < 0.000$).

At the Maatea barrier reef, the highest total densities were found in the families Acanthuridae (2.30 ind. m^{-2}) and Scaridae (0.24 spec. m^{-2}). The Acanthuridae family was mainly represented by *Acanthurus triostegus* (*manini*) and *Ctenochaetus striatus* (*maito*), 37% and 34% of the total density, respectively. For the Scaridae family, only *Scarus psittacus* (common parrotfish) was well represented with 7% of the total density. On the outer slope, the Acanthuridae family was once again dominant (1.61 spec. m^{-2}) with *Ctenochaetus striatus*, *Acanthurus nigroris* and *A. olivaceus* (i.e. 29%, 10%, and 7.5% of the total density, respectively). This top rank was followed by the Scaridae family (1.41 ind. m^{-2}) with *Chlorurus sordidus* and *Scarus psittacus* (i.e. 32% and 8% of the total density, respectively).

In general, there were significant differences in density between sites in the same biotope for the six main families: Acanthuridae, Labridae, Lethrinidae, Lutjanidae, Mullidae and Serranidae (Tab. 1). All of these families were more abundant at Tiahura except for Lethrinidae (t = 2.679 ; dl = 14 ; $p < 0.05$) and Lutjanidae (t = –2.846 ; dl = 5.56 ; $p < 0.05$), which were more abundant at the Maatea barrier reef.

Main species

Just 12 species (Fig. 5) accounted for 87% of the total density of the 22 target species selected for comparison at Tiahura and 96% at Maatea. They belonged to the families Acanthuridae (seven species), Serranidae (two species), Scaridae (two species), and Mullidae (one species).

The highest densities were recorded for *Ctenochaetus striatus* (*maito*) and *Acanthurus triostegus* (*manini*).

However, there were only eight significant differences between sites for the same biotope. This involved *Ctenochaetus striatus*, *Naso lituratus*, *Acanthurus nigricans*, *Cephalopholis argus* and *Acanthurus thompsoni*, whose densities were significantly higher at Tiahura. In contrast, two species had densities that were significantly higher at Maatea: *Acanthurus olivaceus* (*havari*) and *Acanthurus triostegus* (*manini*) (Fig. 5).

Trophic structure

The trophic structures study showed significant differences

Table 1. Mean densities (spec. m^{-2}) (± standard deviation) of commercial fish families at the two study sites and biotopes. Means given in bold indicate significant differences between sites for the same biotope. Meaning of codes: $p < 0.000$ (***); $p < 0.01$ (**); $p < 0.05$ (*).

	Tiahura				Maatea			
Family	Outer slope	± SD	Barrier reef	± SD	Outer slope	± SD	Barrier reef	± SD
Acanthuridae	**1.314****	*0.173*	**0.965***	*0.125*	**0.290****	*0.111*	**0.388***	*0.315*
Balistidae	0.003	*0.005*	0.000		0.000		0.000	
Carangidae	0.000		0.000		0.000		0.001	*0.004*
Holocentridae	0.029	*0.051*	0.026	*0.036*	0.000		0.016	*0.019*
Labridae	**0.068***	*0.046*	**0.039****	*0.028*	**0.011***	*0.019*	**0.005****	*0.005*
Lethrinidae	0.001	*0.004*	0.009*	*0.007*	0.000		0.021*	*0.012*
Lutjanidae	**0.038***	*0.045*	**0.001***	*0.003*	**0.000***		**0.013***	*0.010*
Mullidae	0.010	*0.019*	**0.070***	*0.053*	0.013	*0.015*	**0.026***	*0.016*
Scaridae	0.170	*0.088*	0.269	*0.33*	0.241	*0.132*	0.061	*0.088*
Serranidae	**0.078****	*0.030*	0.005	*0.005*	**0.029****	*0.004*	0.008	*0.013*

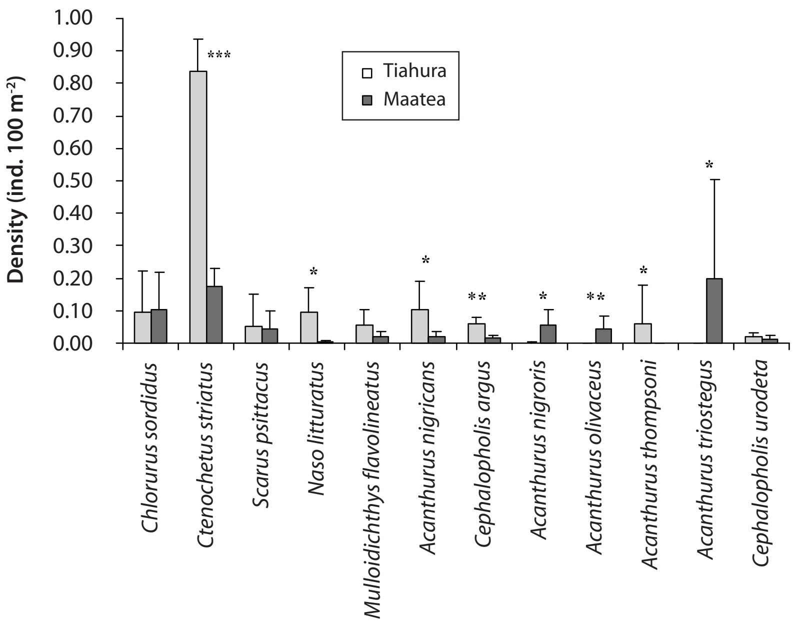

Figure 5. Mean densities (ind. m^{-2}) (± standard deviation) of food fish for the two morphological zones at each site. Meaning of codes $p < 0.000$ (***); $p < 0.01$ (**); $p < 0.05$ (*).

between fish populations at Tiahura and Maatea.

In terms of the number of species, the commercial fish trophic groups that were the most numerous at both sites were the macro-carnivores (6 species) and micro-algae eaters (10 species). In contrast, trends differed in terms of density (Fig. 6). Micro-algae eaters had the highest density followed by macro-algae eaters.

The trophic structure analysis revealed a clear predominance in density for micro- and macro-algae eaters at Tiahura. They were four to five times more numerous than macro-carnivores and piscivores. However, densities for piscivores (*Variola louti*, *Epinephelus hexagonatus*, *Cephalopholis sexmaculata*, *Cephalopholis argus*, and *Caranx melampygus*) and mixed piscivores/macro-carnivores (*Parupeneus cyclostomus*, *Elagatis bipinnulatus*, *Cephalopholis urodeta*, and *Aphareus furca*) were higher on the outer slope at Tiahura.

Macro-algae eaters mainly consisted of *Naso lituratus* (*ume tarei*), which were very abundant on the outer slope of Tiahura. The micro-algae eater group consisted of several taxa and species on the outer slope of Maatea. Finally, the macro-carnivore group covered the barrier reefs of both Tiahura and Maatea and included several families.

Conclusion

Four of the results allow us to conclude that commercial species at certain sites on Moorea are beginning to show signs of overexploitation.

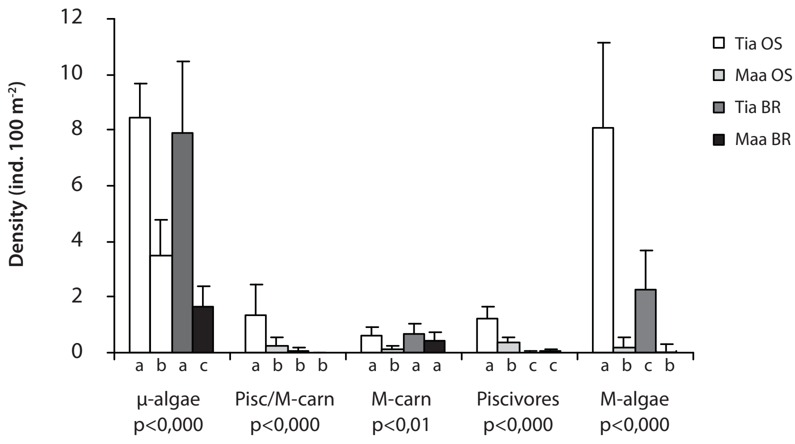

Figure 6. Differences in mean densities for each tropic group (µ-algae: micro-algae eaters, M-carn: macro-carnivores, Pisc/M-carn: piscivores and macro-carnivores, M-algae: macro-algae eaters, p: probability from the results of the single-factor ANOVA, Student Newman Keuls : histograms that have similar letters are not significantly different. TiaOS = Tiahura outer slope; TiaBR = Tiahura barrier reef and Maatea: MaaOS = Maatea outer slope; MaaBR = Maatea barrier reef).

According to the T test, Tiahura had a higher mean density for commercial species on its outer slope and barrier reef than Maatea does. The mean density of four families (Acanthuridae, Labridae, Lutjanidae and Serranidae) was higher on the outer slope of Tiahura and the mean density of three families (Acanthuridae, Labridae and Mullidae) on the barrier reef.
At the Maatea site, the comparison showed that two families (Lethrinidae and Lutjanidae) had a higher mean density on the barrier reef.

Factorial correspondence analysis of the trophic structure showed that piscivores and piscivores/macro-carnivores were associated with the outer slope of Tiahura and that micro-algae eaters were associated with the outer slope of Maatea. These results confirmed that fishing pressure at Maatea is continuous because no fish from the higher trophic levels were recorded, whereas, at Tiahura, a site that is not directly subject to fishing pressure, they were.

Small species of parrotfish, goatfish, soldierfish, rabbitfish and very small specimens of larger species, *Naso unicornis* (*ume*), comprised the major part of fishers' catches at Maatea (Vigliola and Boblin 2006). This decrease in catch size is a clear indication of generalised overexploitation of fish stocks, particularly larger fish.

According to PROCFish project's socioeconomic survey in Maatea (PROCFish/C 2006), there were 294 fishers (i.e. 31% of Maata's population and 57 fishers km^{-2}). Fishing pressure can be considered high when there are at least 5 fishers km^{-2} (McClanahan et al. 2002). This high fisher density confirmed the overexploitation of Maatea's fisheries resource.

This difference in density and spatial distribution can also be explained by habitat factors between the not-so complex, wave swept coast in the south (Maatea) and the more protected one in the north (Tiahura). The topographical complexity of the northern geomorphologic zone does, in fact, provide more shelter and greater food resources.

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